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1 **An overview of China’s recyclable waste recycling and**
2 **recommendations for integrated solutions**

3

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14 **Abstract:**

15 Due to rapid economic growth and population increase, problems of environmental pollution, climate

16 change, and resource depletion have become increasingly serious in China. Recyclable waste recycling

17 (RWR) is becoming one of the key approaches to simultaneously respond to the above issues, and the
18 Chinese government has begun to regulate and promote source separation and urban waste recycling in
19 recent years. However, several barriers still exist, and it is therefore crucial to review China's RWR
20 system in order to identify these barriers, and propose appropriate solutions. This paper firstly
21 summarizes the current situation for China's RWR: (1) recycling in 2016 reached 246 million tons, with
22 0.3% increase from the previous year; (2) regulations have been greatly strengthened in recent years,
23 although regulations on specific RW, source separation, and interrelated technology are still lacking; (3)
24 a pilot recycling program at the city level was initiated in 2006, covering 90 cities, 51,550 recycling sites,
25 341 collection centers, 63 terminal markets, and 123 recycling & processing bases. The paper then
26 identifies several key problems and challenges, including ineffective governance and market
27 construction, inefficient source separation, and the lack of a recycling information platform. In
28 responding to these barriers, a number of solutions are proposed: an integrated RWR framework using a
29 Public-Private-Partnership (PPP) investment model; combining the RWR system with municipal solid
30 waste (MSW) collection system; and using internet technology to establish a comprehensive information
31 platform. The use of internet technology is suggested as a unique and effective way of solving China's
32 RWR problems.

33 **Keywords:**

34 Recyclable wastes recycling (RWR), pilot city program, regulation and policy, internet+, integrated
35 framework

36

37 **1. Introduction**

38 With rapid urbanization and industrialization, China is facing multi-challenges, including resource
39 depletion, environmental pollution and climate change mitigation (Chan and Yao, 2008; Gu et al., 2011;
40 Shen et al., 2005; Zhou et al., 2004). In addition, the increasing quantity of municipal solid waste (MSW)
41 is problematic due to the limited availability of land for new landfill sites (Zhang et al., 2010). Therefore,
42 it is essential to promote the reutilization of recyclable wastes, which can simultaneously respond to the
43 issues of limited landfill space, environmental pollution, and natural resource depletion. The Chinese
44 central government regards recycling of recyclable wastes as one of the main measures for promoting a
45 circular economy (SCC, 2013). Several governmental documents and regulations have been released,
46 particularly in recent years, to promote urban waste recycling and source separation in China (MOC,
47 2006; MOC et al., 2016; MOC et al., 2007). An ambitious target was also set, aiming for a recycling rate
48 of 35% for MSW and a source separation coverage rate of 90% for 46 targeted pilot cities by 2020

49 (NDRC and MOHURD, 2017).

50 Recyclable wastes (RW) are those generated from industrial production and residential sources, but
51 which can be recycled after appropriate sorting and processing (MOC et al., 2007). Typical examples
52 include waste paper, waste plastic, waste glass, waste tire, waste metal, discarded home appliances and
53 waste electrical and electronic equipment (WEEE) (MOC et al., 2007). Developed countries started the
54 MSW management earlier and have achieved significant achievement in building an urban recycling
55 system, especially Japan (Fujii et al., 2012; Geng et al., 2010). However, China is still at its early stage
56 in establishing such an urban waste recycling system and some barriers still exist. Therefore, it is crucial
57 to have a holistic overview on China's urban recycling system so that key barriers on RW Recycling
58 (RWR) can be identified and appropriate policy suggestions can be proposed.

59 Academically, many studies on MSW management have been done, but few focusing on the RWR
60 (Dong et al., 2001; Hong et al., 2010; Wang and Nie, 2001). Existing RWR studies can be classified into
61 three types. The first type refers to those case studies in developed cities and focusing on high value
62 recyclable wastes, such as waste plastic (Chen et al., 2011; Zhang et al., 2007), waste paper (Liang et al.,
63 2012), and particularly WEEE (Awasthi and Li, 2017; Dong et al., 2001; Hong et al., 2010; Kumar et al.,
64 2017; Lu et al., 2014; Wang and Nie, 2001). For example, several studies on extended producer

65 responsibility to manage WEEE in China have been conducted (Kojima et al., 2009; Wang et al., 2017;
66 Yu et al., 2010). The second type refers to those qualitative discussions on China's RWR system. For
67 example, Ouyang and Cao (2012) identified the poor recycling system, outdated development concepts,
68 and disordered marketing rules as the three main barriers for developing China's recycling system, and
69 proposed nine measures for constructing an effective recycling system. The third type refers to those
70 studies on formal sectors and informal sectors in the RWR system. The major finding is that informal
71 recycling practices dominate waste recycling, and will continue to be required in China for the short term
72 (Fei et al., 2016; Li, 2002; Steuer et al., 2017; Wilson et al., 2006).

73 However, no review studies on recyclable wastes in China has been published, with the exception
74 of reviews focused specifically on MSW management. For instance, Chen et al. (2010) reviewed the
75 current situation for MSW management in China, including regulations and policies, waste collection,
76 treatment and disposal, and proposed an integrated waste management framework to improve the overall
77 eco-efficiency of MSW management. Tai et al. (2011) compared the MSW source-separation
78 performance of eight pilot cities and found that only Beijing and Shanghai had a relatively positive result,
79 and recommended that source-separation should be a key priority in MSW management. Wang and Du
80 (2012) summarized relevant experiences from the United States, Japan and the European Union, such as

81 government leadership, legal promotion, technology support, system security, clear authority and public
82 participation, and the authors recommend that China should learn from these experiences to establish its
83 own RWR system.

84 Distinct from the above studies that focus on the review of MSW management, this study focuses
85 more specifically on reviewing China's RWR system and management. Moreover, due to increasing
86 quantities of waste in China, and the lack of a mature RWR system, it is crucial to have an overview of
87 China's current RWR system, including progress, challenges and possible solutions. This paper aims to
88 fill this gap by reviewing China's RWR regulations and policies, identifying existing problems and
89 proposing feasible solutions for improving China's RWR. The remainder of this paper is organized as
90 follows: Section 2 provides an overview of the current situation for China's RWR system, including the
91 existing recycling modes of recyclable wastes;. Section 3 further elaborates on the development of
92 China's RWR regulations and the pilot city program initiated by the Ministry of Commerce; Section 4
93 then identifies the problems and challenges for RWR in China; Section 5 proposes an integrated
94 framework to efficiently develop China's RWR system; Finally, we draw our conclusions in section 6.

95 **2. RWR development in China**

96 *2.1 Regulations and policies on RWR*

97 China's regulations on RWR date back to 1958, when the first governmental document *Instructions on*
98 *Improving Collecting and Utilizing of Waste* was issued (SCC, 1958). However, this document mainly
99 focused on the collection and reutilization of valuable wastes, including scrap metals, waste chemicals,
100 waste oil, waste fiber, *etc.* Later, the Chinese government released several national regulations and
101 policies to promote the recycling of recyclable resources, particularly during recent decades (Table 1).
102 The most important laws in the field of RWR is the *National Circular Economy Promotion Law* released
103 in 2009, and the *National Cleaner Production Promotion Law* released in 2003, which build up a legal
104 framework to guide recycling activities. Besides the aforementioned laws, many regional or local
105 regulations and policies are proclaimed to govern specific recycling activities.

106 Besides the above mentioned comprehensive regulations, there are also many specific regulations
107 relevant to waste electrical and electronic equipment (WEEE), including "*Administration Measure on*
108 *Prevention of Environmental Pollution Caused by Electronic Waste*", "*Management Measure on*
109 *Prevention of Environmental Pollution Caused by Electronic*" and "*Information Industry, and Pollution*
110 *Prevention of Waste Electrical and Electronic Equipment*". These regulations provide detailed measures
111 on collecting, delivering and treating WEEE. In addition, the "*Provisional Management Measures on*
112 *Packaging Resources*" was released in 1999, with descriptions of recovery channels, principles for

113 sorting, and requirements for the treatment of different kinds of packaging materials, including paper,
114 wood, plastic, metal and glass. However, there are no other specific regulations to manage those low
115 value recyclable wastes at the national level, such as waste textiles, waste rubbers and waste glasses. The
116 only national general regulation is “*Measures for the Administration of Recyclable Resources Recycling*”
117 issued in 2007 (NDRC et al., 2007).

118 Several local governments introduced their own local regulations to supervise and manage local
119 recycling markets. These regulations consider the local situation and can better promote the enforcement
120 of national regulations at a local level. For instance, Shanghai released “*The City of Shanghai Guidance*
121 *Catalogue of Recyclable Resources Recycling*” on 2nd May, 2013 (SMCC, 2013). Kunming, the capital
122 city of Yunnan in the southwest China, issued “*The City of Kunming Administration Regulations on*
123 *Recycling of Recycled Resources*” on January 1st, 2014 (SCKMPC, 2014). It clearly stipulates relevant
124 municipal sectors’ responsibilities. For instance, the Bureau of Commerce is responsible for preparing a
125 recycling development plan and supervising recycling activities at the county level. Bureau of Urban-
126 Rural Planning is responsible for integrating the plan for recycling sites into the urban-rural plan. The
127 Bureau of Environmental Protection is responsible for controlling pollution generated from processing
128 recyclable wastes (including collection, sorting and final treatment). These local regulations proactively

129 promoted the local development of the RWR system.

130 **Table 1**

131 Laws or policies which refer to RWR in China

Effective Time	Laws or Policies	Brief Description	Issuer
1991/12/26	Notice on Strengthening Administration of Recyclable Resources Recycling	Specifying categories of recyclable resources; Preventing illegal business in recyclable metals; Requiring enterprises positively collect low value recyclable resources.	SCC
2003/01/01	Clean Production Promotion Law	Setting rules to require enterprises employ clean energy, advanced technology and integrated management to decrease pollution and increase utilization efficiency of resources all the way.	NPC
2007/05/01	Measures for the Administration of Recyclable Resources	Providing crucial provisions to collect, trade and administrate recyclable resources; Identifying government departments' responsibilities.	NDRC, MOPS, SAIC,

	Recycling		MEP
2009/01/01	Law on Promoting the Development of Circular Economy	Clarifying requirements of Reduce, Reuse and Recycle (3R); Emphasizing process of recycling should meet national required standards.	NPC
2010/05/28	Guideline on Further Advance in Development of Recyclable Resources Recycling Industry	Making policies to develop industry of recyclable resources recycling and establish administration schemes. Suggesting governments to foster leading enterprises and set up modern information system	MOC
2011/10/31	Opinion on Construction of Complete and Advanced Waste Recycling System	Forming basic principles and main targets to construct modern and advanced RWR system; Listing major tasks, including improving sorting level, strengthening technological support and completing recycling system.	SCC
2013/01/23	Development Strategy of Circular Economy and	Concluding achievements and obstacles of circular economy in 2005-2010; Making action	SCC

	Recent Action Plan	plans to promote development of circular economy at social level.	
2014/12/31	Implementation Plan of Important Resources Recycling Engineering (Technology Promotion and Equipment Industrialization)	Making plans to promote technological development and equipment production in the aspects of urban mineral (recyclable resources), remanufacturing, industrial waste recovery and construction of waste goods recycling system.	NDRC, MOST, MIIT, MOF, MEP, MOC
2015/01/21	Construction of Recyclable Resources Recycling System in Mid-long Term Planning (2015-2020)	Introducing current characteristics and problems of recyclable resources recycling; Planning major tasks and programs to construct a complete and advanced RWR system in 2020.	MOC, NDRC, MOLR, MOHURD, ACFSMC
2016/05/05	Opinion on Promoting Transformation and Upgrading in Recyclable	Encouraging innovating RWR system, such as Internet+; Transforming extensive management modes to intensive management modes.	MOC, NDRC, MIIT,

Resources Industry

MEP,

MOHURD

, ACFSMC

132 Note: ACFSMC (All-China Federation of Supply and Marketing Cooperatives), SCC (State Council of
133 China), MEP (Ministry of Environmental Protection), MIIT (Ministry of Industry and Information
134 Technology), MOC (Ministry of Commerce), MOF (Ministry of Finance), MOHURD (Ministry of
135 Housing and Urban-Rural Development), MOLR (Ministry of Land and Resources), MOPS (Ministry
136 of Public Security), MOST (Ministry of Science and Technology), NDRC (National Development and
137 Reform Commission), NPC (National People’s Congress), SAIC (State Administration for Industry &
138 Commerce).

139 *2.2 Pilot program of RWR*

140 The Ministry of Commerce (MOC) of China initiated a program of RWR systems in pilot cities in
141 2006, in which 26 cities were included in the first batch of pilot cities (MOC, 2006). Later, 29 pilot cities
142 and 35 pilot cities were announced as the second batch and the third batch in 2009 and 2012, respectively
143 (MOC, 2009, 2012). The geographical distribution of the three batches of pilot cities in China is shown
144 in figure 1. Most of them are located in the relatively rich and developed area of eastern China. Statistical

145 data show that 51,550 recycling sites, 341 collection centers, 63 terminal markets, and 123 recycling &
146 processing bases were established under the three batches of pilot city projects (ChinaIRN.com, 2014).
147 The aim of the pilot program was to promote the construction of a formal RWR system, strengthen the
148 enforcement of regulations on RWR, and normalize the qualification standards for recycling enterprises
149 and individuals. MOC anticipated that by end of the third batch of pilot city program, approximately 90%
150 of communities could set up formal RW recycling sites, 90% of the RW could enter into the formal
151 trading market and final treatment system, and 80% of the typical RW can be recycled in pilot cities. The
152 intention of the program was that all the local governments involved should summarize the successful
153 experiences from the pilot projects, and then share them to guide the development of RWR system in
154 other Chinese cities. All the pilot cities were required to elaborate on implementation schemes, make
155 annual plans, and prepare their MSW policies by considering the local realities.

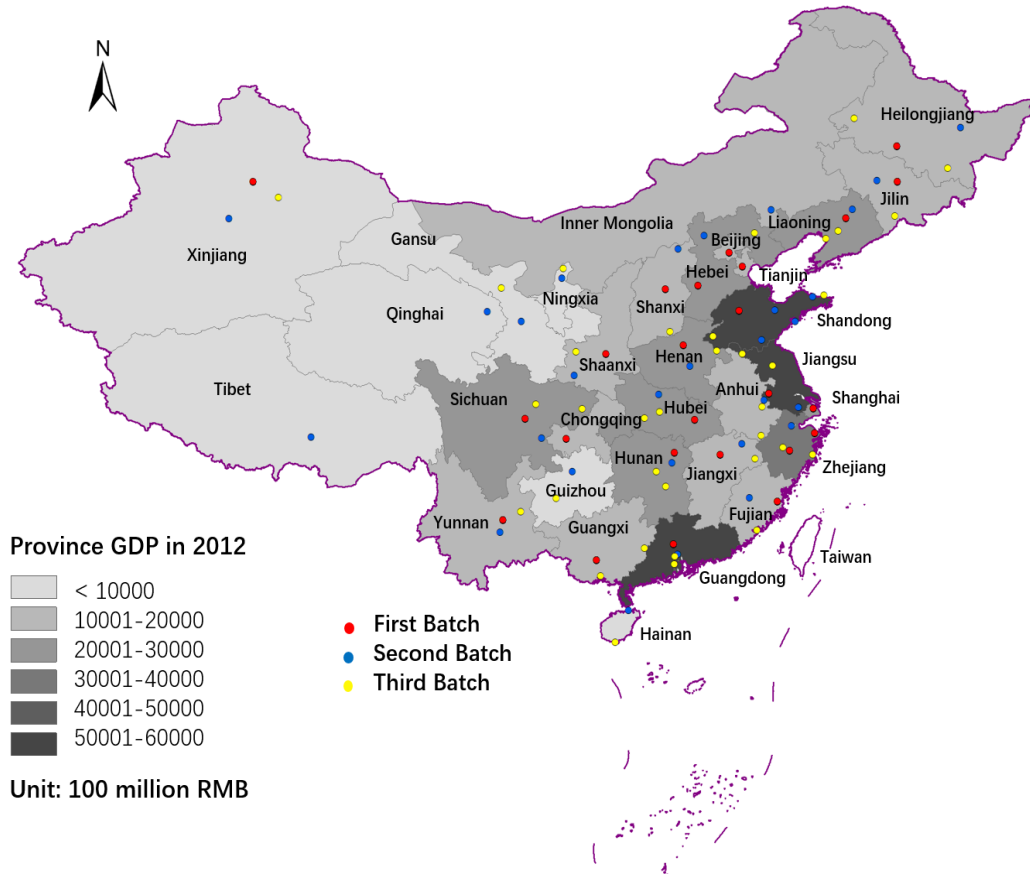
156 The implementation of the pilot program is a step-by-step process. The first pilot cities include four
157 province-leveled municipalities and many provincial capitals. These cities have relatively large
158 economies and mature infrastructure for collecting, delivering and treating RWR. Four main objectives
159 were included. Firstly, all the pilot cities should establish and improve their management of RWR,
160 including construction planning, policies, and standards. Secondly, all the pilot cities should develop

161 networks to support their RWR system, such as a community-based recycling network, a non-
162 community-based recycling network, an industrial waste metal recycling network, and a recyclable
163 wastes transaction market. Thirdly, all the pilot cities should foster recycling enterprises to promote the
164 development of the whole industry. Finally, in order to improve the awareness of recycling amongst
165 employees, all the pilot cities should engage in capacity building activities for both bottom participators
166 and senior experts.

167 The second batch of pilot program includes 29 cities and 11 waste transaction markets. The aims of
168 this batch include energy saving and emission reduction, resources conservation, ecological protection
169 and increasing the consumption of recycled wastes. There are three key objectives in this batch. Firstly,
170 all the pilot cities should create new business models and standardize the recycling sites. According to
171 the construction plan, the local government should encourage all communities to build up their waste
172 collection sites so that more recyclable wastes can be collected. Secondly, all the pilot cities should
173 improve their treatment technologies. The program also intended that successful experiences and useful
174 technologies from other countries should be transferred to these pilot cities to improve their source
175 separation. Moreover, all the pilot cities should support the delivery of such wastes so that treatment
176 companies can easily source adequate wastes for their operations. Thirdly, all the pilot cities should

177 improve their waste transaction markets so that recycled wastes can be easily sold. Necessary
178 environmental protection facilities should be established as well so that secondary pollution can be
179 avoided. The key feature of this batch is the promotion of waste transaction markets as these markets
180 play an important role in connecting the upstream collection firms and the downstream treatment firms.

181 The third batch of 35 pilot cities mainly came from prefecture-level cities and some county-level
182 cities. Most of them have reasonably stable recycling systems and good economic conditions. The pilot
183 cities were required to not only make detailed construction plans but also to coordinate the plans of
184 relevant government departments. Moreover, at least two leading recycling enterprises should be fostered
185 for each pilot city to facilitate the development of the RWR system. Finally, the pilot cities should make
186 relevant local laws and supporting policies to support recycling system construction, such as financial
187 support, land arrangement and tax preference.



188

189

Figure 1 The distribution of RWR pilot cities

190 **3. Current situation and achievements**

191 *3.1 Status quo of China's RWR*

192 After several decades of development, China has made considerable progress in RWR. The total

193 recyclable amount of the ten dominant types of recyclable wastes reached 246 million tons in 2016 (0.3%

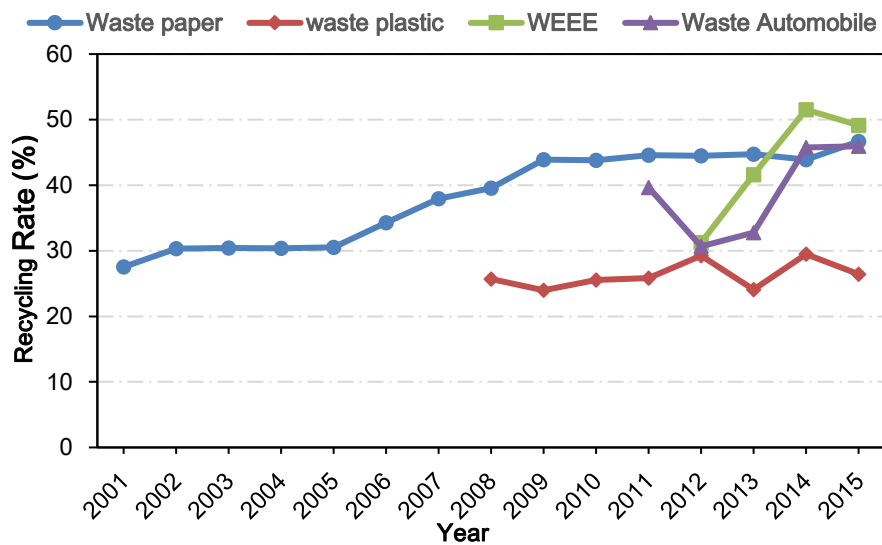
194 increase from previous year), with an economic value of 515 billion RMB (MOC, 2017). The recycling

195 of several common wastes, such as waste paper, waste plastic, WEEE, waste automobiles and waste steel,

196 has been improved. For instance, waste paper is one of the most common recyclable resources in China,

197 and its recycling rate increased from 27.5% in 2001 to 46.7% in 2015 (figure 2). Compared with waste
198 paper, waste plastic has a lower recycling rate, ranging from 20% to 30%.

199 With the improvement of living standards, more and more WEEE and waste automobiles were
200 generated. The recycling rate for WEEE increased sharply from 31.3% in 2012 to around 50% in 2015
201 (figure 2). One feature of China's RWR is that the recycling of waste depends on policies. On July 1st,
202 2012, *Measures for the Collection, Use and Management of Waste Electrical and Electronic Equipment*
203 *Treating Funds* was issued (MOF et al., 2012). This policy stipulates that the subsidy for recycling one
204 television or one microcomputer is 85 RMB, for one refrigerator is 80 RMB, and for one washing
205 machine or one air conditioner is 35 RMB. Although this policy increased the collection of WEEE,
206 almost half of WEEEs still cannot be collected through this official channel due to the lack of a mature
207 recycling system.



208

209

Figure 2 The recycling rates of four main recyclable wastes in China.

210

Data source: Industry Development Report of Recycled Resources of China (China National Resources

211

Recycling Association, 2016).

212

3.2 Existing RWR modes

213

There are three recycling modes for China’s RWR, namely, formal modes, informal modes and

214

innovative modes (figure 3). Informal waste vendors collect and process a significant share of recyclables,

215

while formal source separation of recyclables is still at a relatively small scale (Linzner and Salhofer,

216

2014). Taking Suzhou as an example, the informal system collected 60% of total domestic recyclable

217

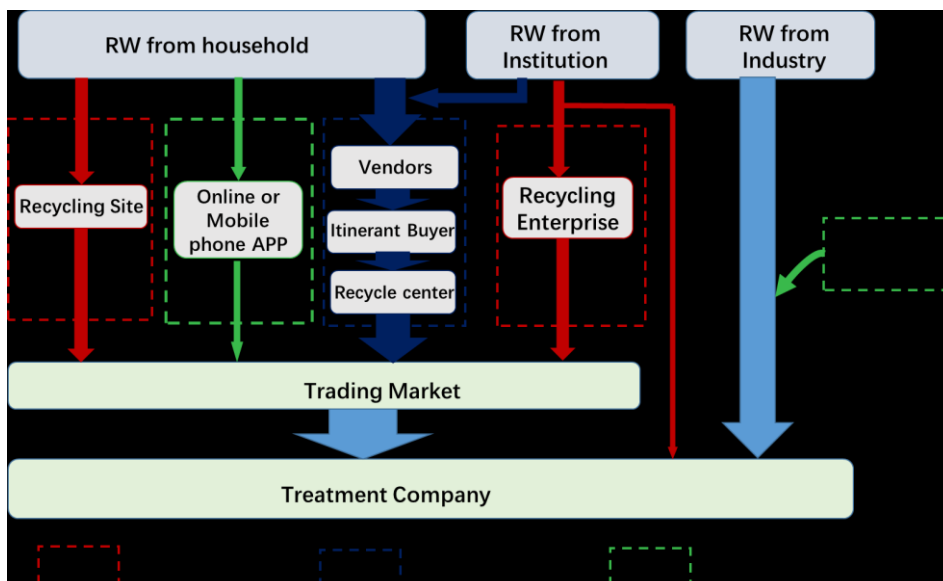
resources, while the formal system only accounted for 16% (Fei et al., 2016). As for innovative recycling,

218

it is an emerging recycling mode and has developed rapidly in recent years with the development of

219

information technology.



220

221 **Figure 3** Network of recycling modes in China.

222 In terms of the formal recycling mode, formal recycling networks for households have been developed
223 in some pilot cities, with fixed recycling sites within their communities. The fixed community-recycling
224 sites are usually established on a commercial basis, although the waste collection companies were
225 generally still supported by the local municipal government (Wang et al., 2008). The collected RWs are
226 delivered to the local waste trade market so that potential buyers can easily purchase them. This process
227 of formalizing the RW system can gradually substitute or eliminate the informal sector (Zhang and Li,
228 2010). This formal recycling mode also covers RW from different institutions, including governmental
229 agencies, commercial buildings, schools and hospitals, etc. Recycling enterprises collect RW and deliver
230 it to the local waste trade market or the treatment company. It is a simple and direct mode which has
231 shorter transportation distances and higher efficiency.

232 In terms of the informal recycling mode, most informal vendors are small-scale and labor-intensive.
233 They are mostly unregulated and unregistered, with basic recycling technologies and services (Wilson et
234 al., 2006). However, they play a vital role in collecting RW, particularly for WEEE recycling. Statistical
235 data show that the informal sector collected approximately 98% of WEEE in China in 2007 (Yu et al.,
236 2009), and the majority of the collected WEEE is also processed by the informal sector (Li et al., 2006).

237 However, the distribution of the informal sector is uneven, and the sector mostly only engages in the
238 higher value wastes, such as waste paper and waste plastic. Also, due to low barriers to entry, many
239 informal vendors do not have higher education and rely on the informal recycling activities(Wilson et al.,
240 2006). It is difficult to entirely forbid the informal sector, as doing so may induce several social problems
241 such as increasing unemployment or lack of access to waste services for households. Most informal
242 recycling vendors provide their services to local households, although occasionally they may also serve
243 institutions. This is because the local government can easily control most public institutions while it is
244 difficult for the local government to control households. Another feature of the informal sector is that
245 most vendors use tricycles to collect RW, making them able to collect RW with lower costs (Li, 2002).

246 As for the innovative recycling mode, it applies modern information technologies such as the
247 internet, big data, and mobile phone apps to facilitate online trade, which is more convenient, cheaper
248 and easier to operate. However, this mode is still in its infancy but is highly likely to play an important
249 role in promoting China's RWR in the future. For instance, Beijing Incom Recyclable Resources
250 Recycling CO. Ltd. utilized kiosk machines for collecting waste clothes, and established relationships
251 with local communities, universities and museums so that discarded clothes from these entities can be
252 collected. For one individual, he/she can access a local kiosk machine and print a stub (with a matrix

253 code) by touching this machine's screen. Then he/she can attach the stub to an item of discarded clothing
254 and then put it into this kiosk machine. The clothes will then be separated so that those clean and usable
255 clothes can be donated to poor areas, while those that cannot be reused would be recycled. Individuals
256 who donate clothes in this way can earn points which can be redeemed for philanthropic activities, which
257 are implemented by the recycling company as well.

258 **4. Existing problems and challenges**

259 *4.1 Ineffective government administration and market construction*

260 Ineffective government administration and immature markets are two critical factors that impede
261 the development of China's RWR. Although the Chinese government has done a lot in recent years to
262 promote the RWR, there are still scope for the government to strengthen its legal system and
263 administration. For example, "*Measures for the administration of recyclable resource recycling*", which
264 was issued in 2007, is the only specific regulation in the field of RWR. Besides, the legal power of this
265 regulation is limited. Also, there is a lack of specific industrial standards, technology standards,
266 classification standards and test standards for most of the recyclable wastes. Therefore, more general and
267 specific legislation is needed in order to guide the development of the recycling industry. In addition,
268 existing regulations concentrate more on WEEE and other high-value recyclable resources, and there are

269 no specific regulations governing low-value recyclable resources, such as waste glass or waste compact
270 fluorescent lamps.

271 Another key problem is the lack of a centralized administrative department to take charge of the
272 RWR system. Currently, several departments, including MOC, MOF, MEP and MIIT, are involved in
273 RWR management. MOC has responsibility for RWR management, mainly related to trade and logistics
274 for RW. The City Construction Administration Bureau is responsible for municipal waste collection and
275 management at the local level. MEP is in charge of environmental pollution from the transportation of
276 waste and final waste treatment. The coordination of these departments is extremely difficult and
277 inefficient, leading to an urgent need for a new agency to specifically coordinate the RWR system.

278 Regarding to the establishment of recycling markets, several challenges still exist since informal
279 recycling vendors and scavengers are the dominant components of the current recycling market,
280 especially in recycling WEEE (Chi et al., 2011; Tong et al., 2017).- Informal sectors have the advantages
281 of flexibility and a low operation costs, and so they are more competitive than formal sectors, which
282 hinders the development of formal recycling markets. Moreover, recycling rates are closely related to the
283 value of recyclable wastes. Therefore, most of the low-value recyclable wastes have relatively low
284 recycling rates due to their high recycling costs and low recovery benefits. In contrast, traditional

285 industrial wastes, such as waste steel and waste nonferrous metals, have comparatively complete
286 recovery chains and high recycling rates. In summary, the disorder of informal recycling and low rates
287 of recover for lower value wastes are key barriers for the establishment of China's formal recycling
288 market, which requires government intervention.

289 *4.2 Insufficient MSW separation*

290 MSW is one of the main source for recyclable wastes, with approximately 30% of MSW being
291 recyclable, although it has a high proportion of organic components (Table 2). However, the separation
292 rate of household wastes is extremely low. Tai et al. (2011) found source-separation rates vary from 8.9-
293 40.1% in eight Chinese cities. After the implementation of a pilot program for household waste separation
294 in eight cities, only Beijing and Shanghai achieved around 60% household waste separation, while the
295 other six cities had less than 20% household separation.

296 The reasons for low levels of source separation include two factors. First is the low level of public
297 awareness and incentives for recycling (Zhuang et al., 2008). There is almost no promotion or guidance
298 on RWR, and most of residents do not have the right knowledge to separate recyclable waste. The only
299 motivation for waste separation is that they can receive some money from informal recyclers. Second is
300 that there are not adequate or convenient recycling facilities, which is a considerable barrier to recycling

301 behavior. For example, some residents do not have space to keep their recyclable wastes. According to
 302 (Zhang et al., 2016), enhanced accessibility of recycling facilities would encourage people to take
 303 recycling action. As for the cost of building recycling facilities, it may be possible that recycling
 304 companies who will benefit from high value RW recycling, or companies who produce the RW, should
 305 be responsible for the investment in accessible recycling facilities.

306 **Table 2**

307 MSW compositions in four municipalities in China

Composition	Organic	Paper	Plastic	Glass	Metal	Textile	Others
(%)	garbage						
Beijing	63.39	11.07	12.07	1.76	0.27	2.46	8.98
(2006)^a							
Shanghai	66.70	4.46	19.98	2.72	0.27	1.80	4.07
(2004)^b							
Tianjin	56.88	8.67	12.12	1.30	0.42	2.47	18.14
(2006)^c							
Chongqing	59.20	10.10	15.70	3.40	1.10	6.10	4.40

(2006)^d

Average	61.54	8.58	14.97	2.30	0.52	3.21	8.90
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308 Data source: a (Li et al., 2009); b (Hong et al., 2006); c (Zhao et al., 2009); d (Hui et al., 2006).

309 *4.3 Limited recycling information platforms*

310 Recycling information platforms refers to a comprehensive database that contains information on
311 recyclable resources, which can be accessed by relevant stakeholders. Geldermann (2010) suggests that
312 advanced recycling information platforms are not only beneficial for stakeholders, including producers,
313 management authorities and third party service providers, but also increase the efficiency of recycling
314 system. However, such platforms are still lacking for most recyclable resources in China, except for
315 limited information focused on WEEE recycling.

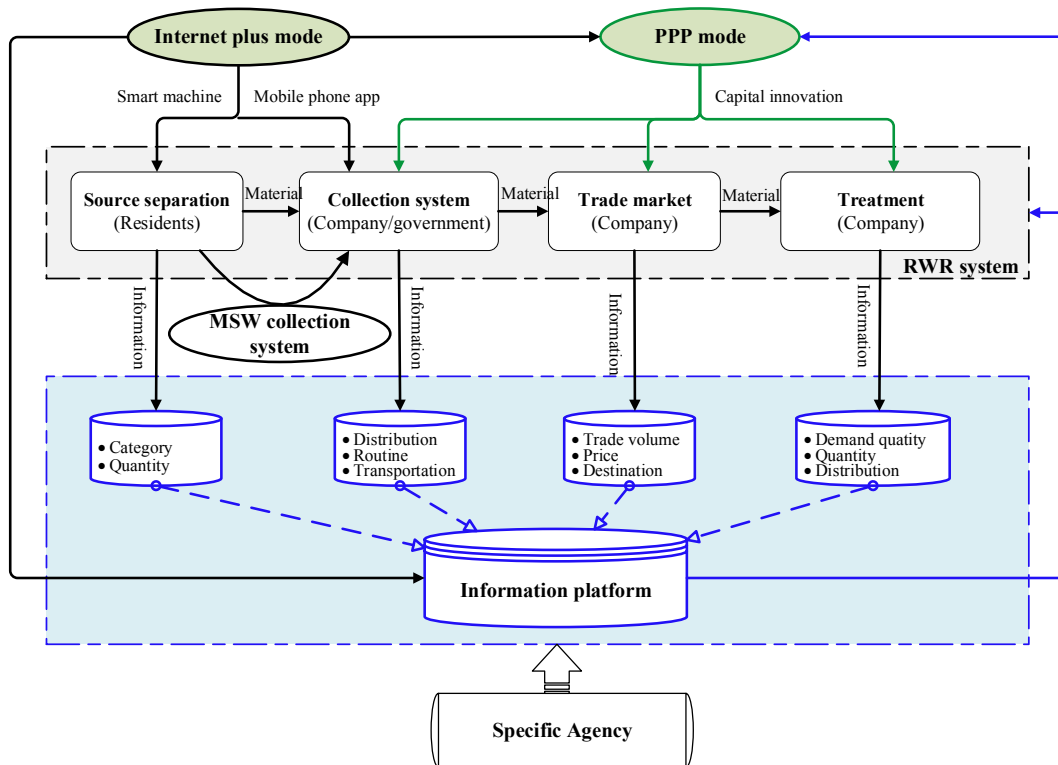
316 The lack of information platforms has impeded the development of China's RWR system in several
317 ways. For citizens, recycling information has a significant effect on recycling behavior (Nixon and
318 Saphores, 2009). A recycling information platform should provide easy and convenient access to
319 information about recycling sites, recycling categories and recycling prices. In terms of the recyclable
320 resource trade, information asymmetry is a common phenomenon and is a great barrier. It makes the
321 market inefficient, and lowers stakeholders' willingness to trade in a large quantities. In such a situation,

322 the formal sector cannot compete with the informal sector since the informal sector is more flexible. In
323 addition, the lack of recycling information platforms has a negative influence on governmental
324 management as well. Administrative authorities are not able to collect adequate data to make appropriate
325 policies and govern the downstream recycling industry.

326 **5. Proposing an integrated framework for China's RWR system**

327 Considering the reality of a large population, income inequalities, rapid development and limited
328 management systems within China, it is difficult to directly adopt successful practices from other
329 countries. We strongly recommend that economic incentives, modern technology support and
330 government leadership are the three key areas for improving China's RWR system. A proposed integrated
331 framework is illustrated in figure 4, which considers measures from the perspectives of capital flow,
332 material flow and information flow to strengthen the recycling system under the support of a specific
333 agency. Capital innovation through PPP (public-private partnership) is important for providing financial
334 support, particularly for downstream processes such as collection systems and recycling treatment
335 projects. Combining the RWR recycling system with the MSW collection system, and the modern
336 internet technology is recommended for material flow optimization, especially for efficient upstream
337 recycling. In addition, the establishment of a single information platform is proposed in order to provide

338 a holistic understanding of the RWR system, and to facilitate system control and optimization. It should
 339 be noted that these three recommendations are not new concepts. For example, PPP and internet+ have
 340 already been introduced, with some success, within individual systems. Our recommendation of an
 341 integrated system aims to provide a more systematic and comprehensive solution to the existing problems
 342 of limited investment in recycling, information asymmetry, and the lack of access to recycling facilities,
 343 by combining a number of existing promising solutions.



344

345 **Figure 4** Proposed integrated framework for China's RWR system

346 5.1 *Capital scheme innovation to solve the capital barrier*

347 Capital is crucial for the RWR system. For instance, Japan's successful urban recycling projects

348 were enabled by government finance (Van Berkel et al., 2009). Due to the low financial returns within
349 the RWR industry, and the existence of informal sectors, the formal recycling sector is less attractive for
350 capital investment. Simultaneously, the government has limited financial budgets to support the
351 development of recycling infrastructure and networks. Thus, financial innovation is becoming one of
352 the key factors in establishing the RWR system.

353 PPP is an innovative form of public financing that combines both public and private sectors, rather
354 than relying exclusively on the public sector (Broadbent and Laughlin, 2003). PPP is particularly flexible
355 and efficient in solving the financing problem for high-investment projects (Chen et al., 2010), and has
356 been employed in fields such as infrastructure, transportation and environmental protection (Chen, 2009;
357 Zhang et al., 2015; Zhang, 2014). Since 2015, PPP has been applied to the RWR industry in China. PPP
358 increases the financial resources available to the recycling industry by leveraging private sector
359 investment in recycling infrastructure and new recycling technologies. Several successful programs have
360 been accomplished through PPP, for example, Yichang Supply and Marketing Cooperatives Jixin Assets
361 Management Co., Ltd and Guangdong Zhishun Chemical and Environmental Protection Equipment Co.,
362 Ltd employed a PPP to recycle waste plastic in Hubei province (Sanxia Daily, 2016). This program solved
363 the problem of RW collection and reduced the level of ‘white pollution’, i.e. pollution from discarded

364 plastic bags, with capital from the private sector. The program also formed a closed recyclable resources
365 industrial chain, and provides an example of a successful application of the PPP approach.

366 Another important financial measure is the policy of tax deduction and exemption. A number of
367 government and company representatives indicated, during discussions with the authors, that a favorable
368 tax policy is one of the key factors determining the survival of RWR companies. The economic returns
369 from RWR are much smaller compared with other manufacturing industries, thus it is impossible for the
370 RWR sector to bear the same tax rate. Initially, many RWR companies started because of tax exemptions,
371 but many subsequently closed following the abolition of the tax free policy. Both the government and
372 the RWR sector are aware of the importance of the preferential tax policy, and the government is now
373 considering an appropriate tax rate in order to promote the development of the RWR system.

374 *5.2 Support recycling by improving recycling convenience*

375 Accessibility and convenience are the most important factors influencing recycling behavior in
376 developed countries (Davis et al., 2006; Gonzalez-Torre and Adenso-Diaz, 2005; Miliute-Plepiene et al.,
377 2016). Recent studies show that individuals with easily accessible recycling facilities are 25% more
378 likely to recycle than those without easy access (Zhang et al., 2016). Therefore, it is crucial to establish
379 convenient recycling sites and facilities to promote China's RWR system. However, it is difficult to set

380 up a mature RWR recycling system within a short time. Two innovative recycling modes are strongly
381 recommended to facilitate the convenience of recycling. The first is to combine RWR with the MSW
382 collection system since MSW collection and transportation systems are already well established. The
383 logistics network for MSW is also be used for recyclable resources, and RWR sites can use the same
384 facilities as MSW, just adding more bins and vehicles for recyclable wastes. This integrated system could
385 efficiently promote source separation by supplying enough convenient facilities. Moreover, sharing
386 facilities and processes ensures comparatively low costs and higher efficiency.

387 Second is to strengthen emerging innovative recycling practices by integrating RWR with modern
388 technologies. The Chinese Premier Li Keqiang proposed the notion of “Internet plus” in the
389 Governmental Work Report in 2015 to create new engine for economic growth, meaning the application
390 of the internet and other information technology such as cloud computing, big data and the internet of
391 things in conventional industries (Xinhua News, 2015). Internet+ was on the list of significant economic
392 keywords in 2015, and has been practiced by a number of recycling companies. Such innovative
393 recycling practices can be achieved through three pathways. (1) Installing smart recycling machines so
394 that people can recycle waste at any time, and can also get reward points to exchange for commodities.
395 (2) Use mobile phone software such as Wechat to spread awareness of RWR recycling, and enable people

396 to reserve convenient times for door-to-door collection services. (3) Establish online trading platforms
397 to connect upstream recycling companies and downstream treatment companies, which will not only
398 greatly improve the efficiency of RW trade but will also facilitate the establishment of RWR supply
399 chains. In summary, the obvious advantages of the above innovative recycling practices are convenience
400 and low cost, which are the dominant barriers for the current RWR system. The government has also
401 identified this solution for China's RWR system, and supports this approach in the "*Circular economy*
402 *promotion plan in 2015*" (NDRC, 2015).

403 5.3 Set up a comprehensive information platform

404 As mentioned above, information asymmetry is another significant factor in impeding RWR in China.
405 Almost all stakeholders are not able to get sufficient and accurate information on recycling activities.
406 The government holds the most data about RWR, but currently does not share that information, and
407 recycling companies do not have enough information to find sufficient recycling waste sources. As for
408 residents, most are not aware of recyclable waste recycling, or how to participate in recycling. For
409 researchers, it is also a great challenge to study RWR because of the difficulty in accessing information
410 and data. Therefore, a publicly accessible and comprehensive information platform that integrates supply
411 side and demand side information should be established to link all stakeholders and strengthen the

412 sharing of information. The Chinese national policy *Guidance action on promoting the “Internet Plus”*
413 (SCC, 2015) suggests that the RWR industry should take full advantage of the rapid development of the
414 internet to establish a successful information platform. Functions such as advertising, trading, statistics
415 and management, can be added into this platform as well. It could not only help the government to
416 administrate this industry, but can also help citizens and companies to access to recycling information.
417 This would contribute to the development of the formal recycling sector in China, because citizens would
418 be able to register their household recyclable resources online and select formal recycling companies
419 rather than the informal vendors to sell their RW. In addition, formal recycling companies would be
420 able to access information about upstream RW supply and downstream demand, thereby strengthening
421 the formal recycling value chain.

422 **6. Conclusions**

423 The Chinese government and enterprises have made great efforts to promote the development of
424 the RWR system. Several achievements have been made, including several laws and regulations on RWR,
425 three batches of pilot city program, and increased recycling rates. However, it should be noted that several
426 challenges still exist. The three main challenges are: insufficient regulations which encourages the
427 informal recycling market; inefficient source separation caused by a lack of recycling awareness and

428 recycling facilities; and the absence of a recycling information platform. Finally, we propose an
429 integrated framework to comprehensively improve China's RWR system. Capital flows, material flows,
430 and information flows should be strengthened through financial innovations such as PPP, combined the
431 RWR system with the existing MSW system, and the establishment of an information platform,
432 respectively. The emergence of innovative recycling practices, particularly the use of an internet+
433 approach, is the key for developing China's recyclable wastes recycling.

434

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442

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