Growing the Circular Economy

Opportunities for Resource Recycling in a Zero-Carbon China

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About Us

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Introduction

China's proposed carbon-neutral target provides a strong policy impetus to accelerate the country's transition to zero-carbon energy. According to the analysis of RMI's 2019 report China 2050: *A Fully Developed Rich Zero-Carbon Economy* (*Zero-Carbon Economy* report), resource recycling will reduce the demand for primary products and services at the source, and is among the most effective and cheapest means of decarbonization. Based on the *Zero-Carbon Economy* report, this paper focuses on analyzing the contribution of resource recycling to achieving carbon neutrality in China's zero-carbon scenario and the opportunities that carbon neutrality brings to the resource recycling industry.

Resource Recycling and Zero-Carbon China

Resource Recycling and Zero-Carbon China

Resource recycling provides a systematic solution to support zero-carbon development, contributes to carbon reduction, and creates significant economic and social benefits. According to the analysis produced by the Ellen MacArthur Foundation in collaboration with Material Economics, adopting resource recycling principles in just five industries—steel, aluminum, cement, plastics and food—would reduce global annual greenhouse gas emissions by 9.3 giga tons (Gt) by 2050—equivalent to today's global emissions from the transportation sector.[1]

According to our research, the development of resource recycling-related industries in China could reduce carbon emissions by 40 Gt between 2020 and 2050, contributing over 30% to the zero-carbon transition target.
The basic recommendations coming out of global research and analysis on carbon transitions tend to converge on the following measures:

On the demand side:

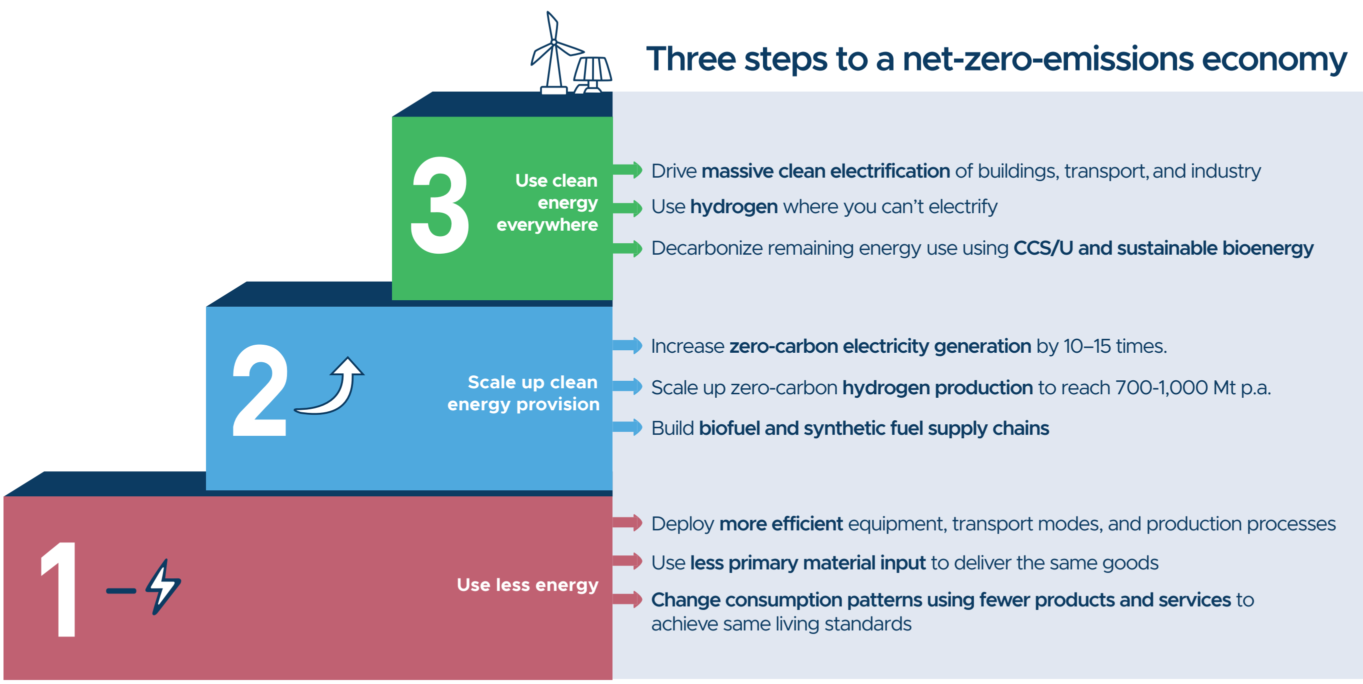
- Reduce demand for energy consumption as much as possible
- Improve material and energy efficiency in manufacturing
- Implement large-scale electrification and clean energy substitution (such as biomass and hydrogen)

And on the supply side:

- Use renewable energy such as wind, solar, and hydro to replace fossil energy as much as possible
- Deploy carbon capture, utilization, and storage (CCUS) technology to deal with carbon dioxide produced by unavoidable fossil fuel use

The Energy Transitions Commission's report, *Making Mission Possible: Delivering a Net-Zero Economy*, pointed out demand reduction as the basis of other zero-carbon measures, and resource recycling is the key.

Exhibit 1: Three steps to build a net-zero economy

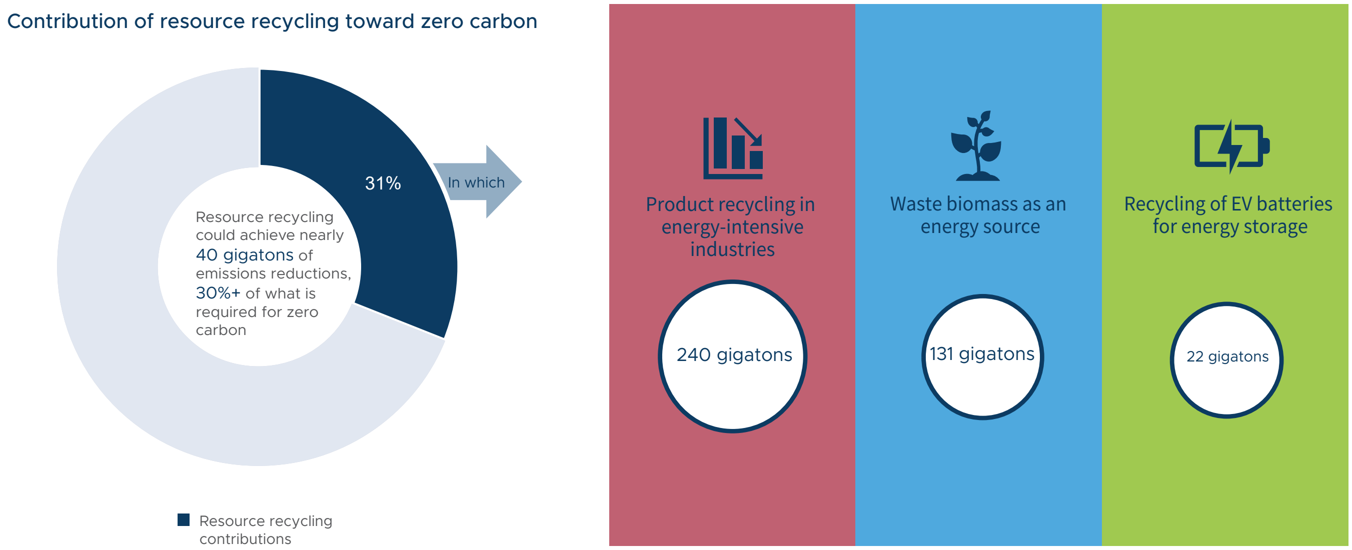


Source: ***Making Mission Possible: Delivering a Net-Zero Economy,*** **Energy Transitions Commission, 2020**

The field of resource recycling and utilization in China is broad and diverse. By taking into account relative potential contributions toward carbon neutrality and market development, we have identified three major areas of focus. These include product recycling in energy-intensive industries (steel, cement, aluminum, and plastics), biomass waste as an energy source (straw, forestry waste, domestic waste, and animal manure), and recycling of EV batteries for energy storage.

This study estimates that if China is to achieve zero carbon emissions by 2050, these three resource recycling sectors could achieve nearly 40 GT of carbon emissions reduction between 2020 and 2050, representing more than 30% of total target emissions reduction. At the same time, these three key areas are expected to form a huge market of nearly ¥3 trillion by 2050.

Exhibit 2: Relative emissions reduction and market share in three major areas



Source: RMI analysis

Market Potential of Resource Recycling

Market Potential of Resource Recycling

Confidence in the circular economy and the market potential of resource recycling is growing, as countries increasingly adopt carbon-neutral and zero-carbon targets. Studies show implementation of circular economy policies in Europe, mainly characterized by resource recycling in areas of transportation, the built environment, and food, will achieve an annual economic benefit of €1.8 trillion by 2030.[2] Compared with other key technologies in the zero-carbon transition, resource recycling has achieved relatively high technical and commercial maturity and is expected to attain a considerable return on investment in the near-term. The next five years will be an expansionary period for large-scale resource recycling and the realization of investment value. Stakeholders should seize the opportunity to pick this low-hanging fruit.

In China, resource recycling in these three areas will create a ¥3 trillion annual market by 2050.

Exhibit 3: Breakthroughs in key areas of the circular economy serving China's zero-carbon transition, and their market potential

Key Areas	Key segments	Breakthroughs	Market size in 2050
Product recycling in energy-intensive industries	Recycling steel scrap	• Ensure the vertical integration of steel scrap supply and recycling, and focus on the trend of continuous expansion of EAF steel production	￥713B
	Recycling cement	• Focus on areas with strict policy targets of construction waste recycling such as the concrete recycling market, and vigorously develop clinker recycling technology	￥24B
	Recycling aluminum	• Improve the technical level and cost economy of waste aluminum treatment to meet the alloy composition and performance requirements	￥643B
	Recycling plastics	• Improve waste plastic collection and treatment system, and mechanical recycling business model and chemical recycling technology innovation	￥334B
	Others (other non-ferrous metal, paper, tires etc.)	• Implement technology and business models from a lifecycle perspective covering design, use, discard, treatment, recycle, and reuse	￥428B
Waste biomass as an energy source	Straw and forestry waste as an energy source	• Support construction of the whole industrial chain covering collection, processing, transportation, and utilization, and promote multi-channel and high value-added utilization	￥343B
	MSW collection and utilization as an energy source	• Improve the MSW classification system, including collection equipment, closed transportation, and terminal disposal, etc.	￥180B
	Animal manure collection and utilization as an energy source	• Utilize the advantages of animal manure resources and terminal channel resources, and improve the technical level of energy utilization	￥63B
Energy storage market in a circular economy	Recycling EV batteries for energy storage in the power system	• Focus on large-scale business model innovation and technological breakthroughs such as disassembly/dismantling, cascading, and resource utilization	￥115B

Source: RMI analysis

Product recycling in energy-intensive industries: The steel, cement, aluminum, and plastics industries could reduce demand for primary products by between 16% and 53% by 2050, with recycled products accounting for up to 60% of total production, and potential carbon reduction of 23 billion tons.

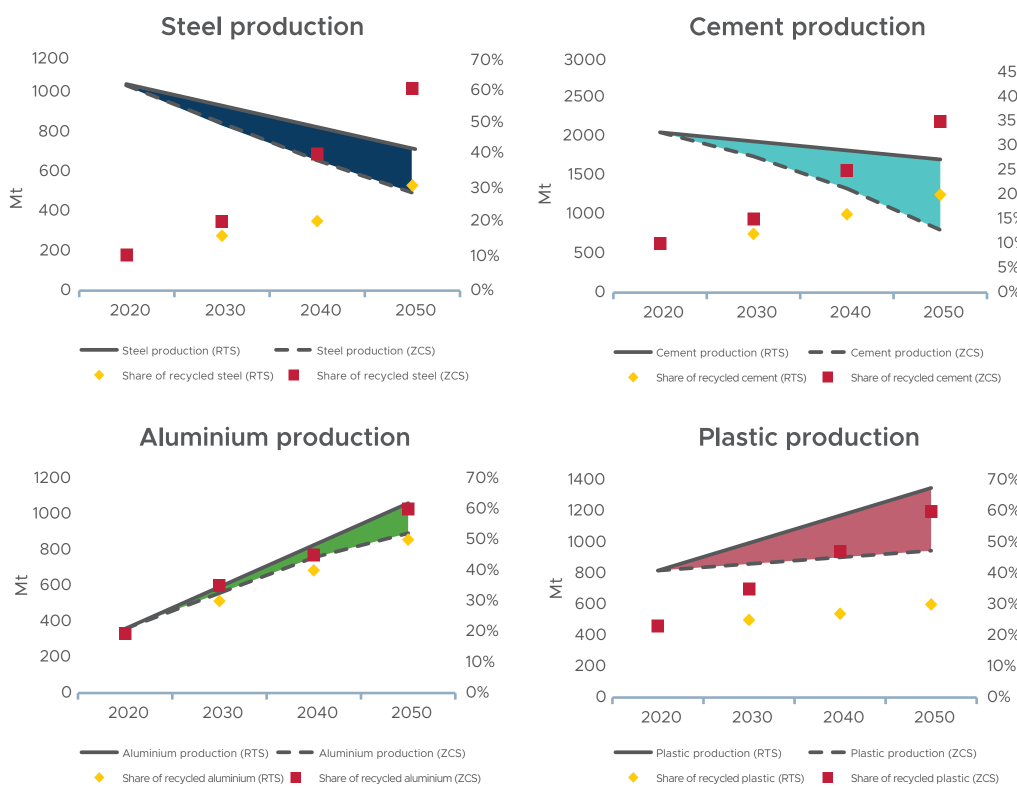
The production of industrial raw materials, such as steel, cement, aluminum, and plastics, consumes a lot of energy and emits a lot of carbon, making total decarbonization difficult on a large scale. At present, the widely accepted means to decarbonize these energy-intensive industries includes strengthening resource recycling to achieve demand and production material reduction, further improving energy efficiency, increasing electrification, substitution of fossil fuels for cleaner energy such as hydrogen and biomass, and deployment of carbon capture, utilization, and storage (CCUS). Compared with other means of decarbonization, strengthening resource recycling obviously has the advantages of high technological maturity, large return on investment, and strong utilization of existing assets. The above industries may further explore potential opportunities in the following areas:

- Reducing per unit raw/base material requirements through waste mitigation at the design phase
- Reducing per unit of service resource requirements through shared-use business models and increasing product service life
- Reducing per unit emissions of raw/base materials principally by increasing the proportion of recycled materials in these products

With full realization of recycling potential, the steel, cement, aluminum, and plastics industries could see demand reduction of 16%–53% by 2050. The annual total production of steel will drop from nearly 1 billion tons today to 475 million tons in 2050. Additionally, the proportion of electric-arc short-process steel with steel scrap as raw material will rise from about 10% at present to 60% of the total steel output,[3] reaching parity with developed countries. This means that the annual production of primary steel will fall from 950 million tons currently to 190 million tons in 2050, presenting an emissions reduction of over 10 billion tons between 2020 and 2050 compared with the reference scenario.

Under this plan, annual production of cement will fall from approximately 2.4 billion tons today to 800 million tons in 2050, and recycled cement will account for 35 percent of total cement production, contributing 7.5

Exhibit 4: Output trend and recycling potential of steel, cement, aluminum, and plastics industries



Under the reference technology scenario (RTS), the trend of technological progress, economic development, and population growth remains unchanged, with product output mainly determined by the economic structure and living standards. The RTS scenario assumes no significant demand reduction or increased rate of recycling. Under the zero-carbon scenario (ZCS), China will achieve zero carbon emissions by 2050, with significant demand reduction measures and improved recycling levels.Data based on rough estimations.

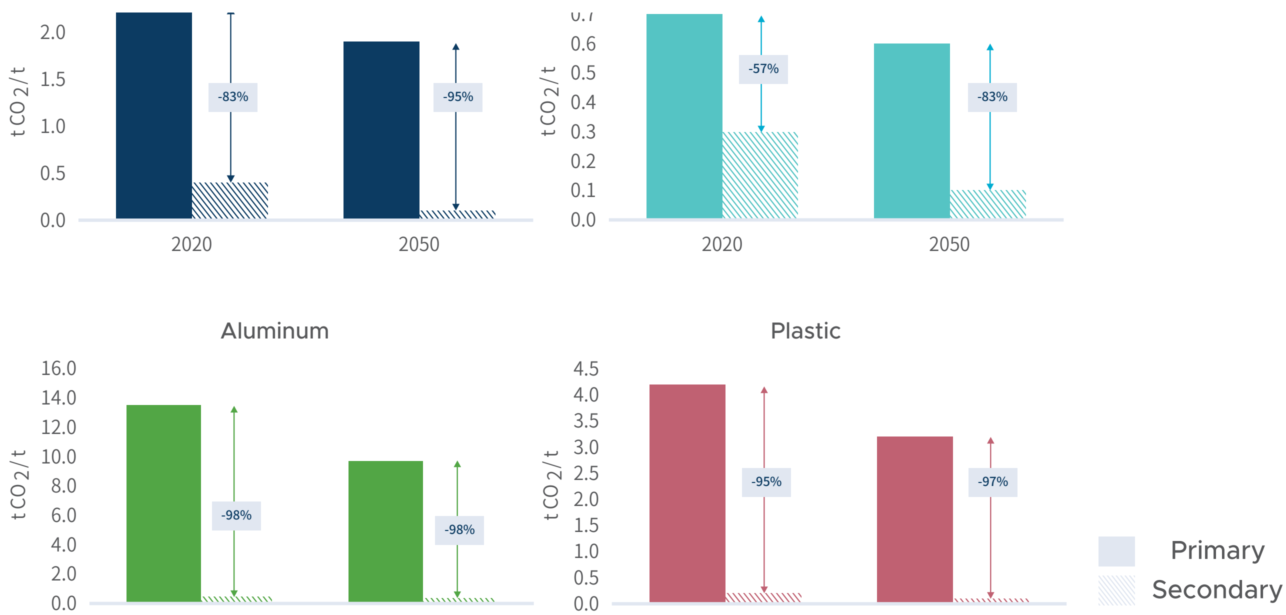
Source: RMI analysis

billion tons of emissions reductions between 2020 and 2050 compared with the reference scenario. Recycled cement can be used as concrete aggregate, roadbed, and backfill materials due to its cost advantage compared with new cement. As technology advances, unhydrated cement may be recovered from construction waste.

Although China's annual aluminum production will rise from 36 million tons today to about 89 million tons in 2050, the proportion of recycled aluminum will increase from 16% to 60%, presenting 2.4 billion tons of emissions reductions by 2050 relative to the reference scenario. Annual production of plastics will rise slightly from 82 million tons currently to 95 million tons in 2050, with the proportion of recycled plastics rising from about 23% to 60%, contributing 3 billion tons of emissions reductions relative to the reference scenario.

The carbon emissions intensity of recycled products is at least 60% lower than the carbon intensity of producing primary products.[4] By reducing demand and fully realizing the potential of recycling, these energy-intensive industries could reduce carbon emissions by up to 23 billion tons by 2050 relative to the reference scenario. Under the zero-carbon plan, product recycling in energy-intensive industries will reduce carbon emissions more than 50% by 2050 compared with the reference scenario.

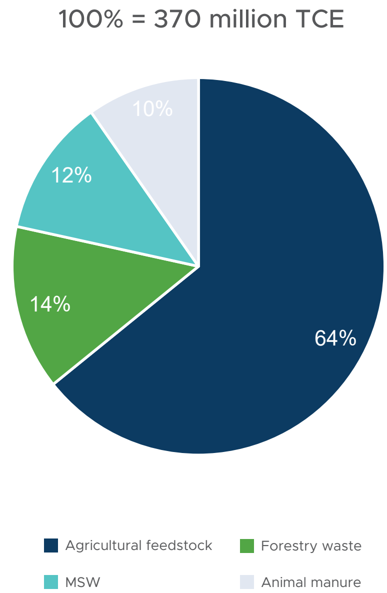
Exhibit 5: Carbon emission intensity comparison between primary products and recycled products in the steel, cement, aluminum, and plastics industries



Source: ***The Circular Economy—a Powerful Force for Climate Mitigation,*** **Material Economics, 2018**

Waste biomass as an energy source: The energy utilization potential of crop straw, forestry waste, municipal solid waste (MSW), and animal manure is up to at least 370 million tons of coal equivalent (TCE) per year. This will contribute 13 billion tons of emissions reductions by 2050, with a market size in 2050 close to ¥600 billion.

Exhibit 6: Energy utilization potential of waste biomass in China



Source: RMI analysis

There are numerous applications for waste biomass. This study focuses solely on the potential of biomass waste-to-energy, primarily considering the feedstocks of crop straw, forestry wastes, municipal solid waste (MSW), and animal manure:

- At present, China produces 805 million tons of crop straw, with 674 million tons available for collection and 585 million tons used. Energy utilization rate accounts for 8.3% of the total.[5] Through improved management, accelerated technological research, and scaled industrial development, straw-to-energy is expected to reach 240 million tons of coal equivalent (TCE). In addition, straw also has broad market potential as fertilizer, feed, and raw material for various manufacturing applications.

- At present, China produces about 140 million tons of forestry waste annually through forest harvesting and wood processing, and 100 million tons of forestry waste through tree pruning. This is equivalent to 42 million TCE after energy utilization based on a utilization rate of 50%.[6] Under RMI's zero-carbon scenario, China's forestry waste-to-energy is expected to exceed 50 million TCE by improving the collection and use rates.

- Municipal waste in China's cities reached 228 million tons in 2018,[7] with a majority incinerated for power generation. As the scale of waste-to-energy continues to expand, RMI's 2050 zero-carbon scenario suggests that MSW-to-energy will exceed 43 million TCE, at a total market value reaching ¥180 billion, with output markets accounting for 60% and equipment investment accounting for 40%.

- Anaerobic fermentation of livestock and poultry manure for biogas energy generation at scale presents a promising direction for future development, though currently less than 60% of China's livestock and poultry waste is utilized as feedstock.[8] Large-scale development of livestock and poultry breeding industries will provide opportunities for centralized treatment of livestock and poultry waste in the future.

This study estimates that by 2050, the energy recycling potential of the above four kinds of waste biomass will reach at least 370 million TCE/year, with market size reaching ¥600 billion and cumulative carbon emissions reduction exceeding 13 billion tons.

Recycling EV batteries for energy storage: The market for recycled EV batteries is expanding. By 2050, EV battery recycling will be a key resource for grid storage, with a market of at least ¥115 billion per annum.

EV battery recycling generally occurs in two modes: cascade utilization and disassembly. Cascade utilization refers to the secondary use of batteries once storage capacity attenuates below requirements for EV usage. Disassembly refers to full decommissioning, and the recovery of valuable resources, such as cobalt and lithium.

In the zero-carbon energy transition, the reuse of used EV batteries can provide considerable energy storage capacity for grid applications. According to RMI's prediction, by 2050, the theoretical potential of recycling used EV batteries for grid storage will be close to 590 gigawatt-hours, or 37% of the total energy storage, assuming a 50% use rate of decommissioned EV batteries. Based on this vision, displacing coal generation with cascade utilization of EV batteries for grid storage will reach a carbon emissions reduction of 800 million tons between 2020 and 2050, with a market reaching at least ¥114.5 billion in 2050.

The Trend of Resource Recycling Industry Development

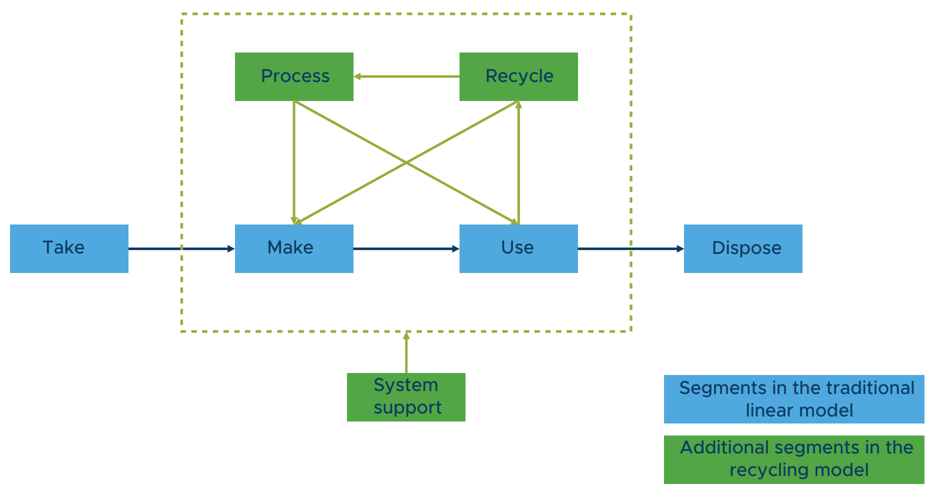
The Trend of Resource Recycling Industry Development

The goal of resource recycling is to form a closed loop of resource utilization as much as possible. The traditional model of resource input, manufacture, use, and disposal is unsustainable in a world of finite resources. In the transition to a carbon-neutral scenario, the parties involved in the traditional mode of production will work in cooperation with the solution providers and the new industries of material recovery, recycling, and processing, all under guidance of system facilitators responsible for the development of the closed loop circular economy (Exhibit 7).

The introduction of resource recycling in these key industries will not only contribute to the realization of China's zero-carbon vision, but also promote the development of industry; create new markets in supply, consumption, and ancillary services; and generate huge commercial value. In the zero-carbon scenario, the emergence of markets related to resource recycling will bring opportunities for different participants, fulfilling product and service requirements within the closed loop paradigm. Industrial development will no longer follow the linear model of "take-make-use-dispose" but will develop within a new business ecosystem formed through the integration of new circular relationships.

We will see these industrial relationships develop in various industries, showing the characteristics of diversification, interconnection, and transparency that enable product manufacturers, solution providers, and system facilitators in the new ecosystem to find new markets, promoting continued growth and development. The following section will analyze the possible trends, acting mechanisms, and related market opportunities.

Exhibit 7: Toward a circular production cycle



Source: RMI analysis

Recycling of steel scrap:

In the future, China will have sufficient steel scrap resources to boost the large-scale development of the steel scrap recycling industry chain. In 2020, China's steel scrap volume exceeded 220 million tons. The growing supply of domestic steel scrap supply will cover the demand of electric-arc furnace (EAF) plants, exceeding 305 million tons/year by 2030.[9] EAF, or "short-process" steel production relies on scrap steel as the primary feedstock. With China entering a later period of industrialization, scrap steel resources from urban construction continue to grow. Durable goods such as automobiles and appliances are also entering their phase-out periods in such volume as to provide sufficient scrap steel resources. Additionally, foreseeable liberalization of import restrictions on steel scrap will also provide further resources.

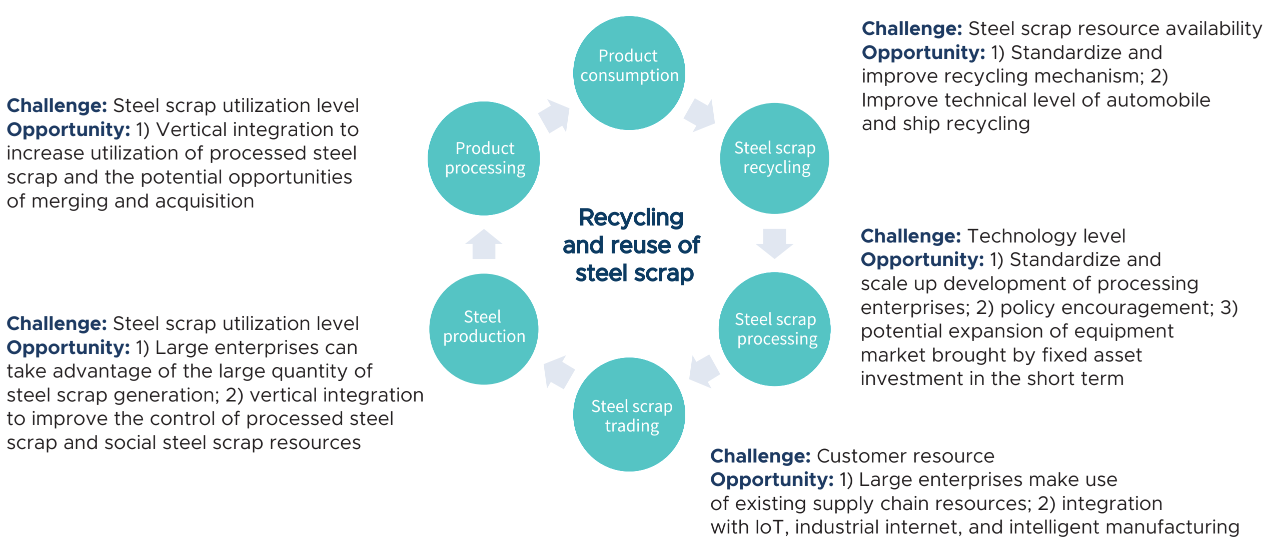
Due to the high cost of mining and the low grade of iron ore in China, domestic iron ore supply will not increase significantly and cannot provide a reliable basis for self-sufficiency. The *Draft Guidelines on Promoting High-Quality Development of the Steel Industry,* released by PRC's Ministry of Industry and Information Technology, set a target of 45% self-sufficiency in iron supply by 2025. With the increasing availability of scrap steel resources and the official mandate for increasing self-sufficiency in iron production, various capital sources have accelerated their development in the scrap steel industry, especially in upstream dismantling and recycling and midstream processing.

Along with this trend, large steel enterprises are expected to pursue vertical integration with scrap steel resource processing. This will mean a transition away from basic oxygen furnace (BOF) "long-process" production that is reliant on raw material inputs of iron ore, limestone, and coal. For steel scrap recycling enterprises, further breakthroughs lie in managerial improvements and industry standardization, while also keeping an eye to opportunities for integration with large steel enterprises.

With the increasing proportion of EAF steel production in the steel manufacturing industry at large, the distributed production model with scrap steel as a basic input emerges and will continue to develop. In contrast to the vertically integrated production model associated with long-process steelmaking, short-process steel allows for a distributed production business model to emerge. This distributed model has advantages including cost-effectiveness and flexible scale and location.

Under this new business model, investment and operating costs can be adjusted flexibly according to the needs of production capacity and output volume, facilitating the cultivation of a distributed production model close to raw materials or markets. EAF steel production will be more common in southeast coastal areas where scrap resources are abundant. As China's net steel production is expected to decline in the future, there may be a shift in domestic steel capacity if the shorter-process production based on steel scrap becomes more cost-effective. At the same time, EAF plants located in inland areas can make full use of the widely distributed scrap steel and deliver the finished steel to the nearest markets.

Exhibit 8: Challenges and opportunities in each segment of the scrap steel recycling industry



Source: RMI analysis

Recycling cement:

Due to the localized characteristics of cement production and transportation, future cement recovery and recycling markets will have a distinct regional nature. This indicates that relevant opportunities will come mainly from two aspects. First, regional policy objectives will play the primary role in cultivating local industry and markets. Where there is clear, strong policy support, market potential will be sooner realized.

At present, there are 35 cities with construction waste management pilot programs in China. Additionally, some provinces and other cities have set higher targets for the recycling of construction waste. Clarity of relevant policy objectives will establish early market regions for the cement recycling industry and provide reference for optimizing the allocation of investment resources. Second, since there is hardly any regional difference in the generation and recycling process of construction waste represented by cement, regional resource recycling and utilization patterns are highly replicable, and experiences garnered from earlier pilot programs will be broadly applicable. In the short term, diverse policy support and pilot project experimentation are critical to develop a feasible model. In the long term, specialized construction waste recycling companies are likely to emerge and mature.

Recycling aluminum:

Market expansion for recycled aluminum is likely to continue of its own accord due to existing economic incentives and favorable material characteristics. Aluminum's corrosion resistance lends its strong recoverability and capacity for ongoing recycling. Therefore, a relative economic advantage persists in favor of recycled aluminum alloy usage versus primary production. The energy consumption of recycled aluminum is only 3%–5% of that of producing the same amount of primary aluminum. Producing 1 ton of recycled aluminum can save 3.4 tons of standard coal, 14 tons of water, and 20 tons of solid waste.[10] In addition, the transportation sector is already the largest market for recycled aluminum, and the demand for recycled aluminum is expected to be further boosted with the increasing trend of lightweight vehicles.

Recycling and reuse of aluminum has already achieved relatively scaled development and standardization, but recycling process efficiency must still be improved. We anticipate the emergence of new integrated business models. During the 13th Five-Year Plan period (2014–2019), aluminum recycling progressed rapidly. This period saw the establishment of a group of major recycling enterprises including Sigma Group, Lizhong Group, and Shunguo Group, and the creation of corresponding industry norms to ensure a healthy market environment. However, development of this industry has not kept pace with the rapid increase in demand for recycled aluminum, due to its diffuse and inefficient arrangement.

Under these current circumstances, there is a big opportunity for an orderly consolidation in the processing and supply of recycled aluminum. Another opportunity lies in the integration of upstream and downstream industrial chains and the simplification of transactions. For example, aluminum production enterprises can integrate aluminum scrap recycling and processing businesses, and directly use aluminum scrap as raw material. Likewise, downstream aluminum demanding enterprises such as electronic products and automobile manufacturers can directly connect with aluminum recycling enterprises to form a closed loop of raw material supply.

Recycling plastics:

Full realization of recycling potential will greatly reduce the demand for primary materials for plastic production. The goal is for recycled plastic to account for 60% of total production in China by 2050, compared with about 23% today. At the same time, since the applications for plastics covers a large number of consumer-oriented industries, recycling will promote the commercialization of more innovative ideas, which will not only become a competitive advantage for enterprises under the theme of sustainable development, but also become a positive force in promoting the development of the circular economy.

With the improvement of Chinese residents' living standards, the demand for plastics will continue to maintain an overall growth trend. In the future, the plastic recycling industry will have sufficient supply of resources, but it needs to continuously improve operations and technology in order to better leverage the market. Currently, China's annual per capita consumption of plastic is about 45 kg,[11] about half that of major developed countries. With the continuous improvement of living standards, the demand for plastic will continue to rise, presenting considerable market potential for the industry as a whole.

At present, plastic recycling in China relies on relatively simple mechanical processes, bearing the limiting factor that higher value-added products cannot be made by this method. Chemical recycling, which reduces recycled material to base polymers and can be used to produce higher value-added products, is anticipated to grow as a segment of the industry with improvements in technology. We expect mechanical plastic recycling to achieve its full potential by 2030, and for this to be the jumping off point for the rapid development of the chemical-based plastic recycling industry.

The rising consciousness of the new generation of consumers regarding sustainability, and an increasing willingness to pursue green products and packaging, will drive major consumer goods companies to reduce, recycle, and reuse plastics. According to the survey conducted by Kantar Consulting, 93% of Chinese consumers believe that manufacturers or brands are not doing enough to reduce white waste (polystyrene, polypropylene, PVC, single-use plastics, etc.). The survey also found that reducing, replacing, and reusing plastic is an important measure that manufacturers should take. Following this consumer trend, manufacturers and brands are engaging in relevant product research and development, production, marketing, and sales.

For example, Love Beauty and Planet launched by Unilever in recent years is using a bottle body that is packaged with 100% post-consumer recycled plastic. Kiehl's has had an empty bottle recycling program since 2018, encouraging consumers to bring empty bottles to the counter for recycling and exchange points for gifts, so as to provide consumers with continuous incentives for brand repurchase and empty bottle recycling. Coca-Cola not only gathered consumers to participate in Clean Beach public welfare activities to recycle wastes, but also launched environmentally friendly fashion products made of recycled plastic through cooperation with HowBottle. These include the “I Do Care” jacket made of 13 recycled plastic bottles and “24 Bag” made of 24 recycled plastic bottles. Furthermore, for every 24 “24 Bags” sold, a relief tent will be donated to the disaster areas.

These actions from enterprises not only make plastic recycling a phenomenon, but also enrich the connotation of sustainable and low-carbon life through diversified creativity. This helps to promote the continuous strengthening of consumer awareness and contributes to the popularization of the circular economy concept among people and industries.

At the same time, the development of a plastic recycling industry will give rise to new forms of business services, including the emergence of new value chain links, as well as the formation and strengthening of new interactive relations. The downstream enterprises of plastic production (i.e., consumer goods companies) have a growing incentive in plastic recycling and the use of recycled plastics, giving birth to new service-oriented enterprises.

For example, HowBottle focuses on the solution of recycling all kinds of products from plastic bottles, which combines the links of plastic recycling, design, and production. For another example, TerraCycle focuses on the recycling process and provides the design, coordination, and implementation of offline recycling programs. Through the accumulation of cases with Kiehl’s, Colgate, L 'Occitane, and Amore, it has gradually formed a professional plastic recycling business in China. Meanwhile, in the new value chain, the formation and strengthening of the interactive relationship will also create new market demand for the application of digital technology, and develop information traceability, resource integration, and action scheduling in plastic recycling.

Biomass waste as an energy source:

In the short term, the current challenges for the utilization of biomass waste as an energy source in China lie in the difficulty of collecting these biomass resources. Additionally, the cost of this resource is high, which is mainly due to the small scale and relatively scattered biomass sources. In the future, with the advancement of urbanization and the evolvement of social and economic structures, the potential land-intensive production and large-scale development modes of agriculture, forestry, and pasture will significantly improve the recycling efficiency of biomass resources. This will also greatly reduce the cost.

For the recycling process, the large-scale adoption of mechanized agriculture and forestry in the future will promote the integration of recycling and utilization process. Under this trend, the large-scale recycling and utilization of biomass waste in the future may be largely regional. The areas with higher probability to have large-scale and intensive agriculture and animal husbandry shall be deployed early, making full use of the advantages of abundant biomass resources and possibly a higher degree of mechanization.

For the use process, the reuse of biomass waste will focus more on high value-added applications. In terms of energy utilization, the corresponding opportunities include the production of solid, liquid, and gaseous biomass fuel. Among them, the technology that can effectively promote scale will focus on two aspects: one is the breakthrough of new fuel technology, including the production of aviation kerosene, biodiesel, and ethanol from agricultural, forestry, and animal husbandry waste. The other one is large-scale engineering constructions, such as biological natural gas engineering, large- and medium-sized biogas engineering, and low-nitrogen combustion technology used in large-scale biomass boilers.

Recycling of EV batteries:

Although the market for battery recycling for energy storage is promising, the technology and market are still in the emerging stage. Continued technological breakthroughs and further market regulation are the two key points for the sustainable and healthy development of this industry. The corresponding development of industrial form and opportunities will also be closely linked with these two aspects.

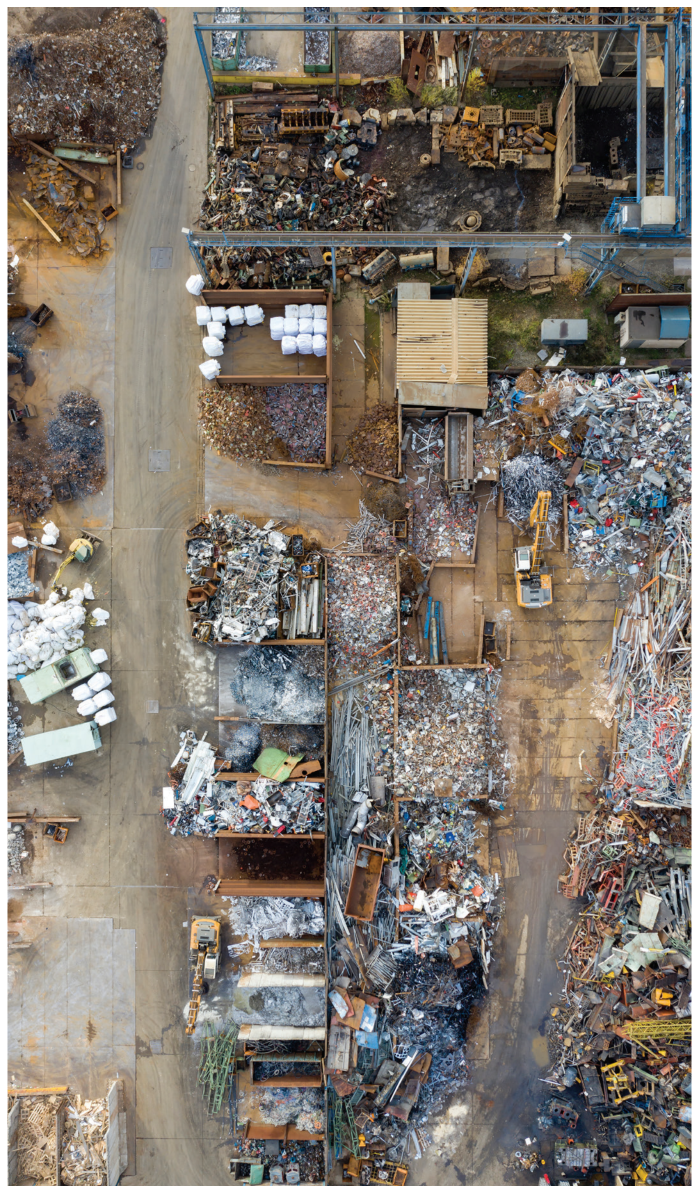
At the policy level, the policies and regulations that promote the process of industry standardization will create a favorable environment for the creation of the market. For example, the Industry Specifications for Comprehensive Utilization of Used Power Batteries for New Energy Vehicles (2019) and the Interim Measures for the Announcement of Industry Standards for the Comprehensive Utilization of Used Power Battery for New Energy Vehicles (2019) released at the national level in January 2020 promoted the establishment of a traceability information system and a database for the comprehensive utilization of used batteries. This will improve the transparency of information on different types and states of batteries. The regulation at the policy level is of great significance for the power battery recycling industry in its early emerging stage.

At the technical level, the key technical breakthrough is the battery consistency issue in the cascade utilization of batteries, and there is a corresponding opportunity in the exploration of systematic solutions. The consistency of the battery (that is, the consistency of all characteristic parameters in the life cycle of all cells in the battery pack) is the key to the smooth operation of the cascade utilization project.

Because the default performance settings of batteries are different, and multiple major factors such as charging methods, temperature field uniformity, and self-discharge difference vary, the capacity distribution of EV batteries at retirement is significantly uneven. These span from 50% to 80% of initial capacity, which will greatly increase the cost of operation and maintenance in the later stage and cause certain safety risks. In order to solve this problem, it is very important to study degradation mechanisms of battery performance and the evaluation of battery health states.

At the whole industrial chain level, the corresponding opportunity lies in the integration and deployment of resources in the upstream and downstream links. In the field of used battery recycling, there is no leading enterprise with obvious advantages. In order to tap the potential of large-scale development, it is worth paying attention to the integration opportunities of different businesses in the industrial chain, such as cascade utilization and disassembly utilization enterprises, battery producers and collectors, battery recycling enterprises and resource materials enterprises, etc.

In addition, there is an opportunity to integrate with the third-party commercial service platform and technology evaluation system to explore the win-win mode of multi-party cooperation. For EV manufacturers, due to sufficient downstream demand, the deployment of power battery recycling can help open new businesses and create new growth points by taking advantage of EV sales and service networks.



Industry Opportunities Overview:

In general, resource recycling and the opportunities in related industrial chains may come from the expansion of innovation space based on the existing value chain, the formation of new business links and the new interaction between different business links. We can grasp the future trend and further explore the corresponding opportunities from the following three main characteristics:

1. The expansion of innovation space based on the existing value chain: Product manufacturers will innovate in resource exploitation, product production, and sales in order to comply with international and domestic economic policies. They will also respond to market trends and competition. In business-to-business (B2B) industries, the use of recyclable materials means less reliance on limited resources, which increases risk resilience, gives companies the ability to stay ahead of policy and regulation, and, in some cases, offers the possibility of cost reduction. In the business-to-consumer (B2C) industries, with the rise of civic awareness of the new generation of consumer groups and the large-scale penetration of social media in people's lives, consuming is not only a transaction behavior. It is also an important channel to realize personal value and show personality.

Buying and using recyclable products or products made from recycled materials is seen as an act of social responsibility and a fashionable lifestyle. This consumption pattern will prompt companies represented by consumer goods companies to integrate the concept of "circular economy" into the source of product design, select upstream suppliers using recyclable materials, optimize the design and operation of the production process, and enhance corporate responsibility image through creative implementation of marketing and sales. This will allow enterprises to remain sustainable and maintain their advantages under the new competitive environment.

In B2B, B2C, or B2G (business-to-government) markets, the motives and strategic choices of product manufacturers participating in the circular economy ecology are different. However, in each case the introduction of the concept of the circular economy will stimulate innovation and create new opportunities in existing business links such as product design, manufacturing, and sales.

2. The formation of new business links: In order to realize the transformation of the industry ecosystem from a linear model to a circular model, new business links of the industrial chain will be formed with a new profit pool created. They will become bridges that connect the existing business links of the industrial chain. This improves the collaborative efficiency and can reduce the cost of the whole value network in the long run. Additionally, through the interaction and combination of elements, new market demands can be created.

Specifically, four main types of new businesses links will be created, including reuse, repair, mechanical recycling, and chemical recycling. Businesses of stakeholders that can grasp new opportunities may cover one or more of the four types of new business links. This can mean a material recycling solution provided by service providers such as TerraCycle and LOOP to product manufacturers, or a consumer-oriented second-hand goods or maintenance enterprise or platform, such as Xianyu. These business forms are completely different from the traditional production and trading mode and will bring about a new incremental market through the creation of deeper and high-frequency industrial link interconnection.

3. The new interaction between different business links: In a value chain characterized by a circular model, the connections and interactions between business links will generate new business opportunities. This ecosystem is built by transparency, to ensure that the connections between all the links in a more complex ecosystem are established and function effectively.

Since the COVID-19 outbreak, information transparency has been widely discussed and has drawn great concern in both public affairs and business environments. At the same time, as a means of business driver, digital technology has been gradually promoted in the application of business management. The introduction of a circular mode of industrial ecology involves the combination, collaboration, tracking, and evaluation of many different elements. This includes high requirements for the transparency of the whole value network and the perfection of supporting mechanisms.

Under this trend, government platforms will play a powerful role of dispatcher. Digital solution providers and related technology providers will also have the opportunity to enter this new market, expand diversified business forms including B2C/B2B/B2G, become the enabler of industrial ecological development, and realize their own business growth.

However, resource recycling is largely an economic behavior, which is greatly restricted by the market space and relevant policies. The market space of different types of wastes and different recycled products varies greatly, and there are also uncertainties under increasingly complex domestic and international conditions. If the recycled products themselves belong to excess capacity and backward capacity, the expected benefits will not be generated, but may be counterproductive. While exploring the market opportunities associated with resource recycling, it is important to note the uncertainties.

Endnotes

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