CIRCULAR-ECONOMY PILOT ENTERPRISES IN THE
NON-FERROUS METALS INDUSTRY

PROGRESS AND POLICY RECOMMENDATIONS

China Non-Ferrous Metals Industry Association

Metals Recycling Branch

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Abstract

The non-ferrous metals industry is a resource-intensive industry and a key part of the national economy. Since China’s policy of ‘reform and opening-up’ started in the early 80s, its non-ferrous metals industry has developed considerably, vastly expanding in industrial scale and output of its core products. It has ranked first in the world in terms of total output for the past five years in a row, with its competitiveness and overall industrial strength both gradually increasing. At the same time, the domestic demand for non-ferrous metals has rapidly grown with the development of the national economy and the raising of living standards. However, the growth of the industry is bringing great problems with it. There are real and growing limitations on the availability of resources, new impacts on the environment are constantly emerging, and reckless growth has led to an unbalanced industrial structure. At present, China’s non-ferrous metals industry is in urgent need of a solution to the gap between the short supply of domestic natural ore and the increasing demand for metals; between a deteriorating environment and greater production scale; and between limited energy supplies and ever-increasing overall energy consumption. Circular economy is not only an inevitable choice for sustainable development of the industry, but is also crucial to its future competitiveness, and that of the nation.

The industry needs the government to adopt active measures to support the industry in its development of circular economy.

1、Strengthen the Establishment of Policies and Regulations for Developing Circular Economy in the Non-Ferrous Metals Industry

The government needs to speed up legislative work related to the development of circular economy in the non-ferrous metals industry. Systematic corresponding support policies should be issued in order to establish laws, regulations, and a policy-support system as soon as possible. The following laws should be established as soon as possible: “Comprehensive Disposal Regulations for Non-Ferrous Metals Residues and Tailings,” “Recovery Regulations for Waste Lead-Acid Batteries,” “Recycling-Management Regulations for Waste Aluminum Cans” and other laws and regulations.

Efforts should be sped up to consider and formulate special programs for the development of circular economy in such key areas as developing a market for the exchange of secondary, and the recycling of secondary metals. “Entrance
Qualifications for the Recycled-Metals Industry” should be issued. Outdated means of production, and enterprises with a low resource-usage rate or serious environmental pollution, should be eliminated to optimize the structure of the industry and promote the healthy development of a recycled-metals industry.

2. Promote Demonstration Circular-Economy Projects and Publicize their Effectiveness to Maximize Impact

State treasury bonds, special-purpose funds, and other means of government financial support means should be used to support a group of demonstration circular-economy projects in the non-ferrous metals industry. The focus should be on: recycling of non-ferrous metals waste and scrap; building scrap and waste-metal recovery and transaction markets; assessment and utilization of ore tailings; comprehensive recycling of associated resources; recovery of valuable elements from industrial wastewater; usage or treatment of smelting waste; development of environmentally friendly alternative materials; and usage of low-concentration sulfur dioxide.

3. Establishing Favorable Tax Policies to Promote Non-Ferrous Metals Recycling

Right now the tasks of recovering and of using waste non-ferrous metals in China are split over two separate industries, i.e. the recycling of waste materials, and the use of waste materials in production. The government exempts enterprises that recover waste material from value-added tax (VAT) on the sales of these materials; however, this causes enterprises that use domestically recycled waste materials in production to be unable to deduct 7% of VAT, and causes several other problems of tax evasion. The tax rates should be made uniform as soon as possible to provide a level playing field and support the domestic development of non-ferrous metals recycling. We suggest a 17% VAT be collected on the sale of waste materials and the recycling of waste materials, and to other tax exemptions or subsidies to encourage the industry.

We also suggest the government to issue product certifications for energy-saving, resource-saving and material recycling products, and entitle enterprises to favorable tax policies based on these certifications.

4. Increase Investment in Scientific R&D to Strengthen the Technological Basis for Circular Economy

Special projects should be established to assist the development of circular economy in the non-ferrous metals industry, to form new systems and mechanisms for technical innovation. The emphasis should revolve around the technical topics and
critical technologies, aiming to achieve technological breakthroughs, which will dramatically push the development of circular economy.

To promote the usage of non-ferrous recycled metals, we suggest the national authorities in charge of science and technology to establish a non-ferrous metals recycling technology support plan, to guide capable enterprises in establishing specialized technical-development co-funding projects, to actively support the technical development of the non-ferrous metals recycling industry. Through such a plan, domestic and international recycling technology efforts can be joined together, a testing base can be built for new technologies and equipment, to turn around the situation of weak R&D capabilities.


Currently about one third of the copper, aluminum and other key non-ferrous metals waste material utilized in China are recovered domestically, while the rest is made up by imports. This situation is expected to continue for the years to come, and the percentage of imports is even expected to increase somewhat. Collection for recycling of non-ferrous metals in China is still less than in developed countries such as the U.S. and Japan, and another 5 to 10 years are needed before large amounts of waste non-ferrous metals become available.

In order to make better use of foreign non-ferrous waste, we suggest expanding the variety of imports, loosening entrance requirements, and simplifying the registration procedures for foreign importers, while ensuring supervisory measures to prevent pollution from illegal imports.

Support should be given to the unified planning of processing parks and the enterprises within them, basic environmental-protection facilities should be constructed, technological upgrades should be implemented, and fund-raising, financing and other measures to speed up industry concentration and upgrading should be provided. The construction of a group of model national-level recycled non-ferrous metals processing parks should be sped up. Those national-level recycled non-ferrous metals processing parks should be allowed to treat imported waste household electronics, automobiles, and other recyclables. Time limits on the phasing out (closing down) of recycled-material processing enterprises that are not able to enter recycling parks or solve their pollution problems on their own accord should be strictly enforced.
To improve the quality of waste non-ferrous metals imported into China, we suggest that price-based duties and fees currently levied on imported scrap and waste non-ferrous metals be replaced by quantity-based duties and fees.
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Introduction

The Seventeenth National Congress of the Communist Party of China which just concluded was a milestone in the Party’s history. In his report to the congress, Party General Secretary Hu Jintao listed as the top priority, among the problems China faces, the excessive resource and environmental costs of economic growth. This shows that resource and environmental issues have become central concerns for the Party’s Central Committee.

In this report the concept of ecological civilization is brought up for the first time. The aim is to have, by 2020, an industrial structure, and growth and consumption patterns, that save resources and protect the environment, as part of a large-scale circular economy and enhanced proportion of use of secondary energies. Discharge of major pollutants is to be brought under control, and the quality of the environment improved remarkably. The concept of ecological civilization is to be firmly established throughout society. Efforts must be made to strengthen energy and resource savings and environmental protection to encourage sustainable development.

The non-ferrous metals industry is a resource-intensive industry and a key part of the national economy. Since China’s adoption of the policy of reform and opening-up, its non-ferrous metals industry, through continuous reform and adjustment, has developed considerably, expanding its industrial scale and increasing its output of core products. It has ranked first in the world in terms of total output for five years in a row, with competitiveness and overall industrial strength both gradually increasing. At the same time, with the rapid development of the national economy and increasing living standards, demand for non-ferrous metals has been increasing in China. This development, however, faces remarkable problems related to its sustainability, problems related especially to the environment and limited availability of resources. Overly rapid growth has led to an unbalanced industrial structure. At present, China’s non-ferrous metals industry is in urgent need of solutions to the gap between the short supply of natural ore in the country and the increasing demand for metals, between a deteriorating environment and greater production scale, and between limited energy supplies and ever-increasing overall energy consumption.

The development of circular economy is key to implementing scientific development, as well as the sustainable development of the non-ferrous metals industry. Therefore, summarizing the experience and performance of China’s non-ferrous metals industry
in developing circular economy, studying the development pattern of circular economy, analyzing issues faced in developing it and recommending measures for the non-ferrous metals industry to do so, will be highly significant to optimizing industrial structures, transforming production, and realizing clean and sustainable economic development.

1. Urgency of Developing Circular Economy in the Non-ferrous Metals Industry

For more than a decade, China’s non-ferrous metals industry has maintained rapid development and expansion, with the output of 10 non-ferrous metals ranking first in the world for 5 years in a row now. In 2006, the total output of China’s 10 most important non-ferrous metals (copper, aluminum, lead, zinc, nickel, tin, antimony, mercury, magnesium and titanium sponge) was over 19 million tons, up 17.5% year-on-year, while the consumption volume reached 19 million tons. These quantities made China the world’s largest non-ferrous metals producer and consumer. Meanwhile, technological progress has continued, the industrial structure has improved, and the competitiveness of individual enterprises and synergies within sectors have increased, with the “China Factor” growing on the global non-ferrous metals market.

![Figure 1.1: 2000-2006 outputs of Major Nonferrous Metals in China](image)

China’s non-ferrous metals industry faces challenges to its development from limited availability of resources and pressure on the environment. Efforts must be made to realise rational development in accordance with the spirit of the Party’s Seventeenth National Congress. Only through greater efforts in developing circular economy and building a resource-saving, environmentally-sound industry can these bottlenecks be dealt with. Circular economy is not only an inevitable choice for sustainable development of the industry but also crucial to its future strength, and that of the nation.

1.1. Ever-increasing Resource Shortages and Dependency on Overseas Supplies

With its faster and faster industrialization and urbanization, China’s demand for non-ferrous metals has been growing drastically, the fastest growth in the world. This has made a significant contribution to overall growth in demand for such metals. Table 1.1 compares China’s consumption of copper, aluminum, lead and zinc in 2006 with the average growth in demand worldwide for these metals since 2000.
Table 1.1 China’s Consumption of Major Metals in 2006 Compared with the World’s Average Growth Rate since 2000

<table>
<thead>
<tr>
<th>Item</th>
<th>Copper</th>
<th>Aluminum</th>
<th>Lead</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption volume in 2006 (million tons)</td>
<td>3.6</td>
<td>8.8</td>
<td>2.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Increase since 2000 (%)</td>
<td>86.0</td>
<td>165.4</td>
<td>241.5</td>
<td>137.6</td>
</tr>
<tr>
<td>Annualized growth rate (%)</td>
<td>10.9</td>
<td>17.7</td>
<td>22.3</td>
<td>15.6</td>
</tr>
<tr>
<td>Annualized global growth in same period (%)</td>
<td>8</td>
<td>12</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: China Non-Ferrous Metals Industry Association

Both economic and social development face extreme resource pressures, stressing the severeness of the resource-security problems. As the non-ferrous industry is a supportive industry, it has played a major role in the development of the country’s economy as a whole. However, the overly rapid development of this industry, with the high price that is being paid in resource consumption and environmental damage, is not sustainable. The rapidly increasing consumption of key resources and the short supply of non-ferrous minerals are becoming an important factor restricting sustainable development of China as a whole. The per-capita share of 45 major resources are less than half of the world average; the per-capita reserves of copper are less than a tenth of the rest of the world, and those of aluminum about a quarter.

The rapid growth of demand for non-ferrous metals has exacerbated the problem of low domestic mineral supplies, with a rapidly widening gap between demand and resources. China is not naturally rich in non-ferrous mineral resources, especially the four major non-ferrous metals: copper, aluminum, lead and zinc.

At present China has a serious shortage of copper and nickel, low levels of aluminum, lead and zinc, with considerable dependency on overseas markets. It has good reserves of tungsten, tin and antimony, but they are threatened by overexploitation. Molybdenum, rare earth and magnesium are abundant, but so far to little industrial and economic advantage. As data provided by the China Non-Ferrous Metals Industry Association show, 67% of total domestic copper ore reserves have already been exploited and utilized. For bauxite this number is more than 50%, lead ore 68%, zinc ore 72%, tungsten ore 79%, molybdenum ore 60%, tin ore 60% and antimony ore 87%, indicating extremely limited reserves which cannot guarantee the demands of sustainable development. China’s non-ferrous mineral resources, then, should be to develop and utilize with domestic demand in mind, and with restrictions on exports.

According to the 2005 calculations of domestic output of crude metals or concentrates, China’s copper reserves can only be guaranteed for nine more years; those of bauxite
for less than 18 years (for aluminum oxide); those of lead for only 5 years; those of zinc for only 8 years. All of these are far lower than the world average, indicating severe shortage of resources.

Since domestic non-ferrous mineral resources have a low guarantee level for economic development, dependence on overseas markets is increasing, with imported raw materials generally on the rise in recent years, as shown in the following figure.

![Figure 1.3: Table of Raw Materials Imported to China in the Recent Years](image)

Source: China Customs, China Non-Ferrous Metals Industry Association

In 2006, of major non-ferrous-metal raw materials in China, copper accounted for about 65%, aluminum for about 50%, lead for about 35%, while about 13% of zinc depended on imports. It is predicted that the next 5-15 years will see fast growth in China’s non-ferrous metals consumption, and more and more copper, aluminum and other major non-ferrous metals will have to be imported.

### 1.2 Difficulties Saving Energy and Decreasing Discharges

China’s non-ferrous mineral resources feature abundant small deposits of ore but few large ones, abundant thin deposits but few high-grade ones, abundant paragenetic deposits but few single ones, and abundant refractory deposits but few free-milling ones, leading to extended ore dressing and smelting, complicated technologies, and resulting in large energy and water consumption and pollutant discharges. With ever-increasing scale of production, energy consumption and overall discharge of the three wastes (waste gas, wastewater and industrial residue) are increasing, and the tasks of saving energy and reducing discharge are difficult in this industry.
Major pollutants discharged by the non-ferrous metals industry include:

1) Atmospheric pollutants: sulfur dioxide, fluorides, asphalt fume, industrial dust and smoke.

2) Water pollutants: heavy metal ion – mercury, cadmium, hexavalent chromium, copper, lead, zinc, COD, suspended particles, sulfides, acidic wastewater, etc.

3) Solid waste pollutants: ore refuses, ore tailings, red mud and furnace slag, etc.

The following figure shows discharges of atmospheric pollutants in non-ferrous metals production in recent years.

Table 1.2 Wastewater Discharged by the Non-ferrous Metals Industry (in tons)

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of enterprises surveyed</td>
<td>88</td>
<td>86</td>
<td>87</td>
<td>108</td>
<td>118</td>
</tr>
<tr>
<td>COD</td>
<td>14,024</td>
<td>14,011</td>
<td>10,468</td>
<td>9,547</td>
<td>9,254</td>
</tr>
<tr>
<td>Suspended particles</td>
<td>26,806</td>
<td>9,556</td>
<td>6,626</td>
<td>5,620</td>
<td>4,408</td>
</tr>
<tr>
<td>Petroleum</td>
<td>354.1</td>
<td>413.8</td>
<td>375.0</td>
<td>241.7</td>
<td>436.4</td>
</tr>
<tr>
<td>Sulfides</td>
<td>17.13</td>
<td>52.63</td>
<td>14.88</td>
<td>25.66</td>
<td>/</td>
</tr>
<tr>
<td>Mercury</td>
<td>5.09</td>
<td>2.04</td>
<td>1.51</td>
<td>0.53</td>
<td>0.50</td>
</tr>
<tr>
<td>Cadmium</td>
<td>74.79</td>
<td>57.79</td>
<td>37.91</td>
<td>2.21</td>
<td>19.67</td>
</tr>
<tr>
<td>Lead</td>
<td>212.2</td>
<td>185.6</td>
<td>101.2</td>
<td>304.4</td>
<td>68.73</td>
</tr>
<tr>
<td>Copper</td>
<td>/</td>
<td>230.8</td>
<td>199.3</td>
<td>168.5</td>
<td>467</td>
</tr>
<tr>
<td>Zinc</td>
<td>/</td>
<td>1064</td>
<td>477.4</td>
<td>297.0</td>
<td>393.4</td>
</tr>
<tr>
<td>Arsenic</td>
<td>134.5</td>
<td>138.7</td>
<td>115.4</td>
<td>121.8</td>
<td>108.7</td>
</tr>
<tr>
<td>Hexavalent chromium</td>
<td>1.21</td>
<td>2.25</td>
<td>1.04</td>
<td>0.83</td>
<td>0.51</td>
</tr>
</tbody>
</table>


1.3 Sustainable Development is the Inevitable Choice for the Industry

Analysis of the availability of raw materials and the estimated future demand show that the security of the industry, and with it the security of national strategic resources, are facing severe challenges.

It is of the highest urgency to vigorously promote circular economy in the non-ferrous metals industry, to ensure the security of national strategic resources, to break the resource limitations, and to reduce the risks of further development. Considering China’s actual conditions, including a huge population, a relative shortage of resources, and a fragile natural environment with limited capacity to absorb pollution, excessive exploitation and consumption of resources needs to be avoided. Choosing a new path of saving resources, protecting the environment, and increased re-use and recycling, is the inevitable choice for the industry.

The non-ferrous metals industry is a resource-intensive industry, and the nature of its production processes gives it the potential to develop circular economy.

Because of its resource characteristics, China’s non-ferrous metals industry has relied on technological innovation to make great progress in comprehensive utilization of resources, exploiting refractory and associated ores, ore tailings, and depleted sites, all
of which were hard to exploit in the past. In non-ferrous metals mines, the ore recovery rate increased from an average of 53.2% during the 1980s to 79.4% in 2005; the ore-dressing recovery rate from 80.1% to 84.1%; the smelting recovery rate to 95%; associated metals comprehensive utilization rate from 30% to 50%; mineral-resource utilization rate from 38% to 60%, while resource consumption dropped by 36%. recovery rate of associated metals from 30% to 50%; mineral resources utilization rate from 38% to 60%, and resources consumption dropped by 36%. The industry already has favorable conditions for developing circular economy.

Non-ferrous metals are generally suitable for secondary use, with high efficiency of resource use over its entire life cycle, and the process of re-use characterized by low energy consumption and insignificant environmental pollution. With current technology, furnace slag from non-ferrous metals production, secondary copper and aluminum resources from industrial production and municipal waste, discarded home electrical appliances and electronic products all have good re-utilization value. For instance, copper, aluminum and other important metal resources can be recycled repeatedly without limits, with the recycling rate gradually increasing year by year. Recycling of non-ferrous metals provides a good base for developing circular economy in the industry. At present, China’s secondary-metals industry includes several large-scale enterprises, capable of fine scrapping and the processing and utilization of scrap and waste metals, enabling China to utilize imported low-grade metal scrap and giving the country a powerful international cost competitiveness hardly achievable in developed nations with their high manpower costs; thus very suitable to China’s abundant manpower. In addition, development of the secondary-metals industry can solve environmental problems, greatly reducing investment and energy consumption and boosting the recycling rate for recyclable raw materials. Furthermore, the layered structure of domestic economic development has created significant market demand for secondary metals. Different domestic economic development and consumption levels have lead to differences in regional economies and consumption levels, such as of vehicles, car parts and components, mechanical/electrical products, home electrical appliances and electronic products, leading to layered market demands. Recycling scrap and waste metals will also create such a layered structure, with significant market demand in different regions.
2 Progress in the Development of Circular Economy in the Non-ferrous Metals Industry

The non-ferrous metals industry has been making efforts to reduce resource consumption and increase the efficiency of resource utilization, placing an emphasis on promotion of recycling the “Three Wastes” (waste gas, wastewater and industrial residue) and clean production and metals recycling, thus laying down a reliable foundation for the development of circular economy.

2.1 Recycling of Metal Resources and Cascade Utilization of Energy

Non-ferrous metals have good recycling performance, and the utilization of secondary metals can not only save primary mineral resources but also energy, while reducing pollution. The level of utilization of secondary resources of a given country reflects its capacity for sustainable development. In 2006, China’s output of secondary non-ferrous metals reached 4.5 million tons, accounting for 23.6% of the total output for 10 common non-ferrous metals. During the period from 2003 to 2006, China’s annual output growth of secondary non-ferrous metals was 19.8%, with the secondary metals industry already a key part of China’s non-ferrous metals industry. At present, China’s non-ferrous metals recycling level is markedly higher than that of steel, plastic, glass, rubber, and so on, at the top of the list of raw materials.

![Figure 2.1:Productivity of China's Recycled Metal Production in 2003-2006](image)

Source: China Non-Ferrous Metals Industry Association Metals-Recycling Branch

Non-ferrous metals recycling has remarkable energy-saving and discharge-decreasing effects. In 2006, the secondary non-ferrous metals industry saved over 25 million tons of standard coal and 1.5 billion tons of water, and reduced discharges of solid wastes by 1.2 billion tons and of sulfur dioxide by 413,000 tons. The secondary metals
industry has become a key part of China’s efforts to develop circular economy and of the non-ferrous metals industry’s efforts at saving energy and decreasing discharges.

The industrial layout of China’s secondary metals industry includes the three major waste-metal processing and utilization centers in the Zhujiang Delta, Changjiang Delta and on the Bohai Sea. Scrap and waste metals in the country are concentrated mainly in such secondary-resource recovery and transaction markets as those in Miluo, Hunan Province, Changge, Henan Province, Linyi, Shandong Province, Jieshou, Anhui Province and Fengcheng, Jiangxi Province. Those markets have developed from basic collection and separation to include further processing. In addition, industrial parks that import and scrap waste metals have sped up their development and established considerable production capacity, such as the Ningbo Metal Processing Park in Zhejiang, Ziya Environmental Protection Industrial Park in Tianjin, Taicang Generative Resources Processing Park in Jiangsu, Taizhou Secondary Metal Park in Zhejiang, Zhangzhou Secondary Metal Park in Fujian and other parks. China’s administrative direction is known as “Enclosed Recycling Zone Administration”, which involves concentrating the imported waste-metals-scraping industry into special zones, which makes them easier to manage, makes it better for the utilization of secondary resources, and which makes the treatment of gas/water/solid waste more manageable. In 2006, the State Environmental Protection Administration further approved secondary resource processing-park projects in Wen’an, Hebei Province, Yantai, Shandong Province, Wuzhou, Guangxi Province, Jiangmen and Zhaoqing, Guangdong Province. The most exciting news is that a number of large primary non-ferrous metals enterprises are one-after-another building large-scale production bases handling copper, aluminum and other secondary metals. For example, CHINALCO has built a 200,000-ton aluminum recycling project in Qingdao, Jiangxi Copper group corporation and Yunnan Copper group corporation have launched a 100,000-ton copper-recycling project in Qingyuan, and the Guangzhou Steel Group has built a 150,000-ton secondary aluminum and zinc project in Guangzhou.

The non-ferrous metals industry is a consumption-intensive industry that is able to utilize the energies from its own production processes, leading to remarkable cascade energy utilization. The heat generated by ore sulfides during smelting is utilizable, and most advanced enterprises are equipped with waste-heat boilers for power generation. Aluminum-oxide producers are able to meet their own production needs by using steam boilers for power generation.

2.2 Ever-Increasing Efficiency of Resource Utilization

With its continuously increasing technological innovation abilities and management
levels, the resource-utilization efficiency of China’s non-ferrous metals industry has kept improving in terms of mining-loss rate, ore-depletion ratio, ore-dressing recovery rate, smelting-recovery rate, the proportion of finished products made of wrought materials, and other key technological and economic indicators. In the past decade in particular, when the quality of China’s mineral resources has been on the slide, the resource-utilization performance of non-ferrous metals has been rising. According to statistics of the National Development and Reform Commission (Medium and Long-term Development Planning and Studying for Developing Circular Economy of the Non-Ferrous Metals Industry and Boosting the Resource-Utilization Rate, 2005) the average ore-recovery rate for domestic non-ferrous mines today has reached 79.4%, the ore-dressing recovery rate 87%, smelting-recovery rate 95%, while the proportion of finished products made of wrought copper or aluminum has increased to 65% and 71% respectively, all much higher than when China just started opening up.

As experience has shown, the development of circular economy relies on advanced technologies and plants, with a high priority on technological advancement, increasing investment and R&D, introducing advanced technology, perform large-scale technological renovation, not only boosting resource-utilization levels but also bringing remarkable economic benefits. A few examples to illustrate this point:

Through technological innovation and optimization of mining and dressing systems and technologies, the Jiangxi Copper Group Corporation has greatly boosted the metal-recovery rate at mines, reduced raw-ore dressing grades, and expanded resource reserves and extended the service lives of mines. It has also taken on heap-leaching technology in response to the difficulty of recovering copper from copper-containing ore refuses, and has a complete command of the “heap leaching – electric extraction – electric integration” hydro-metallurgical technology for copper extraction, and made other achievements in terms of scaled production, higher resource-utilization efficiency, and reduced production costs.

Based on the characteristics of bauxite resources in China, the China Aluminum Corporation has independently developed a Bayer dressing technology for aluminum-oxide production and developed a new intensive-sintering technology for aluminum oxides, remarkably boosting the economic utilization rate of bauxite resources with a low aluminum-silicon ratio, thus making breakthroughs in China’s bauxite resource-utilization technologies. In addition, the China Aluminum Corporation has created a circular-economy industrial chain and boosted resource-utilization efficiency by optimizing its industrial structure. Taking the largest domestic aluminum processor, the Southwest China Aluminum Group Corporation of China Aluminum, as an example, since it began using flat section ingots and cast/rolled sheets supplied by electrolytic aluminum plants, its comprehensive energy
consumption for wrought aluminum materials has dropped from more than 700 kgce/ton to more than 300 kgce/ton, a remarkable increase in energy savings.

The Jinduicheng Molybdenum Group Corporation and other large-scale non-ferrous metals mining enterprises have made their non-ferrous ore-dressing recovery rate reach international levels by use of large-scale, high-efficiency ore-dressing plants and reasonable ore-dressing technologies and agents.

The Tongling Non-Ferrous Metals Holding Group and other major domestic copper-smelting enterprises have remarkably boosted the sulfur dioxide recovery rate in smelting through promotion of flash smelting, ISA smelting and other advanced smelting technologies, with the sulfur dioxide recovery rate in copper smelting increasing from 70% to 95%. At present, the comprehensive energy consumption of domestic enterprises using advanced technologies in crude copper smelting has dropped to more than 300-kg of standard coal per ton, placing them at the level of top international enterprises.

The Shanghai Sigma Non-Ferrous Metals Corporation has built Asia’s only production line for aluminum ash re-disposal, replacing the traditional, out-of-date “indigenous smelting method using a crucible furnace,” and provided an effective solution to the aluminum-ash disposal problem that had hindered development of the secondary aluminum industry. The production line uses mechanical methods to dispose of aluminum ash, not only boosting its recovery rate but also preventing pollution. The waste slag from the extraction of metallic aluminum can be used to produce refractory materials and ceramic products, thus achieving the goal of lowering discharges and preventing pollution.

The Ningbo Jintian Group Co. Ltd. has independently developed a secondary copper-bar large-tonnage electrical furnace smelting-stream turning of latent fluid-multithread horizontal continuous casting production technology, an original and practical technology at which it is the international leader. Application of this technology has shortened a 2-3 day production process to 45 minutes, boosting production and resource-utilization efficiency and reducing energy consumption.

2.3 Strengthened Capacity in Comprehensive Recovery of Associated Elements

China’s non-ferrous mineral resources feature abundant associated ore reserves. Vigorous efforts at comprehensive utilization of associated resources can significantly boost both profits and resource-utilization efficiency.
Comprehensive utilization of associated resources is a key indicator of the development level of the non-ferrous metals industry. With its recent technological innovation, China’s non-ferrous metals industry has kept increasing its comprehensive recycling of valuable elements. At present, almost all domestically produced platinum, and diverse metals such as indium, germanium and gallium, come from comprehensive utilization. According to statistics of the National Development and Reform Commission (Medium and Long-term Development Planning and Studying for Developing Circular Economy of the Non-ferrous metals Industry and Boosting the Resource-Utilization Rate, 2005), nearly one third of the country’s sulfuric acid, 10% of its gold and 90% of its silver now come from comprehensive recovery during smelting of non-ferrous metals, with the volume of metals obtained by the non-ferrous metals industry through comprehensive recovery already accounting for about 15% of its annual output; or 10% of the output value in terms of profits and taxes. In 2005, China’s indium output was 310 tons, cadmium 4,077 tons, bismuth 10,605 tons, germanium 66 tons and gallium 18 tons, all first in the world, with almost all those products coming from comprehensive recovery during smelting of non-ferrous metals.

2.4 Ever-increasing Efforts at Pollution Control and Recycling the “Three Wastes”

Wastewater, gas emissions and solid wastes generated during non-ferrous metals production have an impact on the environment that cannot be ignored. In recent years, China’s non-ferrous metals industry has relied on technological advances to promote clean production, eliminate out-of-date technologies and plants, and increasingly try to control pollution, leading to year on year reductions of discharges of major pollutants.

According to statistics of the China Non-Ferrous Metals Industry Association, major pollutants discharged in the industry’s wastewater in 2005 were remarkably lower than those discharged in 2001, as shown in Table 2.1.

<table>
<thead>
<tr>
<th>Item</th>
<th>2005 discharge (ton)</th>
<th>Down from 2001 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>9,254</td>
<td>34</td>
</tr>
<tr>
<td>Suspended particles</td>
<td>4,408</td>
<td>84</td>
</tr>
<tr>
<td>Cadmium</td>
<td>20</td>
<td>73</td>
</tr>
<tr>
<td>Lead</td>
<td>69</td>
<td>67</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.5</td>
<td>90</td>
</tr>
</tbody>
</table>

Source: China Non-Ferrous Metals Industry Association
Sulfur dioxide, fluorides, industrial smoke and dust are major atmospheric pollutants discharged during non-ferrous metals production. In recent years, while China’s non-ferrous metals output has rapidly increased, the annual discharge of sulfur dioxide has more or less stabilized at around 450,000 tons; the discharge of fluorides has dropped every year, with the 2005 discharge of fluorine per ton of aluminum matching the international standard of less than 1 kg. According to statistics from the China Non-Ferrous Metals Industry Association for 118 major enterprises, in 2005, the industrial smoke discharge was 52,000 tons, down from 2001 by 28%, and the industrial dust discharge 37,000 tons, down from 2001 by 30%.

Non-ferrous mineral resources are low-grade, and as a result production of 1 ton of non-ferrous metals requires as much as a thousand tons of ore, resulting in large amounts of ore refuse and tailings, furnace slag, and other solid wastes. With its ever-increasing scale, China’s non-ferrous metals industry is producing more solid waste every year, nearly 100 million tons at present. Comprehensive utilization has become an important requirement for the development of the industry. The utilization rate of solid waste of China’s non-ferrous metals industry has been rising, reaching 13% in 2005, up from about 9.4% in 2001. The aluminum industry’s utilization of waste material has extended from red mud to power-plant fly ash, coal gangue, furnace slag, fluor-gypsum, sulfourea slag, waste catalysts from the petro-chemistry industry, and so on. It has successfully developed and produced cement, red-mud calcium-silicate insulating material, red-mud fly ash bricks, red mud calcium-silicon fertilizer, compound-foaming concrete blocks, environment-friendly ceramic filter bulbs and other new products.

At present, circular economy pilot enterprises including the China Aluminum Corporation, Jiangxi Copper Group Corporation, Tongling Non-Ferrous Metals Group Corporation, Jinchuan Group and Zhuzhou Smelting Group Corporation and others have all implemented international management systems, voluntarily adopting ISO9001, ISO14001 and other standards in their production, and are promoting standardized management and providing a scientific management platform for high-quality, low-cost, low-consumption, low-pollution and safe production. These enterprises have combined resource-consumption control with clean production technologies, based on the principle of “continuous improvement,” and boosted the technological level of recycling, utilization of the “three wastes”, and clean production.

The low grade of non-ferrous ores means that the “three wastes” are generated in large quantities. The first circular-economy pilot enterprises of the non-ferrous metals industry have been successful at recycling the “three wastes” by making greater
efforts at pollution control. “Turning wastes into treasures” has always been a key goal of the industry, and utilization of the three wastes is a key approach to preventing pollution, turning wastes into resources, and developing circular economy.

2.5 Gradually Lowering Energy Consumption

The non-ferrous metals industry is a major energy consumer. In 2005, the annual standard coal consumption of the industry was about 83 million tons, accounting for about 3.8% of total domestic energy consumption. That year its industrial value-added amounted to RMB 218 billion, with energy consumption per 1 million RMB of industrial value-added being 383 tons of standard coal. The non-ferrous metals industry is energy intensive and its continuous growth has been exerting pressure on domestic energy supplies. To make its own development sustainable, the industry makes saving energy its top priority. Through technological advances and management improvements, the industry has achieved significant energy savings in recent years, as shown in the following figure.

![Figure 2.2: Energy Consumption Index for Major Non-ferrous Metal Smelting and Processing in 2001-2005](image)

Source: China Non-Ferrous Metals Industry Association

2.6 The Importance of Development and Use of New Types of Non-ferrous Materials

Non-ferrous metals are important structural materials and indispensable functional materials. Based on the requirements for developing circular economy, production of non-ferrous materials should be designed not only to reduce resource and energy consumption and pollution, but also to be conveniently recovered and recycled.
Therefore, strengthening basic research, developing materials with low alloy contents, simplifying alloy specifications, and trying not to add elements (or adding as few as possible) that are difficult to remove with existing technologies will help the recycling of non-ferrous materials.

The promotion and use of new types of non-ferrous materials play a significant role in energy savings and discharge reduction. For instance, cars are a major part of Chinese life, but consume a lot of energy and discharge great volumes of pollutants. The associated problems make the savings and reductions that can be achieved with lower vehicle weights an urgent issue. One way of realizing this is to use aluminum. Aluminum is lighter than other metals, with only a third of the weight of steel, but has greater strength, and good mechanical performance. It can completely replace steel as a structural material in vehicles, leading to lighter vehicles and significant gasoline savings. According to estimates, for every 10% vehicle weight reduction, gasoline consumption falls by up to 8%. Assuming 50 million vehicles in China by the end of 2006, with one vehicle consuming 4,000 liters of gasoline per year, if every vehicle can reduce its weight by 10%, the total savings will be 16 billion liters a year, about 1% of domestic production. The energy saved using aluminum is 6 to 12 times the energy consumed to produce the parts. Vehicle weight reduction can also reduce pollutant discharge. According to estimates, every kg of aluminum used in a car can reduce tailpipe discharges by 20 kg over the car’s life span. If each of the 30 million vehicles in China today would use 1 kg of aluminum parts instead of the existing steel parts, total discharge reductions would amount to 600,000 tons over their life spans. In addition, aluminum has excellent recyclability, with a recycling life far longer than those of steel, plastic or wood, and low energy consumption throughout its service life. That is especially true of vehicle applications, in which it is not only helpful in reducing weight, thus saving energy and reducing discharge, but also relatively convenient for recycling. At present, discarded vehicles around the world are key sources of recyclable aluminum.

Therefore, even though non-ferrous metals production consumes a lot of energy, widespread use of non-ferrous materials can save energy in high energy-consumption fields such as construction and transportation. Development of solar energy, wind power, tidal energy and other green energies especially need the support of new kinds of non-ferrous materials. Use of such materials in large quantities is of crucial significance, then, for the entire society’s ability to save energy and decrease discharges, and develop circular economy.
2.7 Working Towards an Industrial Chain

As a resource-intensive industry, the non-ferrous metals industry faces increasing pressure in terms of markets, resources, energy, cost and environment. The high-investment, high-consumption, high-discharge and low-efficiency overly rapid growth pattern can no longer survive the fiercely competitive markets both at home and abroad. Efforts must be made to change development philosophies and follow the principles of circular economy to “Reduce, Reuse and Recycle” in order to vigorously develop non-ferrous metals comprehensive-utilization and scrap and waste metal recycling industries, and build industries that feature low consumption, low discharge and high efficiency so as to achieve sustainable development.

The management performance, technological level, resource utilization and savings, and competitiveness of non-ferrous metals enterprises is best reflected by “Four Rs and One C” (ore-recovery rate, ore-dressing recovery rate, smelting-recovery rate, rate of finished products made of wrought material, and comprehensive utilization level). Therefore, the production and operations of such enterprises must be conducted in such a way as to boost the “Four Rs and One C” and form an industrial chain, integrating upstream and downstream sectors, so as to position itself against tough competition and achieve sustainable development. At present, such an industrial chain is starting to take shape in China’s key non-ferrous metals enterprises.

The China Aluminum Corporation, at present China’s largest non-ferrous metals enterprise, has set developing circular economy and creating a resource-saving enterprise as its key objective. In line with its actual business conditions, it focuses on three areas: technological innovation, energy savings, and comprehensive utilization, and it makes vigorous efforts to link the production of heat, power and aluminum, and arranges production, consumption and waste disposal in accordance with the rules of ecology, with a feedback flow of “resource-product-secondary resource” taking shape. Through these efforts, it is trying to utilize all materials in a continuous economic circle, create an ecological aluminum industry featuring resource savings, low energy consumption and recycling.

Paying high attention to resource utilization, the Jiangxi Copper Group Corporation has been increasing core-business revenues through comprehensive recovery of sulfur, gold, silver, molybdenum, lead, zinc, tungsten, selenium, Te, arsenic and other valuable elements in raw materials, reaching profits of 21 billion RMB in 2005, first among domestic copper enterprises. Its 2005 output of acid extracted from fumes was 1.08 million tons, of finished gold 12 tons, finished silver 323 tons, selenium 262 tons and Te 43 tons, giving it not only a key position among its domestic counterparts but also among leading international producers of similar products. At the same time, the
Corporation is currently one of the largest domestic producers of secondary copper, with 36% of its fine copper output in 2005 coming from utilization of waste and scrap copper.

In the face of increasingly strained supplies of raw materials in recent years, the Zhuzhou Smelting Group Corporation, the largest domestic lead and zinc smelting enterprise, has become, through technological advances, one of the non-ferrous metals enterprises with the highest resource-utilization efficiency in China, while reducing energy consumption, recycling the “three wastes,” promoting clean production and vigorously developing circular economy. In 2005, the comprehensive-utilization rate for imported materials of the Corporation reached 75%, with comprehensive recovery that year being 1,472 tons for cadmium, 8 tons for finished gold, 286 tons for finished silver and 59 tons for indium, and the profits from comprehensive-recycling products accounting for more than 50% of total profits, placing it among leading international enterprises in terms of resource recycling.

While strengthening internal resource recycling, key domestic non-ferrous metals enterprises have also taken the lead in establishing relationships of circular economy with both upstream and downstream enterprises in the industrial chain. For example, the rare metal germanium, recovered from power-plant fly ash, has accounted for more than 40% of domestic metallic germanium output, while furnace slag from the smelting of copper, lead and zinc has come into high demand in cement production and highway construction. Industrial chains are forming, joining non-ferrous metals enterprises with related industries.
3. Major Problems Facing the Non-Ferrous Metals Industry in Developing Circular Economy

3.1 Industrial Structure in Urgent Need of Optimization

Although China’s non-ferrous metals industry makes optimization of industrial structure one of its top priorities, there are no signs that the blind rush to launch projects is declining, so the problem of industrial structure still has to be focused on.

In the past decade, China has seen overheated investment in electrolytic aluminum, aluminum oxide, copper smelting, lead and zinc smelting, magnesium smelting and tungsten smelting, among others, leading to under-utilized production capacities at numerous non-ferrous metals smelting enterprises due to lack of stable supplies of raw materials, and resulting in roaring prices of non-ferrous mineral raw materials on markets both at home and abroad. As a result of the overheated investment in electrolytic aluminum after 2000, the domestic production capacity of electrolytic aluminum increased from 3.18 million tons to 10.70 million tons in 2005 (while out-of-date capacity has been eliminated in the same period) over just a few years, indicating a development momentum seldom seen anywhere. However, due to lack of aluminum oxide raw materials and lack of power, around 2 million tons of electrolytic aluminum-production capacity lay idle in 2005, leaving most independent electrolytic-aluminum plants taking losses – a clear demonstration of the ill effects of blind development.

At present, the product structure of China’s non-ferrous metals industry is still oriented to basic raw material products, with low value-added, consuming great volumes of resources and causing pollution, while processed products with high technological content and high value-added still have to be imported in large quantities. In 2006, imported volumes of high-precision aluminum sheet and strip reached 480,000 tons, about one fourth of total domestic output of aluminum sheet and strip that year.

According to the China Non-Ferrous Metals Industry Association, the industry still has lots of out-of-date production technologies and plants with high energy consumption, that squander resources and cause severe pollution, and need to be upgraded or eliminated. These include a small pre-baked cell electrolytic aluminum plants with a total production capacity of 650,000 tons, blast furnace and flame furnace crude copper-production capacity of about 500,000 tons, sintering pot/pan crude lead-smelting capacity of about 1 million tons, and a vertical-retort zinc smelting capacity of about 900,000 tons. Those out-of-date technologies and
processes are severely restricting the industry’s overall improvement and sustainable development.

The non-ferrous metals industry’s continuous increase in scale has produced increasing demand for mineral resources and energy as well as overall discharges of the “three wastes,” exerting unbearable pressure on resources and the environment. Therefore, speeding up adjustment of the industrial structure and eliminating out-of-date production capacity have become necessary to guarantee the development of circular economy.

3.2 Significantly Less Metal Recycling than in Developed Nations

According to statistics of the National Development and Reform Commission in the “Medium and Long-term Development Planning and Studying for Developing Circular Economy in the Non-Ferrous Metals Industry, and Boosting the Resource-Utilization Rate”, China’s non-ferrous metals resource-utilization rate is only 60%, 10% lower than that of developed nations; the associated metals comprehensive-utilization rate less than 30%, only half of that of developed nations; and the energy consumption for non-ferrous metals products about 15% higher than the international level, indicating great potential for boosting resource-utilization efficiency and reducing energy consumption.

Since China has become a major non-ferrous metals producer and consumer, it should also be a major secondary non-ferrous metals recycler. But China’s secondary non-ferrous metals recycling rate is still very low. Despite the industry’s scale, it has a low level of intensiveness, out-of-date technology, high energy consumption, low metal-recovery rate and is characterized by severe pollution.

By the end of 2005, there were about 2,000 domestic secondary-aluminum enterprises, but only one of them delivered an output greater than 100,000 tons a year, with the output of most enterprises being less than 10,000 tons, in plants that are crude and out-of-date. The smelting-recovery rate of aluminum cans is only 50% or so, significantly lower than that of developed nations, where the recovery rate is more than 80%.

There were about 3,000 domestic secondary-copper enterprises in 2005, only 2 with an output greater than 100,000 tons, with the overwhelming majority at less than 10,000 tons, involving technology with low production levels and product quality, a low metal-recovery rate, and severe pollution.
There are about 300 secondary lead enterprises in China, but only one of them delivered an output greater than 100,000 tons in 2005, with the overwhelming majority small, out-of-date, and severely polluting. China’s smelting rate of lead wastes and scraps is only about 85%, compared to 95% in developed nations.

In addition, China’s regeneration and utilization of zinc is far lower than that of developed nations. Although the largest zinc consumer in the world, China’s annual recovery of zinc waste and scrap is only about 100,000 tons, with a low recycling rate. Technologies like galvanization, zinc recovery from steel-making fumes, and recycling of dry batteries, commonplace in other countries, are virtually unknown in China.

### 3.3 Low Recycling Rate of the “Three Wastes”

China is a major non-ferrous metals producer, consuming great volumes of minerals, energy and water, and discharging huge amounts of solid waste, wastewater and exhaust gas during production. In 2005, non-ferrous metals mines produced 160 million tons of ore refuse, about 120 million tons of ore tailings, 7.8 million tons of red mud and 7.66 million tons of slag, and discharged more than 400,000 tons of sulfur dioxide and 270 million tons of wastewater. Those “three wastes” are both pollutants and potential resources. However, China’s non-ferrous metals industry currently has little recycling of the “three wastes,” with the solid-waste utilization rate being only about 13%, an involving no utilization of low-concentration sulfur dioxide or recovery of valuable elements from industrial wastewater. Except a few large-scale enterprises that are utilizing the waste heat from smelting for power generation, most enterprises have a very low waste-heat utilization rate. The low level of recycling of the “three wastes” has become a significant issue for developing circular economy.

### 3.4 Weak Technical Support Capabilities

Compared with other major mineral-producing countries, China’s non-ferrous metals industry lags significantly in terms of resource development and utilization technologies, with weak integration and innovation capability for “three wastes” recycling and control technologies, lack of major breakthroughs in energy conversion and cascade-utilization technology, and research on secondary-resource recycling just beginning. There is therefore an urgent need to strengthen the technical-support system for recycling of secondary resources.

In the field of mineral-resource development, solution mining technology, which can
remarkably boost the resource-utilization level, has just been introduced; high-efficiency large-scale mining and dressing plants have to be imported in most cases; and R&D efforts related to mine security and pollution control cannot meet the requirements for developing circular economy.

In the field of smelting, China has few independently developed core technologies for increasing efficiency and energy-savings. Although advanced technologies such as flash smelting, Noranda enriched-oxygen smelting and ISA enriched-oxygen smelting have been introduced, there have been insufficient efforts at digesting, absorbing and re-innovating. That is particularly true of the secondary non-ferrous metals industry’s overall technologies and plants, which have become out-of-date, leading to significant problems in product quality, environmental protection, energy consumption and metal recovery, and cannot provide the support needed to develop circular economy. Concerned government agencies should boost their support for R&D of the secondary-metal industry’s technology and plants.

In the field of processing, efforts lag in developing new environment-friendly materials that can replace lead solder, free-cutting brass, Ag/CdO contact materials and mercury-containing zinc powder, among others; development of solar energy, fuel cells and other new kinds of energy sources and materials have yet to be strengthened; and the development of new materials in accordance with the concepts of circular economy is just getting underway.
4. Case Studies of Circular Economy in the Non-Ferrous Metals Industry

4.1 Progress of Circular Economy at CHINALCO

Aluminum Corporation of China (CHINALCO) was established in February of 2001, and has established three main businesses: aluminum, copper and rare earth, in its 5 years of development; its assets, productivity, sales revenues and profitability are all well developed, and it can be considered a world leader in the non-ferrous metals industry.

As a resourceful and comprehensive enterprise, CHINALCO has always seen energy conservation and waste reduction, the implementation of clean production and development of circular economy, as the basic ways to establish a first-class enterprise. It continues to develop innovative technologies for that purpose, and has concentrated effectively on energy efficiency and cascade use as well as striving for zero-waste by using advanced techniques and technology, and improving on-site management. The overall energy consumption of CHINALCO’s aluminum production fell 16.2% between 2001 and 2005, the overall electricity consumption for each ton of electrolytic aluminum fell by 378 kWh, and most of its enterprises had achieved zero-waste and achieved breakthroughs in recycling. Under the principles of “reduction, recycling and resource management,” CHINALCO is continuously developing circular economy, and has been recognized its efforts: the National Development and Reform Committee and China Non-Ferrous Metals Industry Association held a National Non-Ferrous Metals Circular Economy Seminar at the Zhongzhou branch of CHINALCO, and enlisted it as a trial enterprise for the national development of circular economy. CHINALCO’s circular-economy development model is a complete industrial-chain model based on improving the efficiency of resource usage.

CHINALCO is developing circular economy based on comprehensive consideration of energy conservation, consumption reduction, waste reduction, environmental protection, and resource conservation. CHINALCO has prepared a relatively feasible and complete plan to promote circular-economy, titled “CHINALCO Eleventh Five-year Circular-Economy Promotional Plan”. It breaks down objectives into scientific and technological innovation, technological upgrade installation, management, investment, the establishment of an appropriate corporate culture and many others, and lays out how to implement them, in order to ensure the objectives are achieved.
4.1.1 Improving organizational leadership and plan implementation

CHINALCO has established a committee for promotion of resource conservation for developing circular economy, with the general manager as committee director, vice general manager as deputy director, and related department heads as members; a circular economy promotional office has been established under the committee to coordinate the work of promoting circular economy, and each department is responsible for the aspect of circular economy related to its functions. Each of the member companies and subsidiaries of CHINALCO has established their own leadership and working committees, responsible for breaking down related indices, preparing and implementing their own circular-economy promotional plans on the basis of the company’s plan, and supervising the implementation of their plans to ensure they achieve their own goals as part of the company’s overall plan.

In these plans, responsibility is broken down and clearly divided, with appropriate incentive mechanisms, to form a five-level management network that covers the headquarters, enterprises, factories, mines, and workshop and work groups, creating a beneficial work atmosphere under the motto of “everybody sharing responsibility and working toward the same goal,” of energy conservation and waste reduction in the course of developing circular economy.

4.1.2 Optimizing the structure, and improving the level of resource utilization

CHINALCO optimizes its internal structure as a strategic measure for establishing a resource-conserving and environmentally-sound enterprise in the following four aspects:

1) Improving technological structure, switching to energy-efficient technologies.

For alumina, the focus is on promoting the energy efficient Bayer dressing process, intensifying the burning process, and use of the back-increase concentrated-melting technology. CHINALCO’s Bayer-process alumina production was 68.8% of its total alumina production in the first half of 2007, 17.7 percent higher than when CHINALCO was established. For electrolytic aluminum, CHINALCO promoted a large-scale pre-baking tank by closing a highly polluting self-baking tank, and improved and upgraded the outdated equipment of a few member enterprises, dramatically reducing the energy consumption for electrolytic aluminum production and reducing fluoride discharge from 20kg/ton to under 1kg/ton. For the processing of aluminum and copper, CHINALCO invested a great deal in improving technology and equipment, and implementing industry upgrading, so that its overall level is now comparable with the international standard.
2) Adjusting product structure, developing high added-value and low energy-consuming products. CHINALCO has continuously increased the production of high added-value chemical aluminum, entering the high-end international market and quickly gaining market share; it is building advanced recycled-aluminum production lines, the first phase of construction of its Qingdao 200,000-ton recycled aluminum plant is nearly finished and will soon be in production. For electrolytic aluminum, it has formed aluminum-alloy forging bases such as Baotou Aluminum and the Shandong subsidiary, as well as piece-ingot manufacturing bases such as the Guizhou, Qinghai and Henan subsidiaries, which are continuously improving their technologies to produce electrolytic aluminum-alloy.

3) Adjusting the upstream and downstream industrial structure, improving the industrial chain. CHINALCO has followed the government’s industrial policy with acquisitions and reorganizations to form a group of domestic forging and processing enterprises with a large impact on the industry, and consequent improvement of CHINALCO’s industrial chain. CHINALCO is progressing rapidly toward its goal of building six aluminum and three copper processing bases.

4) Adjusting the resource-supply structure, strengthening sustainable development capability. CHINALCO has established a centralized purchasing system due to the domestic resource supply shortage, adjusting and optimizing ore supply structure and developing and perfecting excavation, selection and forging techniques appropriate to Chinese ore resources, with improved recovery and comprehensive collection rates; it has also focused on foreign-resource development in accordance with the “Two Resources and Two Markets” strategy (a Chinese slogan referring to domestic and overseas resources and markets, in this case emphasizing the possibility of importing resources from overseas), and protecting domestic resources.

Its efforts at adjustment and optimization have laid a foundation for CHINALCO to implement sustainable development.

4.1.3 Promoting technological innovation to conserve resources

Since the establishment of CHINALCO five years ago, it has invested almost 3 billion RMB in R&D, and taken on a total of 863 national projects and 38 national programs for scientific and technological development, technological innovation, high and new technology, among others. Six of these have received the national technology advancement award, 340 of them provincial and departmental technology advancement awards, and 600 of them have led to applications for patents, of which
have already been approved. They include empholite aluminum-earth mineral-selection Bayer-processed alumina, the key technology affecting the electrolytic tank, and many other key developments or findings aimed at energy saving, consumption reduction, and the comprehensive utilization of resources.

China’s bauxite resources are mostly low aluminum-silicon-ratio empholite, which gives China’s alumina production the disadvantages of high energy consumption, long processes, heavy investment in construction, poor technical economy indices, and so on, in contrast to the Bayer process commonly used overseas for high-quality bauxite processing. Also, as bauxite quality falls, the technical economy index will do the same, with production costs increasing accordingly, creating serious limitations to the further development of the industry. This has led CHINALCO to develop a mineral-selection Bayer-process technology, which effectively separates aluminum and silicon through mineral selection, increasing the aluminum-silicon ratio in mineral aluminum, so that mineral aluminum with a high aluminum-silicon ratio can still be economically processed. The production of alumina with this combination of mineral selection and the Bayer process turns the “poor mine,” with a 5.9 aluminum-silicon ratio, into a “reasonably rich mine” with a 11.9 aluminum-silicon ratio, making low-quality ore economically viable.

Most of the bauxites in China are of low quality, and have high alkali consumption, a poor dissolution rate, and dramatically increased costs if the Bayer process is applied to them directly. At the same time alumina production itself has many problems, such as a complicated process, high energy consumption, difficulties in attaining advanced enough equipment, and so on. As the shortage of bauxite intensifies and the quality of the ore drops, the increase of ore, alkali and energy consumption in the alumina industry, the decrease of recycling efficiency and productivity, the worsening of the technical economic index, and the increase of production costs are all seriously affecting the sustainable development of the Chinese alumina industry. To cope with this, CHINALCO had developed a lime Bayer process with intensified burning technology for producing alumina, involving tube dissolution, repression of membrane evaporation, red-mud high-efficiency separation, burning of alumina fluids and other new technologies, and industrialized them, contributing greatly to the dramatic reduction of alkali and energy consumption in the production of alumina.

4.1.4 Digestion, processing and reuse of waste material

1.5 to 1.7 tons of red mud are produced for each ton of alumina. It comes from different parts of the production process, and red mud from a different source has different contents and properties, making it difficult to treat and use. To do so,
CHINALCO is cooperating with scientific research institutions to conduct research into and attempt industrialization of comprehensive recovery of rare metals from red mud, the application of Bayer-process red mud in highways, and at the same time reduce pile-up of cinder and other solid wastes. It is also conducting research on using high aluminum-content coal-dust ash to produce alumina; comprehensive usage of, and technology for using aluminum waste; treatment of the red-mud tank for water recovery using film-separation technology and recovery of alkali; development of technologies for industrial-furnace waste-gas recovery and usage; and other projects related to comprehensive usage of resources.

Currently the following successful examples of secondary resource utilization from the production process of alumina include:

1) Cement produced from red mud (replacing clay), and limestone tailings from bauxite mining;
2) Silicon calcium fertilizer produced from red mud. Red mud content can be up to about 25%. The product can improve soil composition, boost the quality of agricultural products, reduce infestation and increase productivity; it is especially effective for organic vegetables and crops.
3) Producing clinker brick with waste stone chips, stone dust, fly ash and slag. In 2006, 1.378 million blind-pore bricks and 450,000 standard bricks were produced this way.
4) Producing micro-pore calcium-silicate insulating material with powdered silicon dioxide, limestone, fiber-strengthening material, circulated water, etc (through the processes of mixing, gelatinizing, forming, steam pressing, drying etc). 30,000 m$^3$ has been produced since 2002, with good profits.
5) Recovery of alumina from alumina inactivate catalyst by Shandong Aluminum Company. In 2004, the company independently developed technology for recovering alumina from inactivate catalyst after extraction of vanadium and molybdenum and comprehensive treatment of its waste, successfully recovering alumina; it has also built a production line for alumina recovery from waste catalyst, which is capable of treating 100,000 tons of waste catalyst as well as producing 25,000 tons of alumina annually.

4.1.5 Scientific land reclamation and promotion of habitat protection

As a resource-oriented enterprise, CHINALCO mines on a larger scale every year, mostly from open-cast mines, for which land reclamation is extremely difficult. CHINALCO has invested a great deal of money and labor in the reclamation of mining land, its integration of mining and reclamation matching the international standard. The land reclaimed by CHINALCO so far amounts to 9,838 acres.
Adopting the “separating – mining – reclaiming” method. Adjusting the sequence of strip mining with this technique speeds up reclamation.

Adopting the concentrated pressure-filter method. This involves making making mud pie by pressurizing and filtering muddy water and using the mud pie as filler soil for goafs; the filtered water can then be used again in washing, leading to “zero release” of wastewater during land reclamation. In addition, land can be joined together on a large scale through constructive reclamation, and the vitality of the microorganisms in reclaimed land reach the level of that in the local soil through microorganism, plant growth and water-retention technologies, soil fertilization and improvement through bio-reclamation, leading to dramatically improved land quality with good potential for agricultural development.

4.1.6 Implementing the wastewater “zero release” project

CHINALCO has been investing more and more in treating polluted water, and has constantly been perfecting its polluted-water-treatment equipment; it has been protecting the environment and developing as an enterprise simultaneously, and by the end of 2006 already had 18 industrial polluted-water-treatment systems in place.

In the processes of water conservation and waste reduction, each subsidiary has taken advantage of CHINALCO’s position as an integrated enterprise with high levels of investment and optimized production techniques in exploring and experimenting with using alkaline processes to treat water polluted with acid, using the burning method to treat tar and polluted water containing chlorine, using the red-mud washing system to treat polluted water with a high floating-substance content, and so on. All of these have promoted water-resource cascade-usage and led to the discovery of economical environmental protection technologies, including:

1) Setting up separate water-purifying circulation systems and water treatment systems for different qualities of wastewater. Recovered and treated wastewater has good quality and a wide range of uses, and is recycled at a rate of over 92%.

2) Following the water-treatment principle of “controlling the output of wastewater, perfecting water treatment, and developing and using recycled water.” This involves shifting from the traditional end-of-pipe treatment to controlling from the source; comprehensive treatment; implementing “water-consumption control and freshwater-allowance evaluation,” “adjusting water usage and perfecting measurement methods,” and other management methodologies. It involves recycling wastewater from different areas, along with treatment of municipal wastewater. While alumina production increased from
374,000 tons in 1997 to 1,024,000 tons in 2006, and electrolytic aluminum from 169,000 tons to 362,600 tons, the Guizhou subsidiary reduced its industrial water consumption from 2,475,000 tons in 1997 to 1,099,000 tons in 2006.

3) Establishing the concept of “grand circulation of water.” A strong foundation was built for balanced supply and demand of water in the whole company through a water-circulation system that supplements the supply of different parts of the company according to need. The Zhongzhou subsidiary has managed to conserve 6,000 tons of fresh water per day through a series of technological improvements. Alumina production increased from 545,000 tons in 2001 to 1,730,000 tons in 2006 while freshwater consumption fell from 10.98 tons/ton in 2001 to 4.78 tons/ton in 2006, a 58% reduction.

4.1.7 Positive effects of developing circular economy

1) Overall energy and steam consumption of alumina production are decreasing every year.

![Energy Consumption for CHINALCO Alumina Production](image1)

![Steam Consumption for CHINALCO Alumina Production](image2)
2) Energy consumption of copper production is decreasing every year. Between 2001 and 2005, energy consumption for every ton of rough copper produced fell 86kg of coal equivalent, and electrolytic alternating-current consumption for every ton of cathode copper fell by 33kWh.

3) Increase in the ratio of raw materials to finished aluminum products per year
4) Decrease in freshwater consumption per ton of alumina per year

5) Production of gallium recovered from alumina production quadrupled between 2000 and 2005, making China the largest producer of gallium.
6) Shandong Aluminum Company of CHINALCO has independently developed a system for comprehensive utilization of waste catalyst to recover alumina and other valuable metals. This system has recovered 38,523 tons of alumina, 3,432 tons of nickel metal, 15,684 tons of vanadium concentrate, 170 tons of calcium molybdenum and 331 tons of ammonium metavanadate altogether, which turned a cumulative profit of over 50 million RMB.

7) Between 2001 and the end of 2005, the rate of recovery of sulfur dioxide by CHINALCO subsidiaries increased from 40.5% to 75.8%, and that of industrial-smoke dust from 95.1% to 97.5%.

4.2 Progress of Developing Circular Economy at Henan Yuguang Gold & Lead Group Co.

Henan Yuguang Gold & Lead Group Co. (Yuguang) has been responsible at establishing conservation and developing circular economy in the recent years, exploring the development of circular economy in the lead industry, and experimenting with combining recycling and original production, as well as successfully building a unified development model for lead and zinc. Starting from the principle of “reduce, reuse, recycle,” it has made great progress in resource efficiency through sourcing from waste materials. The model of combining recycling with original production has enabled Yuguang to achieve dramatic reductions of energy and material consumption, visible improvements in the indices of technical economy and environmental protection, as well as increased of market share and improved relations with local communities.
4.2.1 United production model for lead and zinc

Yuguang is actively developing unified production of lead and zinc through product-structure adjustments and technical improvements. Yuguang has used the two by-products of lead and zinc production, lead skim and zinc dioxide, as raw-material supplies for each other, with recycled products also being used in raw-material replenishments, creating complementary industries and realizing an internal cycle. Appropriate expansion of upstream and downstream industries ensures resource supplies to the main industry on the one hand, and added value through reprocessing, along with increased market competitiveness, on the other. At the same time it is developing “comprehensive usage,” which reduces environmental impact and increases the usage rate of resources. The development of the recycled-lead industry has led to a recycling channel based on the main industry, an external cycle which maximizes resource usage and minimizes discharge.

In this unified production, products are reprocessed into alloy, lead salt, zinc dust and so on. Among them, other than the ones exported, lead-alloy products are used in accumulators, safety lamps and other power-supply products, and exported power-supply products are used to replenish raw materials through recovery, thus recycling resources, improving the level of usage of recycled materials, increasing the added value of products, increasing product range, and achieving good social and economic benefits.

Yuguang uses lead-skim fuming to extract zinc, comprehensively recovering Au, Ag, Cu, Sb, Bi and other valuable elements from anode sludge, recovering Cd, In and so on from zinc-soaked residues and other by-products; it separates various types of wastewater from the production process, then treats and recycles them; it recovers sulfur from the production process to produce sulfuric acid, with reduced pollution and good economic benefits; it recycles the various types of energy from the production process, such as using leftover heat from high-temperature processes, to generate electricity, while the leftover heat from low-temperature processes is reused in the system. All in all, a great deal of energy is conserved.
Yuguang has perfected the process of unifying production of lead and zinc, through the development of a process which recycles the waste material of zinc production in lead production and vice versa, creating a cycle of internal materials, and not only enabling lead and zinc to be raw-material replenishments for each other, but also allowing extraction of silver, indium, cadmium and other valuable metals from their waste, leading to reduced net energy consumption and improved usage of resources.

4.2.2 Combining recycled and original lead production

Yuguang has always been active in technological innovation. In 1998, Yuguang cooperated with China Enfi Engineering Corporation (“ENFI” for short) and other institutions to independently develop an oxygen-enrichment bottom-blown-blast-furnace deoxidization-smelting technology, a new technique based on advanced international lead smelting methodologies.

Yuguang is heavily promoting the recycling of lead because of the shortage of lead ore. Using the wide adjustability to raw materials of the oxygen-enrichment bottom-blown smelting system, replacing ore with lead plaster will solve the problem of lead-ore shortage on the one hand and of the difficulty of treating the lead plaster produced by recycling on the other. Of the 300,000 tons of Yuguang’s electrolytic lead production currently, 50,000 were produced from recycled lead. This combined
method could be taken as a model for China’s recycled-lead industry. The development of the recycled-lead industry was a very important link in the internal establishment of Yuguang’s circular economy, because it had already established recycling in terms of “resource – product – waste material – new resource.”

The new technique perfectly combines advanced molten-pool smelting technology and innovative blast-furnace deoxidization-smelting technology, which have visible economical benefits, and have been accepted by the lead-smelting industry because the oxygen bottom-blown technique single-handedly overcomes many bottleneck problems in the development of lead smelting. It has been launched and applied domestically, with optimistic market forecasts.
4.2.3 Innovation as a way of overcoming technical bottlenecks in lead processing

Yuguang originally adopted the common burning-pot and burner techniques for lead production, leading to high energy consumption, extreme environmental pollution and other problems. Yuguang has always been researching and looking for new ways of dealing with bottlenecks in lead smelting. As part of the ninth “Five-Year Plan,” a
breakthrough was made in dynamic acid-making technology to treat burner smoke and gas. This technology is mainly made up of a large three-way selector valve with quick release and low leakage, computer-automated control DCS software, a temperature controller at the exit that prevents acid condensation, and other key parts. It passed national technical inspection in November of 1998, at which point the technology was the best of its kind in the world, and received the state science and technology advancement award.

This technology has led to noticeable improvements in SO\textsubscript{2} fractional conversion, energy consumption, equipment corrosion, processing ability of equipment and other aspects. According to environmental-protection authorities, dynamic SO\textsubscript{2} conversion technology enables the recycling rate of sulfur to reach over 80%, completely changing the pollution issue of the smoke created during lead production.

4.2.4 Developing clean production and utilization of the “three wastes”

**Waste-gas treatment.** Yuguang was the first to treat burning smoke gas by using dynamic technology, and at the same time the first to adopt the oxygen-enrichment bottom-blown technique, which completely solved the crucial problem of serious pollution caused by sulfur production. The recycling rate of sulfur has reached 92% through a series of technical improvements, while tail-gas discharge are up to standards; furthermore, the tail gas from the oxygen-enrichment bottom-blown system only contains 360mg/m\textsuperscript{3} of SO\textsubscript{2}, far below the national standard of 850mg/m\textsuperscript{3}.

**Wastewater treatment.** Improvements in wastewater treatment were made by adopting the new Gore film-filtering technology, which has ensured that wastewater discharges match the standard.

**Waste-residue treatment.** Recovery of zinc from the blast furnace with the fuming treatment, and the smelting of abandoned residue to supply cement and other building-material enterprises through enterprise cooperation, has led to comprehensive usage of lead skim, the usage rate of which is currently over 96%. The resulting zincilate is used to comprehensively recover fine iron dust and other materials through magnetic selection.

Yuguang places a high emphasis on environmental protection through clean production, reduced consumption, and energy conservation. It has adopted both technical and managerial improvements, with over 98% of its operations improved for environmental protection. 100% of wastewater discharge and 81% of its dust discharges are now approved as non-polluting.
4.2.5 Positive effects of developing circular economy

1) The total recovery rate from smelting has increased from 93.1% in 2001 to 95.7% in 2006.

2) The total recovery rate of sulfur has increased from 56.0% in 2001 to 92.8% in 2006.
3) The comprehensive energy consumption of lead has fallen from 520 kg coal equivalent/ton to 456 kg coal equivalent/ton.

![Figure 4.11: Changes for Comprehensive energy consumption of lead](image)

4) The freshwater consumption per ton of lead has fallen from 27 m$^3$/ton to 16.88 m$^3$/ton.

![Figure 4.12: Changes for Fresh water consumption of per ton of lead produced](image)
5) The usage rate of solid waste has grown from 50.0% in 2001 to 80.2% in 2006.

![Figure 4.13: Changes for Use ratio of solid wastes]

6) The usage rate of leftover heat steam has grown from 50.7% in 2001 to 80.0% in 2006.

![Figure 4.14: Changes for Use ratio for leftover heat steam]
7) The SO2 discharge per ton of lead has fallen from 37kg/ton in 2001 to 17kg/ton in 2006.
5. Suggestions for Measures to Speed up the Development of Circular Economy in the Non-Ferrous Metals Industry

The government needs to take measures to encourage the development of circular economy in the non-ferrous metals industry.

5.1 Strengthening the System of Policies and Regulations related to the Development of Circular Economy in the Non-Ferrous Metals Industry

The government needs to speed up legislative work related to the development of circular economy in the non-ferrous metals industry. Systematic corresponding support policies should be issued in order to establish laws, regulations, and a policy-support system as soon as possible.

Administrative methods for the comprehensive utilization of non-ferrous metals wastes and tailings should be established to determine the indexing system for the comprehensive utilization of resources; to clarify the requirements for recovery rates for mining, mill run and smelting; to regulate the treatment of non-ferrous metals wastes and tailings; and to lay out the requirements for storage and piling, the minimum rate of resource recovery and re-use. Laws and regulations should be established for waste and scrap lead-acid battery recovery management and waste and scrap aluminum can recovery management.

Efforts should be sped up to consider and formulate special programs for the development of circular economy in such key areas as developing a market for the exchange of secondary, and the recycling of secondary metals. Such special programs could over the next 3-5 years further clarify basic guidelines, major targets and tasks, policy measures and key projects for the industry, and thus play a key guiding role in achieving energy savings and discharge reductions.

To regulate the development of the recycled-metals industry, industry entrance and operating qualifications need to be clarified through policies and regulations. “Entrance Qualifications for the Recycled-Metals Industry” should be issued to establish codes regarding scale, technology and equipment, energy consumption, secondary heat recovery, comprehensive usage of resources, environmental protection, and other aspects of recycled-metals industry. Outdate capacity, and enterprises with low resource-usage rates and serious pollution, should be eliminated to optimize industry structure and promote its healthy development.

At the same time, efforts need to be put into promotion, education and awareness building about circular economy, to create a change in the way people think,
establishing the concepts of rational development and circular economy, guiding citizens to develop lifestyles and consumption habits that conserve resources and protect the environment, so that the various social groups will blend in the advancement of circular economy on their own accord.

5.2 Promote Demonstration Circular-Economy Projects and Publicize their Effectiveness to Maximize Impact

State treasury bonds, special-purpose funds, and other means of government financial support means should be used to support a group of demonstration circular-economy projects in the non-ferrous metals industry. In this the focus should be on the following:

5.2.1 Recycling of non-ferrous metals waste and scrap

Projects which could have a powerful demonstration impact in China’s non-ferrous metals waste and scrap include: recycling of waste aluminum pull-tab cans; processing and re-manufacturing of discarded mobile phones and other electronic devices; processing of low-grade copper waste and scrap using a Kaldo furnace or Cu-FRHC technology, which can not only profitably recover the copper, but also a considerable amount of precious metals.

5.2.2 Building scrap and waste-metal recovery and transaction markets

Through appropriate policy guidance, recyclers of scrap and waste non-ferrous metals should be encouraged to develop large-scale operations, forming several large-scale enterprises with nation-wide recovery networks, thus boosting the level of industrial concentration. The increased scale and influence of scrap and waste non-ferrous metals recyclers is important because: it helps to build reliable waste-recovery channels; reduce recovery costs; boost corporate strength; gives them better capabilities and conditions for introducing advanced technologies; prevents secondary pollution; and to modernize secondary material recovery methods. Greater scale for recyclers of scrap and waste non-ferrous metals will also allow clearly-defined social responsibilities in such areas as energy savings, comprehensive recycling, environmental protection and recycling efficiency. It will also encourage large-scale enterprises to develop deep-processing projects for renewable-resource recovery and transaction markets, and extend the industrial chain.

5.2.3 Projects involving the assessment and utilization of ore tailings
To strengthen comprehensive utilization of non-ferrous ore tailings, assessment of potential ore-tailing values must first be conducted to identify their utilization value and establish a database of ore-tailing resources. Further measures can be taken on that basis, using applicable technologies, following the principles of re-resourcing, reduce and environmental protection. Key elements in the comprehensive utilization of ore tailings from non-ferrous metals mines include: recovery of valuable elements in ore-tailing sand; using ore-tailings sand for the production of high-quality wall-building materials; and other ore-tailings comprehensive utilization (including production of wall and floor tiles, cement, microcrystalline glass, etc).

5.2.4 Projects involving the comprehensive recycling of associated resources

Dressing, smelting and recovery of associated valuable elements in non-ferrous metals are an important part of the development of circular economy. Efforts should be made to support enterprises in adopting advanced technology upgrades, to strengthen the comprehensive-recovery process, and strengthen recycling of associated valuable elements. Projects which could have a good demonstration impact include: comprehensive utilization of associated sulfur and ferrous elements in copper ores; and comprehensive utilization of anode sludge and waste residue (material) from copper smelting.

The Gansu Jinchuan Copper, Nickel and Precious Metals Mine; Guangxi Dachang Tin, Antimony & Indium Multi-Metal Mine; and Hunan Shizhuyuan Non-Ferrous Metals Mine, among others, are the multi-metal associated resources mines with the greatest impact in China. They are characterized by extensive resources and high productivity, with considerable impact on domestic and foreign markets; they have profitable comprehensive usage, and have an excellent demonstration impact on the industry as a whole.

5.2.5 Projects involving recovery of valuable elements from industrial wastewater

Non-ferrous-metals ore-selection and smelting wastewater contain valuable elements, which, if not recovered, will cause both waste and pollution. Demonstration projects of means of recovering these, through both independent developments and the introduction of overseas advanced technology, are key to the development of circular economy in the non-ferrous metals industry.

5.2.6 Projects involving usage or treatment of smelting waste

As non-ferrous metals smelting expands in China, its discharge increases accordingly.
Projects that can have an important demonstration impact promoting the usage of residue include: treatment and usage of piled-up kiln residue; comprehensive recycling of selected copper-tailing residues and the burning acid residue of pyrites; recovery of copper from melting-furnace residue; non-hazardous treatment of electrolytic-aluminum-waste groove insert, and so on. Usage and treatment of smelting waste has become a major focus for the sustainable development of the non-ferrous metals industry.

5.2.7 Projects involving the development of environmentally friendly alternative materials

Lead solder, easy-to-cut brass, silver-oxide-cadmium electrical-contact material, mercury-containing zinc dust and other hazardous materials are restricted or banned in developed countries. Therefore, research into and development of alternative materials is necessary. The focus is on choices of alternatives for lead, cadmium, mercury and micro-controlled elements, the design of alloy composition, optimizing formulas and production techniques, while maintaining the original properties including welding, cutting, strength and (resistance to) chemical reactions.

5.2.8 Usage of low-concentration sulfur dioxide

The smelting of non-ferrous metals, especially of copper, lead, zinc and other heavy metals, produces smoke with a high content of \( \text{SO}_2 \), which is usually sent to a sulfuric-acid plant to produce acid. Large factories have high recycling rates for \( \text{SO}_2 \) smoke, hence less pollution. However, smoke with only 1% - 3% \( \text{SO}_2 \) cannot be used directly to produce acid, and is usually directly discharged to the air. The focus for the near future needs to be on supporting smelting enterprises in speeding up the adoption of appropriate technologies for the recycling of low-concentration \( \text{SO}_2 \), which will dramatically reduce pollution.

5.3 Establishing Favorable Tax Policies to Promote Non-Ferrous Metals Recycling

We suggest using pricing, taxation, financing, government procurement and other means to guide and encourage investment to shift toward circular economy. The following areas of the industry are most in need of government fiscal-policy support.

5.3.1 Unify the VAT rate for waste non-ferrous metals recovery and recycling enterprises
Right now the tasks of recovering and of using waste non-ferrous metals in China are split over two separate industries, i.e. the recycling of waste materials, and the use of waste materials in production. The government exempts enterprises that recover waste material from value-added tax (VAT) on the sales of these materials; however, this causes enterprises that use domestically recycled waste materials in production to be unable to deduct 7% of VAT, and causes several other problems of tax evasion. The tax rates should be made uniform as soon as possible to provide a level playing field and support the domestic development of non-ferrous metals recycling. We suggest a 17% VAT be collected on the sale of waste materials and the recycling of waste materials, and to other tax exemptions or subsidies to encourage the industry.

5.3.2 Establish encouraging policies for energy and materials conservation

Because of the characteristics of China’s resources, although energy conservation, consumption reduction, and resource-usage-rate increases can bring great benefits, changes in the market environment could cause the competitiveness of the products of energy-savings and comprehensive-utilization projects to decrease, leading directly to losses for enterprises. This could present a risk to the long-term development and survival of enterprises. Therefore we suggest the government issue product certifications for energy-saving, resource-saving and material recycling products, and entitle enterprises to favorable tax policies based on these certifications.

Whether a resource-conserving project is more profitable than a traditional one depends on market environment; enterprises are therefore discouraged from investing in both resource conservation and environmental protection. We suggest the government support conservation and protection projects with subsidies.

Other than that, we suggest relevant government departments research and establish policies favorable to developing circular economy in the non-ferrous metals industry, such as full or partial exemption on profit taxes, and electricity and energy pricing to be determined based on the characteristics of different regions.

5.4 Increase Investment in Scientific R&D to Strengthen the Technological Basis for Circular Economy

Special projects should be established to assist the development of circular economy in the non-ferrous metals industry, to form new systems and mechanisms for technical innovation. The emphasis should revolve around the technical topics and critical technologies, aiming to achieve technological breakthroughs, which will dramatically push the development of circular economy.
The conclusions of the 17th NPC (referring to the meeting of the National Peoples Congress held in 2007) should be effectively implemented, creating a large ministry for energy saving and reduction of pollution. At this point support for technological development projects should focus on the following important areas:

5.4.1 Developing advanced technology that improves the “Four Rates and One Comprehensive” of ore-resource development

“Four Rates and One Comprehensive” stands for 1) increasing recovery rates from mining; 2) reducing mining and mill-run loss rates; 3) increasing mill run recovery rates 4) increasing smelting recovery rates 5) associated resource comprehensive utilization rates. The key technologies that need to be researched and developed are: safe and efficient mining and disaster-prevention technology; mineral deposit non-waste mining and environmental treatment technology; complex mineral selection and enrichment technology; low-quality copper-ore utilization technology; new flotation technology for diasporic bauxite selection; nickel-oxide ore development and usage technology; technology for recovering natural rutile in porphyry copper tailings; rare-metal comprehensive recycling technology, and so on, all of which will increase selection efficiency and recovery rates. Development of cutting-edge ore technology focuses on digital technology for mines, silicate dissociation and selection research, research on biological extraction of metals, and so on.

5.4.2 Technology for non-ferrous metals smelting

The key is to develop and promote a group of advanced smelting technologies that will reduce energy consumption and pollution, increase smelting recovery, “squeeze the last drop” out of material used and realize “zero discharge.” The principle aspects are: continuous intensive smelting, blow-smelting, and short-process copper smelting; liquid high-lead skim direct-deoxidization technology; heat-smelting magnesium equipment optimization technology; energy-conservation technology for aluminum smelting; technology for the comprehensive treatment of arsenic in the non-ferrous metals smelting process; the Qinghai Salt Lake magnesium-chloride comprehensive-usage research, and so on. In addition, new smelting technologies that are suitable for small-scale production with low energy consumption and good environmental protection and security need to be developed according to the situation in China to satisfy the needs of economic development in the west and other remote areas. The emphasis should be on cutting-edge technologies: intensifying the development of pressure-control oxidation technology; development of super-sized electro bath, new technology for direct extraction of rare metals through fused-salt
electrolysis, and so on.

5.4.3 Technology for non-ferrous metals processing

For processing the focus needs to be on increasing the processing rate of finished materials (reducing waste), reducing energy consumption and metal-burning loss, developing short-process technologies that are environmentally friendly, and actively promoting protective gas smelting, continuous casting, tandem rolling and other advanced technologies. Based on the characteristics of China, it is especially important to speed up the development of processing technologies for small and medium size non-ferrous enterprises, such as continuous casting and complete technologies for plastic integration, both of which are key to improving the overall level of China’s non-ferrous metals processing.

5.4.4 Key technologies for developing recycled-resource usage

The technologies and other aspects to be pursued here include: waste-metal mechanical disassembly, classification and selection technology; surface cleaning and other pretreatment technologies; technology for increasing metal-smelting recovery; property-retaining technology for aluminum recycling; waste battery non-hazardous treatment technology; scrap automobile and household-electronics recycling technology; waste aluminum-can recycling technology; study of comprehensive-recycling technology for aluminum; technology for recovering and extracting precious metals from waste electronic circuits; recovery and treatment technology for smoke dust containing zinc, steel and iron; treatment technology for the gas, liquid and solid waste from recycling; research into and establishment of recycled-metal industry standards, product standards, technical regulations and so on.

To promote the usage of non-ferrous recycled metals, we suggest the national authorities in charge of science to establish a non-ferrous metals recycling technology support plan, to guide capable enterprises in establishing specialized technical-development co-funding projects, to actively support the technical development of the non-ferrous metals recycling industry. Through such a plan, domestic and international recycling technology efforts can be joined together, a testing base can be built for new technologies and equipment, to turn around the situation of weak R&D capabilities.
5.5 Improve Import Management, Support the Establishment of Recycled Non-Ferrous Metals Processing Parks

Developing circular economy and implementing reduction, recycling and re-use are the new path of China’s industrial development. The relevant national development plans require that recycled copper, aluminum and lead reach 35%, 25% and 30% of total productivity respectively by 2010. Collection for recycling of non-ferrous metals in China is still less than in developed countries such as the U.S. and Japan, and another 5 to 10 years are needed before large amounts of waste non-ferrous metals become available. Currently about one third of the copper, aluminum and other key non-ferrous metals waste material utilized in China are recovered domestically, while the rest is made up by imports. This situation is expected to continue for the years to come, and the percentage of imports is even expected to increase somewhat. According to the predictions of the “Chinese Recycled-Metals Industry ‘Eleventh Five-Year Plan,’” the consumption of recycled metal will reach 7.4 million tons and 12.4 million tons by 2010 and 2020 respectively, and since domestic waste-metal resources alone are far from being able to satisfy these needs, large imports will continue to be unavoidable.

Management systems for waste non-ferrous metals imports should be improved to make better use of foreign waste resources, and enterprises should be encouraged to greatly expand foreign waste-metal recovery networks, establish stable channels of foreign waste-metal supply, and strive to avoid risks of price fluctuations, so long as the imports meet the national environmental-protection standards. Relevant government departments especially need to adjust the “Restricted Waste-Material Imports Catalog,” and adjust waste-metal import management policy according to reflect the changes in circumstances. To increase the quality of China’s imported scrap and waste non-ferrous metals, we suggest that price-based duties and fees currently levied on imported scrap and waste non-ferrous metals be replaced by quantity-based duties and fees. The experiences of developed nations suggest that this strengthens and improves administration of imported scrap and waste metal.

At present, recycled non-ferrous metals processing parks play a significant role in China, and have become an important model for developing circular economy in China’s non-ferrous metals industry. China’s administrative direction is known as “Enclosed Recycling Zone Administration”, which involves concentrating the imported waste-metals-scrapping industry into special zones, which makes them easier to manage, makes it better for the utilization of secondary resources, and which makes the treatment of gas/water/solid waste more manageable. We suggest the government support better use of foreign waste non-ferrous metals and promote a rapid, healthy development of recycled non-ferrous metals processing parks in the
following ways:

5.5.1 **Loosen entrance requirements and expand import variety.** The government should issue more import permits or cancel limitations altogether, **simplify the registration procedures for foreign importers**, and give enterprises that enter the designated parks priority and policy support in the issuing of permits for waste-material import and other aspects. At the same time, supervisory measures to prevent pollution from illegal imports should remain to be enforced.

5.5.2 Support unified planning for parks and the enterprises within them, construct basic environmental-protection facilities, implement technological upgrades, and provide fund raising, financing and other measures to speed up industry concentration and upgrading.

5.5.3 Speed up the construction of a group of national-level recycled non-ferrous metals processing parks based on unified national planning, and make them effective as models. Allow national-level recycled non-ferrous metals processing parks to treat imported waste household electronics, automobiles, and other recyclables.

5.5.4 Make it easy to solve problems of custom inspection and clearance for recycled non-ferrous metals processing parks that are close to ports in order to increase clearance efficiency and lower clearance costs.

5.5.5 **Strictly enforce time limits on the phasing out (closing down) of recycled-material processing enterprises that are not able to enter recycling parks or solve their pollution problems on their own accord.**