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Analysis of sixteen zero-waste cities in China

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Research Paper

Introducing a classification framework to urban waste policy: Analysis of sixteen zero-waste cities in China

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A R T I C L E I N F O

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A B S T R A C T

Chinese cities are experiencing rapid urban development while facing severe challenges of environmental pollution. China's central government has proposed several policies to reduce urban waste. However, little is known about the adoption of these policies. Here, we raise the question *how can circular policies be classified, and how can this classification be applied to cities in China that wish become zero-waste cities?* We develop a framework to classify urban waste policies according to: (a) the "5R" principles ("Rethink", "Reduce", "Reuse", "Recycle", and "Recover"), (b) four types of waste (industrial, agricultural, municipal, and hazardous) and (c) six types of policy instruments (legal, economic, network, communication, innovation and projects). We use this framework to analyze urban waste policies implemented by sixteen zero-waste demonstration projects in China. The present study emphasizes combinations of policy instruments, "R" strategy and waste type in the implementation of zero-waste policies. We find that the "Rethink", "Reduce", and "Recycle" principles have been widely implemented by local authorities in contrast to the principles "Reuse" and "Recover". Local governments address waste management by embracing regulations, innovation instruments, and project arrangements, while network-based, economic, or communicative policy instruments are used less often. Based on the results we suggest that local governments embrace a comprehensive approach to the use of the "5R" principles and deploy a diverse portfolio of policy instruments.

1. Introduction

Worldwide there is increasing attention to the harmful impact of waste and environmental pollution. The UN has adopted Sustainable Development Goals (SDGs) to address this issue, in particular SDG12 on sustainable production and consumption (Bernstein & Vos, 2021). Dealing with waste and pollution can be considered of primary importance to the mission of reaching a Circular Economy (CE) (D'Adamo et al., 2022). CE is widely understood as an alternative model of production and consumption, a strategy which theoretically contributes to both economic growth and sustainable development (Reike et al., 2018). Although CE is a generally contested concept (Korhonen et al., 2018), its overall aim is to eliminate waste, to keep products and materials in use for as long as possible, and to regenerate nature (EMF, 2022).

Striving to reduce waste and pollution levels whilst embracing CE as a societal mission is important for countries to reach the SDGs. However, such complex long-term oriented missions can be seen as 'wicked problems' that cut across multiple policy and industrial sectors and tend to be politically contested. They also require breaking through incumbent regimes and socio-technical systems that maintain the status quo of unsustainable institutions, agency and practices (Hekkert et al., 2020). In addition, they demand attention to developing new technology, products and services which contribute to mission-oriented goals. Policies can enable niche development for mission-oriented innovations (i.e., via offering protection, experimentation and demonstration), for example via innovation policy containing subsidies which fund innovative projects, via programs that encourage the formation of innovation networks or partnerships, or via exemptions to legislation that allow

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for experimentation (e.g. via 'regulatory sandboxes'; Dostov et al., 2017; Zhao & Bai, 2021). Moreover, policies and the policy instruments deployed to implement them are only seldom formulated and selected in isolation; they are typically part of a policy mix, that consists of multiple policy goals, instruments, and target groups (Ma et al., 2022). In other words, there is a need to understand how local governments implement CE.

Chinese cities have experienced dramatic urbanization and industrialization over the last forty years, with waste and environmental pollution becoming prominent headaches (Chien & Wu, 2011; Logan & Molotch, 2007; Shao et al., 2006; Yeh et al., 2015). China's industrial solid waste generation reached 3.67 billion tons in 2020 (NBoS, 2021). From 2006 to 2017, the average annual growth rate of general industrial solid waste was 9.9 % (NBoS, 2021). As a response, China's national government proposed various solutions focusing on CE to substantiate the claim that it was well on its way towards reaching the SDGs.

The idea of CE was adopted by China's State Council in 2005, claiming that the country had to become, "resource-conserving and environment-friendly" (SC, 2005). In 2007, the National Development and Reform Commission (NDRC) issued the "*Evaluation Index System for Circular Economy*", and it promulgated the Circular Economy Promotion Law in 2008, which aimed to decrease resource consumption and environmental cost by making use of the principles of "reduction, reuse, and resource recovery" (SC, 2005). The Chinese central government also decided to run pilots in several cities, implementing policies to reach these ambitious goals. For example, CE pilots were carried out in key industries, several policy domains, industrial parks, provinces and cities (SC, 2005). By the end of 2016, 125 pilot provinces, cities, districts and counties were jointly listed as *CE pilots* by the NDRC (NDRC, 2015). Since the 18th National Congress of the Communist Party, China made substantial progress in the development of a CE by formulating a promotion plan in 2015. A few years later, in 2018, the Circular Economy Promotion Law was revised and general industrial solid waste began to decline in volumes only from 2019 onwards (NBoS, 2021). However, although this did lead to an improvement of its overall environmental situation, the amounts of waste disposed were still astronomical (CAoCE, 2021). Therefore, the label "*Zero-Waste City*" (ZWC)[1] was introduced as a city label[2] after the 19th National Congress of the Communist Party. In this period, the new goal of the central government was, "*to enhance ecological civilization*[3] *and build a beautiful China*" (SC, 2018). The ZWC concept aimed at reforming the management of urban solid waste, to reduce, and to recycle solid waste in an effort to diminish its environmental impact, to minimize landfill, as well as to promote the construction of a "*zero-waste society*" (SC, 2018). In 2019, the Ministry of Ecology and Environment (MEE) selected sixteen local authorities and districts with the aim to develop and brand *zero-waste pilot cities* (MEE, 2019), and released an indicator system to evaluate them. Both "*CE pilot cities*" and ZWCs are seen as important means that contribute to ecological civilization in China (Ma, 2021).

It is not known yet how and to what extent the concept of ZWC influences China's sustainable urban development by improving current waste management practices. Although the amount of scholarly publications in the domain of CE is rising (Liu et al., 2019), only few academic publications pay attention to implementation of CE policies (Ma et al., 2022), and even less to policy implementation at the local level, with the exception of Loukil & Rouached, (2012) who focused on the use of individual policy instruments like recycling subsidies in urban waste governance.

To address this knowledge gap, the present study adopts a focus on local policy implementation in the domain of CE, and more particularly, across sixteen ZWCs in China. It does so by studying the selection of policy goals and instruments by local authorities. The identified policies are classified within a framework according to a) the "5R" principles (i.e., "Rethink", "Reduce", "Reuse", "Recycle", and "Recover"), b) six policy instruments used by local authorities (i.e., legal, economic, network, communication, innovation instruments and urban waste projects), and c) four types of waste (i.e., industrial, agricultural, municipal, and hazardous waste). Ultimately, this paper seeks to answer the following research question:

How can circular policies be classified, and how can this classification be applied to cities in China that wish to become zero-waste cities?

Section 2 reviews key literature on urban waste policies, types of waste and policy instruments. In Section 3, the research design and methodology are presented. This section provides background for the Chinese zero-waste demonstration projects and explains our procedures for data collection, data treatment and analysis. Section 4 presents our results on urban waste policy adoption and the co-occurrences of different kinds of urban waste policies across sixteen ZWC demonstration projects. In Section 5, the added value of the present study is positioned within the context of ongoing academic debate. Section 6 summarizes the key findings, theoretical contribution, research limitations as well as suggestions for future study and policy implications.

2. Theoretical background

In urban waste management, waste is recognized as a resource in both production and consumption (Fudala-Ksiazek et al., 2016; Zaman, 2014), where material flows should be reused and recycled repeatedly to maximize utilization (Song et al., 2015). Urban waste policies can be

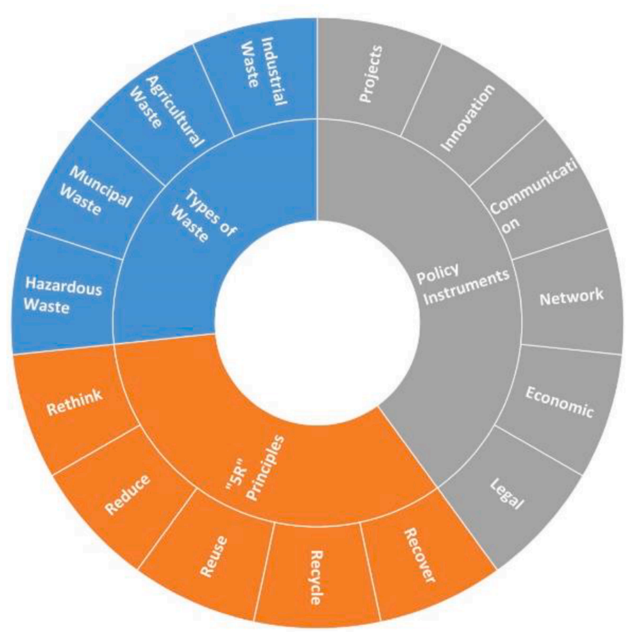

Fig. 1. Classification framework of urban waste policies (detailed explanation can be found in Table A1 of the Appendix).

[1] ZWC is a city label which describes a city which recycles 100% of its municipal solid waste and recovers 100% of all its resources from waste materials (Zaman & Lehmann, 2011a).

[2] City labels have diverse functions related to urban development, allowing cities to become competitive, improving their environmental performance, and experiencing an urban transformation to become more sustainable (de Jong et al., 2018). However, other scholars claim that popular city labels should be seen as merely a tool that is employed by local governments to greenwash their doubtful industrial traces and unsustainable economic activities and practices (Schuetze & Chelleri, 2016).

[3] Ecological civilization is the summary of material, spiritual and institutional achievements made by mankind to protect and build a beautiful ecological environment. It is a systematic project that involves all aspects of economic, political, cultural and social development. It reflects the progress of a society's civilization (Huanqiu, 2012).

analyzed from different angles. For example, previous research suggested that urban waste policies can be identified using different "R" principles, such as the "3R" (i.e., reduce, reuse, and recycle) (Sakai et al., 2011). Other scholars also studied urban waste policy from the perspective of waste types, such as industrial waste, agricultural waste and municipal waste (Jamal, 2020) or the use of (individual) urban waste policy instruments (Kautto & Lazarevic, 2020). However, thus far there has been little attention in the use of urban waste policies by focusing on all three dimensions of the abovementioned, simultaneously. Therefore, we propose an urban waste policy classification framework that focuses on both the "R" principles of waste hierarchy, as well as on various waste types and policy instruments (See Fig. 1). Table 1 shows the description of each dimension of urban waste policies.

2.1. The "5R" principles for urban waste policies

The development of urban waste policies based on the "R" principles of the waste hierarchy framework is a prerequisite for obtaining a CE. These principles initially involved the reduction, reuse, and recycling of resources in an economy, a combination which is known as the "3R principles" (Kirchherr et al., 2017; Ranta et al., 2018). These principles have been extended over time by adding the principles of "Recover" (Yang et al., 2017), "Redesign", "Remanufacturing" (Jawahir & Bradley, 2016; Yan & Feng, 2014), "Repurpose", "Refurbish", "Repair", and "Rethink" (Potting et al., 2017). On the one hand, the 3R hierarchy is one of the most commonly used frameworks in waste management (Hartley et al., 2020) albeit too reductionist to accurately capture its complexity. Other "R" principles are also important, like "Rethink" and "Recover". On the other hand, the framework of the "10R principles" can increase substantially the complexity of policy classification when multiple dimensions are considered simultaneously as it is the case of our study (i.e., considering different types of waste, of policy instruments, and "R" principles). Some of the "R" principles have similar implications. To reduce complexity in the analysis and categorization of waste policies we identified the main features and functions of all "R" principles, and then grouped them according to similarities or possible overlaps. For example, we assigned the principles of "Repair" and "Refurbish" under "Reuse", and we considered the principles of "Repurpose" and "Rethink" to have similar meaning. The selected "5R" principles "Rethink", "Reduce", "Reuse", "Recycle", and "Recover" are considered to be mutually exclusive enough to represent the complete waste hierarchy framework.

2.1.1. Rethink

The "Rethink" principle aims to intensify the use of products or services by sharing or adding multiple functions (Potting et al., 2017). Here, the "Rethink" principle is used in a broader sense including the intelligent design for efficient and effective retrieval of materials (Morseletto, 2020), the re-elaboration and reconceptualization of ideas, process and uses of product (Andrews, 2015), and the embodiment of innovation practices from institutions and systems (Weetman, 2016). "Rethink" should be considered as an overall target for CE given that it occupies the highest position in the waste hierarchy (Elia et al., 2017).

2.1.2. Reduce

The "Reduce" principle refers to minimizing the overall amount of generated and discharged waste (Kirchherr et al., 2017). This includes the minimization of input of natural resources, materials and energy used in production and consumption processes by improving their efficiency, by simplifying packaging (Calcott & Walls, 2000), by miniaturizing and by lightening components and products (Ranta et al., 2018).

2.1.3. Reuse

The "Reuse" principle fosters the reuse of products and packaging of goods in their original form (Weetman, 2016). It includes the reprocessing of used products and materials by repair, innovative reuse,

Table 1
The urban waste policy classification framework.

		Description	References
"5R" principles	Rethink	Make product use more intensive (redesign product or introduce multi-functional products on the market).	(Potting et al., 2017)
	Reduce	Reduce the amount of matter and energy entering the production and consumption processes by improving of management techniques in the production process.	(Jawahir & Bradley, 2016; Van Buren et al., 2016)
	Reuse	Reuse the product as a whole, or its components, after its first life-cycle, for subsequent life-cycles.	(Jawahir & Bradley, 2016; MacArthur, 2013)
	Recycle	Convert waste materials into new materials and objects.	(Jiao & Boons, 2014; Potting et al., 2017)
	Recover	Collect, disassemble, sort, and clean products at the end of their use stage for re-utilization in subsequent life-cycles of the product.	(Jawahir & Bradley, 2016; Kirchherr et al., 2017)
Policy instruments	Legal instruments	Application of regulatory measures to require or specify certain behavior.	(Jenkins, 2014; Liu et al., 2017; Su et al., 2013; Zhu et al., 2019)
	Economic instruments	Application of economic or financial measures to reduce or eliminate waste from pollution industries and promote clean production processes.	(Kautto & Lazarevic, 2020; Morseletto, 2020; Wang & Chang, 2014)
	Network instruments	Application of organizational measures to promote the participation from public and private actors and strengthen the cooperation among departments.	(Britton & Woodman, 2014; Khanna et al., 2014; Shen et al., 2020; Stelling, 2014)
	Communicative instruments	Publication of information to persuade and influence people's preferences and behaviours.	(Kautto & Lazarevic, 2020; Wang & Chang, 2014; Winans et al., 2017)
	Urban waste project	Initiation of projects, engineering, infrastructure development to implement zero-waste management.	(González-Domínguez et al., 2020; Sanchez & Haas, 2018)
	Innovation instruments	Application of some innovative measures, technology, platforms to reduce waste production and utilize waste.	(Cainelli et al., 2020; Fitch-Roy et al., 2021; Nußholz et al., 2019)
4 Types of waste	Industrial waste	Waste residues, dust, debris, and sludge generated during industrial production and processing.	(Soliman & Moustafa, 2020; Zhou et al., 2017)
	Agricultural waste	Waste discharged from agricultural production, livestock and poultry raising, processing of agricultural and sideline products and living activities of rural residents.	(Maji et al., 2020)
	Municipal waste	Waste generated in the process of residential life, commercial activities, municipal construction and maintenance, and office work.	(Buenrostro et al., 2001; Zhou et al., 2014)
	Hazardous waste	Waste having various toxic, flammable, explosive, corrosive, chemically reactive and infectious properties; Nuclear fuel production and processing, isotope application, waste generated by nuclear power plants, nuclear research institutions, medical units, and radioactive waste treatment facilities.	(Duan et al., 2008; Karthikeyan et al., 2018)

refurbishment, and remanufacturing to make them functional again (Zink & Geyer, 2017). Typical applications of the "Reuse" principle pertain to the reuse of glass bottles, second-hand trading platforms, and examples from the sharing economy (Belk, 2014; Henry et al., 2021).

2.1.4. Recycle

The "Recycle" principle addresses waste items that can be reprocessed back into usable resources, materials, products or substances after they have completed their function instead of ending up as unrecoverable garbage (Yan & Feng, 2014). In this way, materials can be fed back into production processes using advanced technologies, such as e-trading platforms for waste, and waste-specific software and business analytics (EEA, 2020) to reduce the need for additional material and energy resources while simultaneously avoiding or minimizing landfilling (Fullerton & Kinnaman, 1995).

2.1.5. Recover

The "Recover" principle refers to waste can be used as a source of energy or valuable biochemical compounds. It refers to the reclamation of resources of valuable biochemical compounds or of energy embodied in waste through incineration (Morseletto, 2020; Potting et al., 2017). Furthermore, it is used here to address the recuperation of renewable resources (Wang & Chang, 2014), the restoration and regeneration of natural capital.

2.2. Policy instruments for urban waste management

Policy instruments are used by public authorities to achieve certain policy goals (Howlett et al., 2009). If policies are to have impact they need to be prepared and implemented in a targeted way (Lascoumes & Le Galès, 2007) by selecting the most effective policy instruments to reach pre-set policy goals in society and realize the intended impact (Eliadis et al., 2005). During the selection of policy instruments, the implementation environment (including the physical environment, incumbent policy network, actors, politics and institutions) and the target groups (at the receiving end of policy) are taken into account, leading to the ones that are most apt in reaching the intended goals, whilst also considering certain public values like efficiency (Bressers & O'toole, 2005). In the present study we discern six types of policy instruments to capture potential differences in the availability and use of governmental resources and incentive mechanisms. Classification of policy instruments is also commonly used in other fields of environmental management (Goulder & Parry, 2008; Halpern, 2010; Ma et al., 2021).

2.2.1. Legal instruments

"Command-and-control" oriented legal policy instruments (e.g., regulations, legislation or permit systems or enforcement) are most commonly used to deal with environmental externalities in urban waste management (Liu & Qin, 2016). Governments deploy administrative measures to restrain and supervise polluting behavior of enterprises (Wang & Chang, 2014). Regulation and governance play a very important role in the waste sector (Pinto et al., 2017). Some scholars argue that regulatory policy instruments have the advantage that they are robust and can take effect immediately (Knill & Tosun, 2009). Others emphasize their disadvantages, such as high administrative costs and the restrictions they impose on innovation (Blazquez et al., 2018; Peters, 2013). Furthermore, governments can enforce measures to shut down excessive polluters.

2.2.2. Economic instruments

Economic policy instruments apply market and financial measures to control and guide the behavior of polluting enterprises (Laes et al., 2018; Milhorance et al., 2020). Subsidies, pricing, economic penalties (e.g. levies), government procurement, and tax incentives are widely used in urban waste management in different countries (Ferreira & Marques, 2015; Shinkuma, 2003), such as Japan and in most EU Member States (Kautto & Lazarevic, 2020). Compared to strict legal policy instruments, economic policy instruments are more flexible and are considered to have lower administrative costs when implemented (Baeumler et al., 2012). However, they are also criticized for wasting public finances (Blazquez et al., 2018). Economic policy instruments can also have serious negative side effects. For example, some scholars argue that emission trading encourages rather than decreases pollution (Blazquez et al., 2018). Policies such as "polluter-pays" and subsidies for clean energy are commonly used in waste management.

2.2.3. Network instruments

Network policy instruments are based on resource dependency and exchange, requiring collaboration from different organizations (Nochta & Skelcher, 2020). These instruments encourage the involvement of state-owned companies, the private sector, voluntary organizations, communities, and families (Khan, 2013). For example, the Japanese government has strengthened citizen participation in practices of separate waste collection. In Shanghai, a community-based co-production strategy for household waste sorting has been proposed as an alternative to the conventional top-down approach (Lu & Sidortsov, 2019). Communication and cooperation within departments can promote information exchange about waste (Peters, 2013), and are considered to operate more flexibly (Shen, 2015). The interaction between governments and other actors is of more horizontal and even-handed.

2.2.4. Communicative instruments

Communicative policy instruments influence and guide the behavior of target groups by means of raising awareness, and exchanging knowledge and information (Büchs et al., 2018). These instruments are considered to be the least coercive of all policy instruments and require low levels of hierarchical control (Carley, 2011). They include public information campaigns, exhortation, advertising, persuasion, and waste information disclosure (Palm & Lantz, 2020; Stelling, 2014). Encouraging the public to engage in garbage sorting by means of education and persuasion has grown increasingly common (Ma et al., 2021). In urban waste management, communicative policy instruments can affect public behavior in a targeted way (Palm & Lantz, 2020) but they are also associated with having a short implementation cycle with poor, short-term effects (Laes et al., 2018).

2.2.5. Urban waste projects

Winans et al. (2017) include industrial parks and ecological projects in their classification of policy instruments. Urban waste projects incorporate the concept of zero-waste management and are used for zero-waste transitions (Sanchez & Haas, 2018). In some countries, local governments often use governmental projects, environmental engineering, programs, industrial parks, recycling plants, and infrastructure provision to improve urban waste management systems and to facilitate the transition to a zero-waste society (Kalmykova et al., 2018). For example, an urban waste project was launched in Turkey to separate and recycle waste at its source (Kızıltaş et al., 2020). Generally, urban waste projects require the government to invest considerable financial capital to install recycling facilities to reduce the consumption of raw materials and to purify dust emissions (González-Domínguez et al., 2020). At the same time, governments need to promote cooperation in the implementation of urban waste projects (Kalmykova et al., 2018). Therefore, a variety of policy instruments can be categorized under urban waste projects, such as dedicated fundings, public and private partnerships.

2.2.6. Policy instruments for innovation

Innovative technologies and measures are used by municipalities to improve waste management capacity (Zaman & Lehmann, 2011), and to achieve more efficient and effective operations of waste management, such as localizing, monitoring, and measuring the level of fullness of containers and tracing of waste transportation (Zhang et al., 2019).

These measures exist but cannot be easily subsumed under the other types of instruments. Therefore, we classify innovative measures as the policy instruments for innovation. Innovative measures are not only technical in nature but can also be related to innovation in service provision (which goes along with technological innovation) or even with social innovation. These innovative measures aim to solve a very targeted and specific waste problem. Examples include adoption of waste-reducing technology in manufacturing (Cainelli et al., 2015), smelting technology, recycling transformation, provision of intelligent application platforms for waste management, improvement of the industrial sludge treatment process, desulfurization gypsum process technology, or fermentation technology of livestock and poultry manure returning to the field (Borrás & Edquist, 2013). Governments also set up recycling labs, innovative demonstration pilots, they introduce R&D platforms and new business models, develop patents, intellectual property rights, and datasets to improve the technology of urban clean production technology (Edler & Fagerberg, 2017). Other smart enabling technologies, such as IoT, big data analytics, cloud computing, cyber-physical system, and artificial intelligence can also be considered as innovation instruments (Zhang et al., 2019).

2.3. Waste categories

Generally, waste can be divided into industrial, agricultural, and municipal household waste depending on where the waste is produced (Alam & Ahmade, 2013). At the same time, waste can be divided into hazardous and non-hazardous waste (Demirbas, 2011). In the present study, we take these two classification methods into consideration and divide industrial waste into general industrial waste (non-toxic) and hazardous waste. Medical and toxic waste are classified as hazardous waste. Zhou et al. (2017) suggest that the major types of waste can be categorized as industrial waste (IW), municipal waste (MW), agricultural waste (AW) and hazardous waste (HW). Here we adopt this categorization since it makes the different types of waste mutually exclusive.

2.3.1. Industrial waste

Industrial waste is generated from industrial activities (Soliman & Moustafa, 2020) polluting the soil, air, and groundwater, clog waterways, erode farmlands, produce toxic fumes (El-Fadel et al., 1997), and disrupting the ecological balance. Industrial waste can be specified into four sub-categories according to their nature (either organic or inorganic), their pollution characteristics, the industrial sector of origin (mining, metallurgical, chemical, food preservation, construction), and the type of industrial process generating it (fired and unfired) (Soliman & Moustafa, 2020).

2.3.2. Agricultural waste

Agricultural waste refers to organic substances that are discarded during agricultural production (Maji et al., 2020) and mainly include non-edible plant-based residues (e.g., crop residues, weeds, leaf litter, etc.) and animal dung (Barros et al., 2020). Some developing countries reuse agricultural waste mainly as animal feed or as an energy source, such as Romania (Ungureanu et al., 2017). The valorization of agrarian waste has a high potential for recovering high-value ingredients but several social, economic and technological challenges remain unaddressed (Gontard et al., 2018). Government interventions to make high value ingredients of agricultural waste economically more attractive, are often flawed, offer few guidelines, and neglect the complex systemic nature of agricultural supply chains (Hoppe & Sanders, 2014).

2.3.3. Municipal waste

Municipal waste refers to household waste generated by residents and through urban activities (Wen et al., 2014). It includes unsorted commercial garbage occurring in marketplaces, piled in streets and public places, garbage from public organizations, schools, or communities. With the development of cities and the continuous improvement of people's living standards, the amount of domestic garbage in urban areas is increasing annually, and the environmental pollution caused by it is becoming a serious concern.

2.3.4. Hazardous waste

Hazardous waste includes solids, sludge, liquids, and containerized gases (other than radioactive and infectious waste) which are dangerous substances that can negatively affect human and animal health or the environment due to their chemical activity or toxic, explosive, corrosive, or other characteristics (LaGrega et al., p. 2, 2010). With the development of the industry, such as manufacturing, processing, and mining, the amount of hazardous waste discharged from industrial production processes and medical activities has increased.

3. Methodology

In the present study, an exploratory statistical research design is used regarding urban waste policy adoption among sixteen Chinese cities running ZWC demonstration projects that have been selected by China's Ministry of Ecology and Environment. The focus here, is on policy implementation and selection of policy instruments, covering three elements that are central to this study, i.e., type of waste, "R" strategy, and type of policy instrument, and the combinations of these. Studying such combinations will enable one to learn what type of "R" strategies and policy instrument types are found with regard to particular waste categories, and which combinations of these cities prefer to implement. The case selection of these cities, data collection, data treatment, and data analysis are addressed below.

3.1. Selection of Zero-Waste city demonstration projects in China

In 2019, the Ministry of Ecology and Environment (MEE) selected sixteen cities and districts as Zero-Waste City demonstration projects (MEE, 2019). The sixteen ZWC demonstration projects are scattered across different regions in China (Fig. 2). Table 2 provides social and economic information of the case cities (e.g., GDP per capita). These cities have different social and economic characteristics and represent megacities, medium and small-sized cities, county-level cities, and new towns. The present study includes all sixteen cities or areas in the research sample. One of them, Chongqing, adopted its entire urban region (主城区) as the constituency to be included in the ZWC program. Data for each ZWC demonstration project were collected from the corresponding (local) Statistical Yearbooks for 2020. Partial social and economic information for Xiong'an, Beijing Economic and Technological Development Area (ETDA) and Tianjin Eco-city is missing because they are new towns or national functional areas and do not yet have individual urban statistical yearbooks.

3.2. Data collection

To identify the type of urban waste policies adopted by zero-waste demonstration cities in relation to waste management, we reviewed online city policy documents on urban zero-waste management. Since the concept of ZWC was already proposed in December 2018, information about ZWC project development was found mainly on governmental websites published by the Chinese State Council, the Ministry of Ecology and Environment, and the various cities that are home to ZWC demonstration projects.[4] The types of policies studied include laws, orders, regulations, opinions, guidelines, rules, standards, notices, announcements and plans (Huang et al., 2021). The data were collected from each one of the studied pilot areas which were first identified as a

[4] We mainly checked the special issue on ZWC construction of Ministry of Ecology and Environment (https://www.mee.gov.cn/home/ztbd/2020/wfcsjssdgz/).

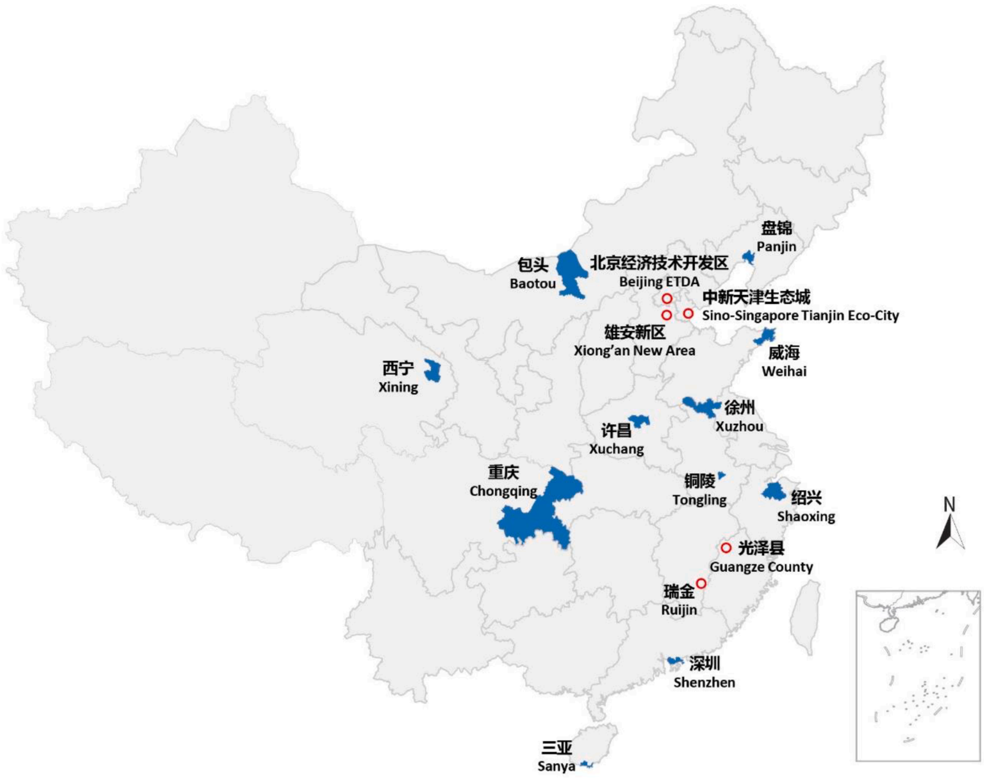

Fig. 2. The location of the sixteen zero-waste demonstration projects in China.

Table 2
Urban characteristics of the sixteen zero-waste demonstration projects in China (2019)[6].

No.	Cities	Permanent population (10^4 persons)	GDP per capita (RMB)	Ratio of primary/ secondary/tertiary sector as GDP[7] (in%)	Urbanization rate[8]	City-level[9]
1	Shenzhen	1343.88	203,489	0/39/61	1.00	First-tier
2	Chongqing	702.89	106,107	7/40/53	0.91	New first-tier
3	Shaoxing	447.87	114,561	4/48/49	0.68	Second-tier
4	Xuzhou	882.56	5985.7	10/40/50	0.67	Second-tier
5	Weihai	257	104,615	10/40/50	0.69	Third-tier
6	Sanya	63	87,105	11/17/73	0.76	Third-tier
7	Xining	238.71	55,812	4/30/66	0.73	Third-tier
8	Tongling	164.1	58,726	6/46/48	0.45	Fourth-tier
9	Xuchang	500.48	76,312	5/54/41	0.54	Fourth-tier
10	Panjin	130	88,983	8/54/39	0.65	Fourth-tier
11	Baotou	290	93,835	4/39/57	0.84	Fifth-tier
12	Ruijin	64.33	25,847	15/38/47	0.47	County-level city
13	Guangze	13.8	82,993	38/34/29	0.48	County-level city
14	Xiong'an	129	–	–	0.42	New Town
15	Beijing ETDA	17.6	1,098,182	0/65/35	–	New Town
16	Tianjin eco city	–	–	–	–	New Town

[6] We tried to collect data on waste streams in each pilot city. The data on waste generated are incomplete due to the differentiation of environmental information disclosure in each city. The information across cities is incomparable. Cities produce different types of waste because their divergent industrial structures. For example, Baotou mainly produces industrial waste while Shenzhen produces more municipal waste than others.
[7] The urbanization rate is the proportion of urban population to the total population.
[8] This classification is based on a Chinese media investigation (YICAI, 2020).
[9] The proportion of the added value of the three major industries to the city's GDP.

ZWC demonstration projects (2019) up until late 2020, as this was the last year for which full data could be obtained.

3.3. Data treatment

To examine the adoption of urban waste policies in each of the ZWC demonstration projects, the urban waste policy classification presented in Section 2 was used to code the data. In the data coding process, the full descriptions of each urban waste policy in each of the projects were screened. Each urban waste policy was recorded and counted based on the identified keywords and key topics: "rethink", "reduce", "reuse", "recycle", "recover", "municipal waste", "agricultural waste", "industrial waste", "hazardous waste", "legal instruments (e.g., regulatory)", "economic instruments (e.g., subsidies)", "network instruments (e.g., public and private participation, collaboration projects or public private partnerships)", "communicative instruments (e.g., exhortation and education)", "innovation instruments (e.g., R&D platforms)", or "urban waste projects". These codes were considered for application with text parts. For example, the City of Shaoxing proposed to, "*limit the use of disposable plastic bags and tableware in large supermarkets, star-rated restaurants, large catering enterprises and large vegetable markets; expand the application range of biodegradable plastic products and reduce the use of disposable plastic bags*".[5] Therefore, we classified this example (of different policies) under the principle "Reduce", addressing municipal waste via a legal instrument (i.e., "Reduce-municipal waste-legal instrument"). In this way, we summarized the data into a matrix in Excel to count the number of co-occurrences of urban waste policies across the three dimensions (See also Table A2; Appendix). The numbers in Table A2 represent the occurrences of urban waste policies in each of the ZWC demonstration projects.

This method can provide a detailed understanding of the application of zero-waste policies in the pilot cities but it is not intended to distinguish the effectiveness of each policy.

3.4. Data analysis

The urban waste policies which were adopted by local governments and which were relevant to the zero-waste demonstration projects, were mapped using the "5R" principle, the four types of waste categories, and the six policy instruments discerned. The results are presented in Section 4.1 (See Fig. 3). Here, zero-waste policy combinations refer to all three dimensions of the classification framework (i.e., waste type addressed, "R" principle used, and policy instrument implemented). Subsequently, we computed the co-occurrences between these three dimensions for urban waste policies adopted by all sixteen sample cities (see Fig. 4 in Section 4.2). Section 4.3 presents the use of waste policies by cities which host the ZWC demonstration projects across the three dimensions (See Fig. 5). We examined the specific description of each dimension for each one of the sampled policies, and by reviewing their application in each city.

4. Results

4.1. The adoption of urban waste policies by 16 ZWCs in China

Fig. 3 presents a breakdown of the different "R" principles upon which the formulation of the adopted urban waste policies occurred, the types of waste they addressed, and the various policy instruments used by the local authorities of the cities which host the sixteen ZWC demonstration projects. A total of 1,036 urban waste policies were found out of which 54 % addressed the "Recycle" principle, 22 % addressed the "Rethink" principle, and 21 % addressed the "Reduce" principle. Only 3 % addressed the "Recover" principle, and less than 1 % addressed the "Reuse" principle. Regarding the type of waste, 34 %, 21 %, 19 % and 15 % of the urban waste policies addressed industrial waste, municipal waste, agricultural, and hazardous waste, respectively. A relationship can be observed between the quantity of waste treatment policies and the amount of waste discharged. For example, in 2019, 196 large and medium-sized cities produced 1.38 billion tons of general industrial solid waste, compared to 235,602 million tons of urban household waste and 45,832 million tons of industrial hazardous waste and medical waste (MEE, 2020). The local authorities of the cities that are home to the sixteen ZWC projects adopted a total of 1090 policy instruments (considering that some policies contained more than one type of instrument, or in other words, the instrument types of this dimension of the framework are not mutually exclusive). Legal instruments (31 %) were the most widely used policy instruments to deal with waste, followed by urban waste projects (31 %), and innovation instruments (21 %). Economic policy instruments (6 %), network policy instruments (6 %), and communication instruments (5 %) were used to a lower extent.

4.2. Co-occurrences of urban waste policies

Fig. 4 presents the number of urban waste policies that co-occurred in all three of the studied dimensions of the classification framework illustrating the kind of policy instruments and "R" principles that were adopted by local authorities to deal with different types of waste.

Fig. 4 shows that "Rethink" strategies are mostly linked to legal policy instruments, that "Reduce" strategies are mostly linked to (innovative) projects, but also legal policy instruments, that "Recycling" strategy are linked to project, innovation policy, but also legal policy instruments, and that "Recover" strategies are linked to projects. However, only few observations were made in this "R" strategy. This also holds for "Reuse" for which no reliable statements can be made in relation to type of policy instruments selected and implemented.

In general, urban waste policies which were based on the "Recycle", "Rethink", and "Reduce" principles were broadly formulated to capture the treatment of all four types of waste studied. This was in contrast to policies which were based on the "Recover" and "Reuse" principles as these were rarely used. Urban waste projects were the most frequently adopted policy instrument addressing all four types of waste, followed by legal and innovation instruments whereas economic, network, and communication instruments were considerably less popular.

Most of the measures that local authorities implemented to deal with industrial waste were related to carrying out urban waste projects like industrial parks and recycling plants, followed by legal and innovation policy instruments. For example, Baotou introduced a set of desulfurization and zero emission renovation projects in its waste management, Xuzhou and Panjin used innovative recycling approaches along with regulatory measures, and Chongqing issued a number of industrial standards to regulate industrial emissions, and legislation on construction waste.

Innovative recycling technologies, projects, and regulatory measures based on the "Recycle" principle were favored by local authorities such as Xuzhou and Guangze to address agricultural waste. An example of innovative policy instruments is found in Weihai where the local administration encouraged its agricultural target group to use straw returning technology and to apply organic fertilizer instead of chemical fertilizer.

Urban waste projects, regulations, and innovation instruments based on the "Recycle" principle were primarily used to cope with municipal waste. For example, Xining and Guangze established projects for the safe treatment of kitchen waste whereas Sanya conducted research on domestic waste reduction and recycling technology and introduced a smart waste classification system. The local authorities of Shaoxing, Shenzhen, and Chongqing also used regulatory measures to reduce municipal waste emissions at source, whereas Tongling organized educational campaigns to persuade the residents of their cities to conduct proper household waste classification.

Hazardous waste was mainly targeted by legal instruments and prevention measures based on the "Rethink" principle. For instance, Xining and Panjin developed supervision systems to improve their management ability on key hazardous waste by assessing relevant enterprises and both Xuzhou and Xuchang issued a series of regulations and work plans for the standardized management and improved supervision of hazardous waste.

These observations suggest that local authorities prefer to use urban waste projects to achieve zero waste targets by either recycling or by reducing waste via comprehensive utilization projects. Furthermore, local authorities also opted for legal and innovation tools to rethink and redesign waste management and supervision systems. The combination

[5] Source: Implementation plan of Shaoxing "ZWC" construction pilot project; Notice restricting disposable consumption items. (https://sxws.sx.gov.cn/art/2020/11/26/art_1511436_43951043.html).

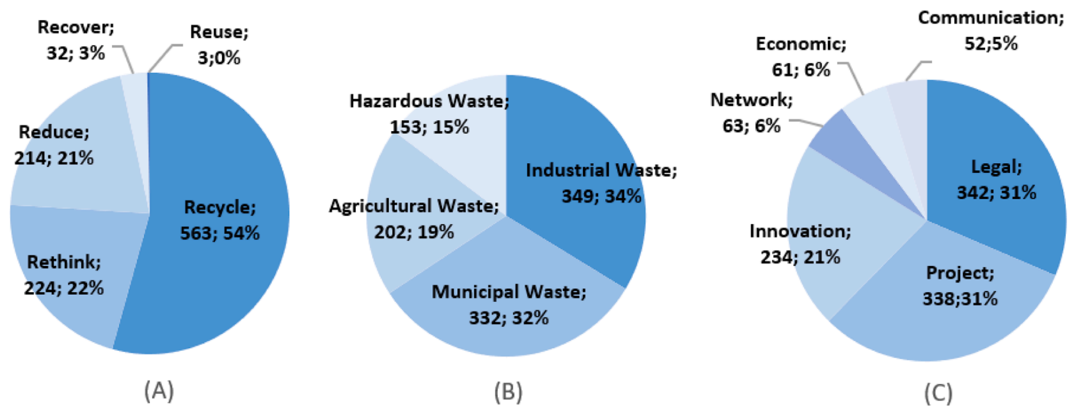

Fig. 3. Breakdown of the urban waste policies adopted by the local authorities of the sixteen zero-waste demonstration projects according to A) the "5R" principles; B) the types of waste; and C) the urban waste policy instruments.

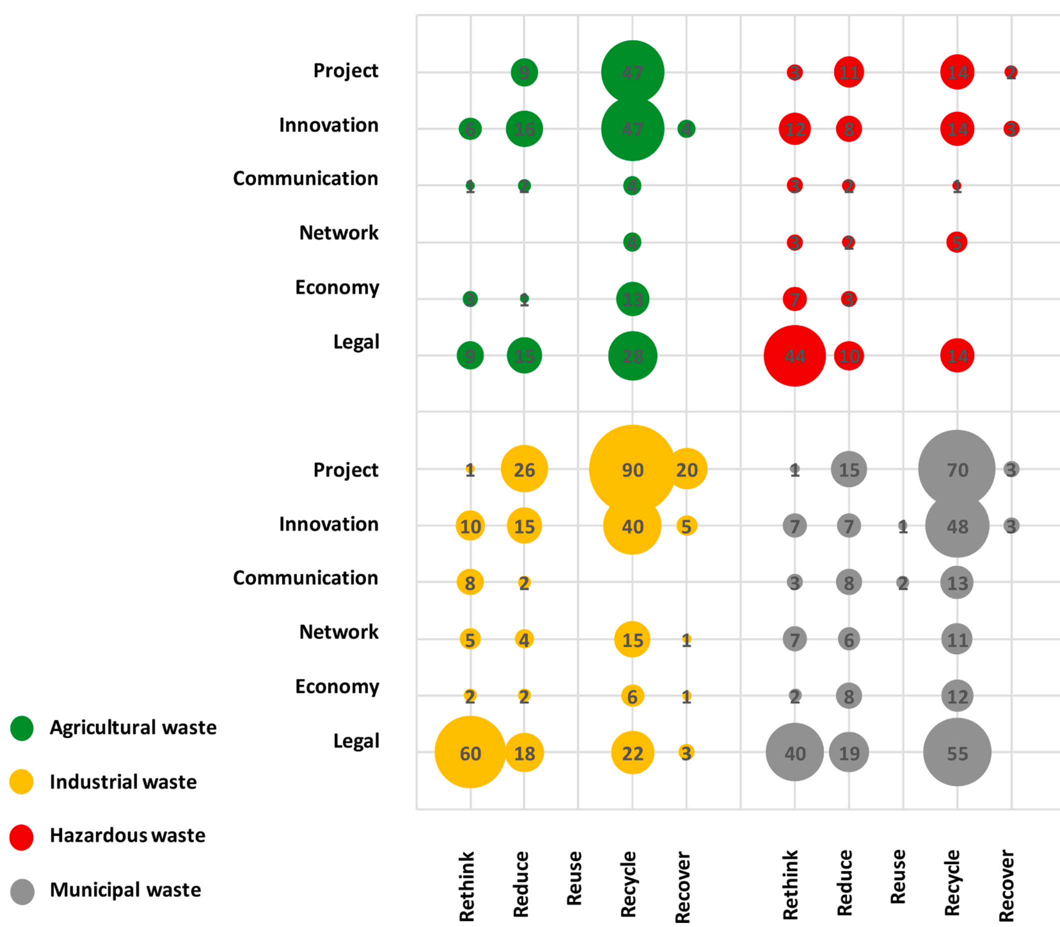

Fig. 4. Co-occurrences of urban waste policies based on the "5R" principles and the policy instruments used to address waste.

of "Reuse" and various policy instruments, as well as the combinations of communication and network policy instruments with the "5R" principles, were found to be only adopted to a limited degree by the sixteen cities hosting ZWC demonstration projects.

4.3. Number and type of implemented ZWC policy and instruments

Fig. 5 shows three dimensions in the adoption of zero-waste policies. Among those, Shaoxing and Xuzhou proposed the largest number of zero-waste policies, 153 and 148 respectively, followed by Baotou, Chongqing and Shenzhen, while Ruijin and Tianjin eco-city issued the least zero-waste policies, 21 and 20 respectively.

As shown in Fig. 5(A), almost all the demonstration projects adopted more policies that were based on the "Rethink", "Reduce", and "Recycle" principles rather than policies based on the "Reuse" and "Recover" principles. Specifically, Shenzhen, Chongqing, Shaoxing, and Xuzhou in majority adopted "Rethink" principles. Shaoxing, Baotou, and Xuchang focused more on the "Reduce" principles, whereas Shaoxing, Xuzhou, Baotou and Tongling were keen on adopting policy based on the "Recycle" principles. Only very few cities, such as Xuzhou, Baotou and Weihai, addressed waste using the "Recover" principle.

Fig. 5(B) shows the implemented policies that deal with different

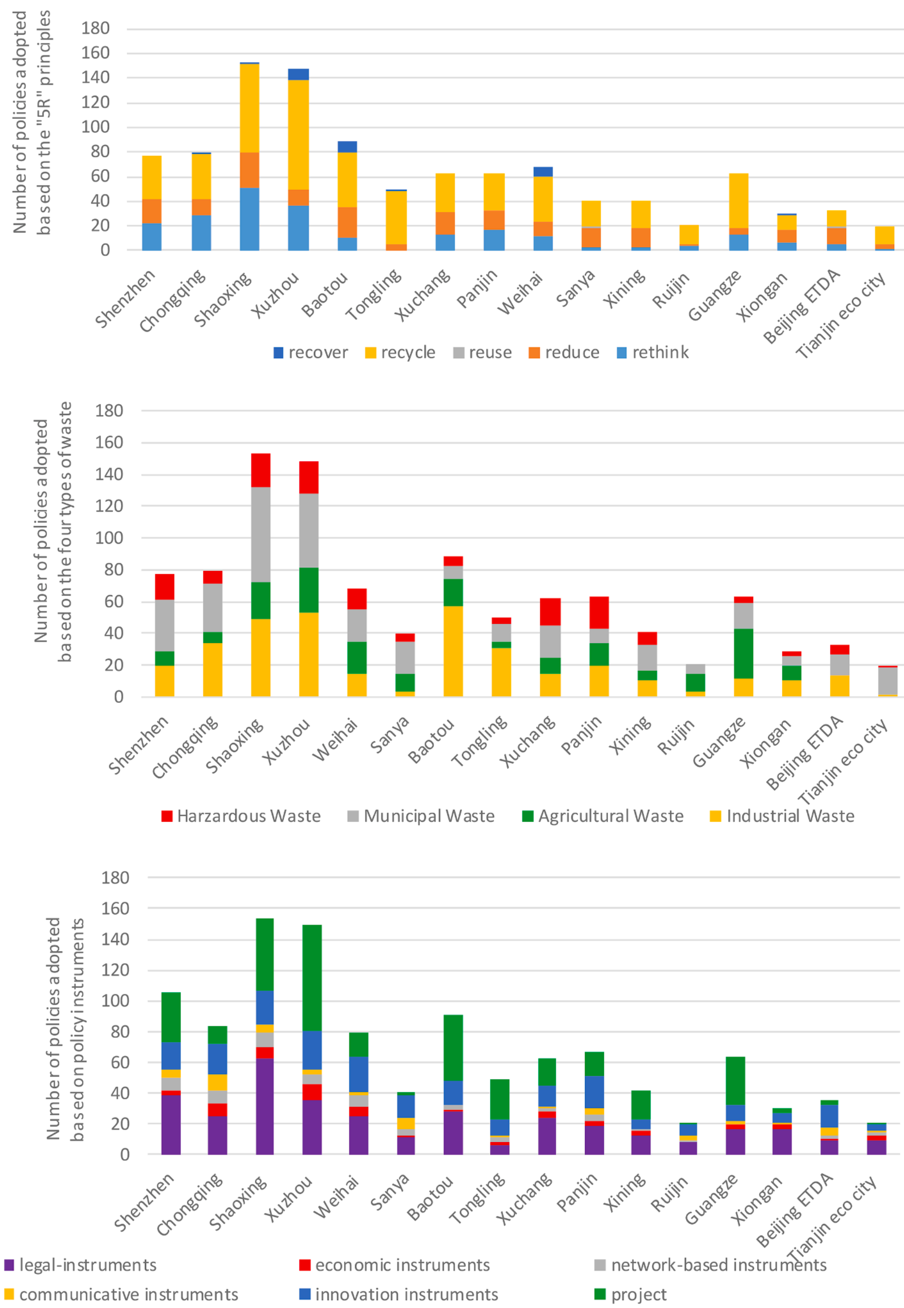

Fig. 5. Adoption of zero-waste policies by local authorities in 16 ZWC demonstration projects: (A) “5R” Principles; (B) 4 types of waste; (C) policy instruments.

types of waste. We found that industrial and municipal waste are the most common type of waste addressed in ZWC policies. Baotou, Xuzhou, Chongqing, and Shaoxing introduced more policies than other pilot cities to deal with industrial waste; this can be explained by the relatively high proportion of secondary industry in these cities. Guangze, Shaoxing, Xuzhou, and Weihai have introduced more policies to deal with agricultural waste. Shenzhen, Chongqing, Shaoxing, and Xuzhou in majority introduced policies to deal with municipal solid waste. This could be due to their relatively high urbanization rates. The cities of Shaoxing, Xuzhou, and Panjin, in particular, issued policies to deal with hazardous waste.

Fig. 5(C) presents the use of zero-waste policy instruments by the cities hosting ZWC demonstration projects. Among those, Shenzhen, Shaoxing, and Xuzhou have adopted more legal instruments than other cities. Compared to other cities Xuzhou, Shaoxing, and Chongqing have adopted most economic policy instruments, although in general, economic policy instruments were only sparsely used. Xuzhou, for example, incentivized support to garbage incineration, power generation enterprises and resource comprehensive utilization enterprises through preferential tax policies, providing subsidies for straw off-field utilization, and promoting green procurement of public institutions. Xuzhou also implemented recycling incentive policies and green loans to deal with agricultural waste and industrial waste. In general, the analysis' results show that few network and communicative policy instruments were used. Only Shenzhen, Chongqing, Shaoxing, Xuzhou, and Weihai implemented a large number of network-based policy instruments to coordinate waste management. These cities pay attention to the division of labor and cooperation among departments, and introduce third-party business units to participate in waste disposal. They also promote the construction of green homes, green enterprises, green communities, and green schools. Innovation policy was found to be implemented in many cities, more particularly in Shaoxing, Xuzhou,

Table 3
The policy options in three dimensions clustered per type of policy instrument.

No.	Policy instruments	"5R" Principles	Waste categories	Examples
1	Legal instruments	Rethink, Reduce, Recycle	Clearly present in all four waste categories; hazardous waste	• Establish inspection and supervision system for industrial waste acid and liquid • Regulations of pesticide packaging recycling
2	Economic instruments	Recycle	Sparely used in all four waste categories	• Funds for leading enterprises in the recycling and utilization of renewable resources
3	Network-based instruments	Reduce, Recycle	Industrial and municipal waste categories	• The government and private capital cooperated to build professional fecal waste treatment centers • Cooperate with local research institutes and conduct copper mine recycling studies
4	Communicative instruments	Reduce, Recycle	Municipal waste	• Garbage sorting education
5	Urban waste projects	Strong in Reduce and Recycle, somewhat present in Recover	Mostly in industrial waste	• Zero-waste tourist destination projects • Coal mine ash re-use projects • Sewage reservoir ecological restoration projects
6	Innovative instruments	Strongly present in Rethink, Reduce and Recycle	Industrial waste and agricultural waste	• Industrial solid waste network monitoring platform • Construction of software and hardware of information system of waste production

Weihai, and Panjin. Examples of innovation policy include the promotion of straw returning technology, water and fertilizer integration technology, and construction waste resource utilization technology. Shaoxing, Xuzhou, Baotou, Shenzhen, and Guangze have implemented a relatively large number of projects on zero-waste construction, including a demonstration project on the community classification of household garbage, a kitchen waste harmless disposal project, and a livestock and poultry manure resource utilization project.

5. Discussion

Previous studies have analyzed the application of individual "R" strategies and policy instruments, but there is a lack of studies that jointly analyze policy mixes in CE using the three dimensions that are central to the present study. Our approach results in a three-dimensional view of waste policies (Fig. 4). This framework could serve as a dashboard to policy makers and implementing agents to cope with complexity and quickly monitor in which areas their policy emphasis is currently located and which issues or aspects are absent in the way they address waste management. The classification framework proposed in this paper provides a novel perspective for analyzing CE and ZWC policies.

Table 3 shows the policy options in three dimensions. The results show that legal instruments are often used in all four of the waste management categories, and can mostly be classified under the "Rethink" principle, followed by the "Reduce" and "Recycle" principles. Innovative policy instruments are prominent in waste management that can be classified under the "Rethink", "Reduce" and "Recycle" principles. Economic policy instruments are more commonly found in the "Recycle" waste category. Network-based policy instruments are used in industrial and municipal waste treatment under the "Recycle" principle. Communicative policy instruments are more frequently used in relation to municipal waste treatment, which can be classified under the "Reduce" and "Recycle" principles. Urban waste projects are found to deal with waste under the "Reduce" and "Recycle" principles, particular with regard to industrial waste treatment. Except for legal instruments, policy instruments are only sparsely found in the hazardous waste category. This is no surprise because hazardous waste, because of its impact on health and environment, is also heavily regulated in other countries using policy instruments pertaining to legal norms, pollution bans, permit systems, legal prescriptions, mandatory recording and monitoring of safe handling, storage, transportation and disposal practices, and reinforcement (Misra & Pandey, 2005; Slack et al., 2004). Next to legal policy instruments, hazardous waste also shows the use of instruments that indicate that innovation policy is implemented (e.g. with innovation and waste project policy instruments).

The cities in which the sixteen Chinese zero-waste demonstration projects are situated have adopted policies that are mainly based on the "Recycle", "Reduce", and "Rethink" principles to deal with waste. Following the guidelines of China's central government, each of the cities hosting ZWC demonstration projects formulated individual plans, including the optimization of waste treatment processes and the division of workload among governmental departments (SC, 2018). This shows the widespread use of the "Rethink" principle. Local authorities use the "Reduce" principle directly to address discharge of waste at the source. To create economic benefits, they prefer to apply urban waste policies based on the "Recycle" principle which is also favored in other countries (Sakai et al., 2011). Japan, South Korea, the United States, and most European countries have set up ambitious recycling targets. For example, in 2015 the Netherlands achieved a recycling rate of 85 % to 97 % for various types of waste (Reike et al., 2018). Compared to the "Recycle", "Reduce", and "Rethink" principles, waste policies based on "Reuse" or "Recover" principles were less adopted by the Chinese cities hosting zero-waste demonstration projects. Intrinsically, the intention of the "Reuse" principle is to encourage the use of second-hand goods and to prevent over-consumption. This goes against the goal of the Chinese government to encourage and expand consumption level which is based on the logic that economic growth is closely related to the latter (Liang & Yang, 2019). In addition, Chinese consumers are typically unwilling to use second-hand goods for various reasons, including low levels of interpersonal trust and low cost of raw material, social status and cultural reasons (Xue & Yang, 2010). These reasons directly restrict the development of the market for reused products and transactions in second-hand goods. In other countries (e.g. in Europe), social platforms (e.g., Facebook) and other platforms (e.g., Dutch "Marktplaats"), are frequently used to conduct second-hand transactions (Parguel et al., 2017). For example, New York City and Singapore are actively engaging their citizens in the reuse of various products (e.g. furniture and automobile accessories) to realize a CE (Kerdlap et al., 2019; Lugo et al., 2020). In addition, the "Recover" principle appears to be less adopted by the local authorities involved with the ZWC demonstration projects. The recovery of metals, nutrients, and other materials from discarded products often requires a large amount of energy, and comes along with environmental, technological and managerial challenges (Burlakovs et al., 2018) which could explain why policy makers give low priority to the 'Recover' principle.

In terms of project type and policy instrument, Chinese cities use mainly urban waste projects along with legal and innovation-oriented policy instruments to implement zero-waste management given that regulation and governance can play an important role in improving environmental management (Pinto et al., 2017). Legal instruments are embraced by local authorities to address waste, save governmental funds, and to lower transaction costs between different departments communicating with each other (Mu et al., 2019). The frequent use of legal instruments in zero-waste management is consistent with previous studies on China's top-down management characteristics in environmental governance (Ma et al., 2021; Tong et al., 2021; Wang et al., 2013). Meanwhile, innovative technologies are often used in tandem with urban waste projects to deal with industrial waste (Winans et al., 2017). Furthermore, Chinese local authorities apply technological and innovation-oriented instruments based on the "Rethink" and "Reduce" principles to lower waste generation at the source, and regenerate the environment. This is similar to other countries, such as like Singapore's digital applications for waste management (Kerdlap et al., 2019). In addition, local authorities also implement urban waste projects based on the "Recycle" principle to utilize waste repeatedly to obtain economic benefits. This is confirmed by the widespread construction of eco- and circular economy industrial parks in China in recent years (McDowall et al., 2017). Apart from providing general industrial and recycling facilities (factories and offices), industrial parks can facilitate the cooperation and networking among recycling companies, and they also promote the formation of local industrial clusters (Dong et al., 2022). Application of urban waste projects match the usual strategy of simultaneously maximizing economic output while minimizing the environmental impact well. This is why policies based on the "Recycle" principle and projects are preferred by local authorities over those based on the "Recover" principle.

From an innovation policy perspective, the results of the present study show that typical innovation policies (encouraging innovation and niche development) are mostly found with the "Recycling" strategy, and to a lesser extent with "Recover" or "Reduce". The former strategy often goes along with (innovation) projects and innovation policy instruments, which is in line with Hemmelskamp et al. (2013). The latter, on the other hand, is more often combined with legal instruments, which reveals a strategy that is more targeted at decreasing unsustainable practices and impact of incumbent regimes. Innovation policies are also likely to be strongly linked with China's "Operation National Sword", a radical decision of no longer accepting low-quality materials from other countries which took place during 2018 and shaped drastically the global recycling system (Heiges & O'Neill, 2022). In "Rethink" and "Recycling", legal instruments prevail implying that these "R" principles are fairly mature, and need less experimentation.

Academic literature suggests that economic instruments seem to be more efficient than hierarchical instruments (Baeumler et al., 2012), but according to the present study's results, they do not seem to be widely used. This is probably due to the widespread promotion of urban waste projects. Network-based policy instruments, seem underutilized in urban waste management when compared to other policy instruments used by the local governments of the sixteen ZWCs. For example, a challenging task which relates to network-based instruments is garbage classification since there might be competing interests between parties during the policy implementation process (Tong et al., 2021). This finding is in line with the work of Lo et al. (2018) and Lo (2016) who found that network-based and organizational policy instruments are not used sufficiently in China's environmental governance. That can be explained by the fact that Chinese local governments lack both the incentives and the capabilities to engage in network governance (Mu et al., 2019). Consequently, forms of collaborative governance practiced in China deviate from international standards and complicate network governance. In contrast, the participation of private companies, communities, and voluntary organizations have become important elements in the environmental governance of European countries and cities (e.g., Sweden and Berlin) (Nochta & Skelcher, 2020). Singapore also uses a collaborative platform for industrial symbiosis to support its zero-waste management (Kerdlap et al., 2019). The present study shows that economic policy instruments are only implemented to a low degree among the sixteen ZWC demonstration projects. In contrast, the CE Action Plan of the European Union (COM(2020) 98 final) encourages the use of economic instruments in the implementation of CE (European Commission, 2020). Even though communication instruments have the advantage of low administrative costs and fast information diffusion (Carley, 2011), they appear less used in the studied sixteen ZWC demonstration projects in China. The local governments involved with the sixteen ZWC demonstration projects encourage local citizenry to classify garbage but only a few channels seem to exist to disclose and disseminate waste information to the general public.

6. Conclusions

This paper started with the following research question, *how can circular policies be classified, and how can this classification be applied to cities in China that wish become zero-waste cities?* It embraced a focus on local policy implementation in the domain of CE, and more particularly ZWC. It did so by focusing on the selection of policy goals and instruments by policy makers, and through introducing a classification framework, which was developed for urban waste policies using three dimensions: (a) the "5R" principles of the waste hierarchy framework, (b) six types of policy instruments, and (c) four types of waste. The framework was used to study what circular policies are used in sixteen Chinese cities home to zero-waste demonstration projects that represent different urban contexts. The main argument made in the present study is to analyze the implementation of ZWC policies emphasizing the combination of the three dimensions whilst using a new classification framework. This framework and the demonstration of it in empirical research contribute both theoretically and methodologically to the CE policy and waste management literature, as well as to the environmental policy studies and sustainable transitions bodies of literature.

Results from the analysis show that the principles "Rethink", "Reduce", and "Recycle" are widely adopted at the local level. A plausible explanation is that policies which are solely based on environmental considerations are perceived by local governments as unattractive since they consider the presence of substantial economic benefits an indispensable requirement. Furthermore, we found that all of the cities studied, use policies mainly to treat industrial and municipal waste. The most commonly adopted policy instruments for treating industrial, municipal, and agricultural waste are urban waste projects and legal policy instruments based on the principles "Recycle" and "Reduce". With regard to these principles, innovation policies were also implemented fairly often. Economic, communication, and network-based policy instruments were found to be used considerably less. Economic instruments were mostly used in the 11th and 12th FYPs (2006–2015) since the Chinese government paid a lot of attention to economic development over environmental protection, which favored the use of economic policy instruments over regulatory and communicative ones (the latter assuming voluntary compliance by target groups). Moreover, communicative policy instruments were more commonly used as complementary to other policy instrument types in environmental policy mixes. However, after the 13th FYP, the central government adopted a more top-down governance approach implementing more stringent regulations whilst focusing on state-led projects and innovation programs, with a decreased use of economic and communicative policy instruments. Network policy instruments were less often used because of the limited capacity Chinese city administrations have, preventing them from actively engaging in actor networks, indicating that cities have a low degree of agency in "managing" these networks.

Limitations to the present study pertain to occasional absence of secondary data, and lack of detailed information regarding stakeholder involvement. Although we examined the presence and the number of waste-related policies in use as categorized according to the classification framework, we acknowledged that the research methods used can neither assess nor compare the individual impact of each policy; they cannot establish relative weights either. Given that Chinese cities are managed in a unique political and institutional setting, it is suggested that future research is conducted in other countries with varying levels of urban development and that more thorough cross-national and cross-city comparative research is conducted. It is also suggested that the classification framework should be further elaborated and validated in future research. Finally, it is suggested that longitudinal studies are conducted to explore the accumulation and evolution of CE policies, and to identify their causal drivers.

It is the very combination of the three elements in our classification framework that allows it to serve the purpose of a policy dashboard. The classification framework can assist analysts and policy makers in scoping, mapping, and developing circular and waste policies - and in particular, policy mixes - which can be used to achieve towards ZWC goals. The framework provides an overview for coping with complexity. In other words, the framework illuminates which segments in the gamut of possible policies are covered well and which ones are absent or only minimally addressed.

Developing and innovating on the waste policy mix will facilitate more accurate waste disposal and enhance the transition towards a CE. In this way, policy makers will be able to select the appropriate "R" principles and match relevant policy instruments according to waste characteristics. Besides, academic researchers and policy analysts can gain a better and more detailed overview per sector / waste category of which type of policy instruments are used and what a policy mix consists of (as a combination of instruments). When conducting ex-post program evaluation, researchers are able to understand and relate certain policy outcomes, and the way implementation (or for that matter policy instrument selection) processes took place over time, to the presence of certain policy instruments (i.e. policy output, and combination of instruments). This framework may contribute to understand why a policy worked well or poorly, why it was feasible (or not), and was considered legitimate by policy target groups, etc.

Local governments are advised to actively bridge second-hand trading platforms and physical stores to foster a social culture of commodity reuse. The results of the present study suggest that some policy instruments require further exploration by policy makers, such as network-based and communicative instruments. For example, local governments may consider how to satisfy the interests of all parties and mobilize actors to carry out garbage classification. Additionally, they could implement resource-saving and reusable education campaigns across different age groups. Since our theoretical framework clearly explains the characteristics of "5R" principles, types of waste, and policy instruments, policy makers could improve the process of waste policy formulation, selection and implementation based on the co-occurrence findings in our study. Realizing real circularity or zero waste may still be a distant dream, but the first steps have been taken and many more will follow.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wasman.2023.04.012.

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