Environmental Development 18 (2016) 2–13

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

Wasted cities in urbanizing China

Guizhen He [a,b,1], Arthur P.J. Mol [c,1], Yonglong Lu [a,*]

[a] State Key Laboratory of Urban and Regional Ecology, Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China
[b] The Earth Institute, Columbia University, New York, NY 10027, USA
[c] Environmental Policy Group, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands

A R T I C L E I N F O

Article history:
Received 10 July 2015
Received in revised form
21 December 2015
Accepted 30 December 2015

Keywords:
Urbanization
Urban planning
Environmental impacts
Wasted cities
China

A B S T R A C T

Urbanization is a characteristic of the 21st century, especially in countries with developing economies and a large amount of rural-to-urban migration. In China, the emergence of "wasted cities and towns" has paralleled urban expansion; large newly built areas that remain unpopulated and have created significant economic and social costs. We conducted a systematic investigation into the prevalence and geographical distribution of these "wasted cities and towns" through an analysis of spatially-detailed data from 1992 to 2014, and by estimating the environmental impacts of these "wasted" cities using available data in mainland China. Between 2008 and 2012, at least 28 ghost cities/towns were documented within 16 provinces, with severe effects on land use and the ecosystem, creating a waste of resources and energy. These cities contributed to poor air quality and climate change, and created unneeded construction and demolition waste. To prevent a further increase in wasted cities, and to turn existing ones into sustainable cities, China has to dramatically change its urbanization and housing policies in tandem with strengthening environmental policies, while taking long-term prevention and short-term execution strategies. Knowing how to manage the phenomenon of "wasted cities" in China is not just an environmental question, but also has strong effects on urbanization and sustainability. Developing reasonable management plans may establish an example for developing countries, and emerging economies in particular. The sustainability of urbanization might be affected if the problems identified here are not resolved. China's experiences with the environmental challenges of urbanization may provide valuable lessons for other emerging economies if the measures recommended here are implemented successfully.

1. Introduction

Half of the Chinese population currently lives in cities. The economic importance of China's urban real estate property market cannot be underestimated because it accounts for roughly 15% of the nation's gross domestic product and directly affects other sectors such as banking and construction. Because more than 75% of the Chinese population is expected to reside in cities within the next twenty years, the establishment of new cities and extension of existing ones is expected to

* Corresponding author.
E-mail address: yllu@rcees.ac.cn (Y. Lu).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.envdev.2015.12.003
2211-4645/

Table 1
Main indicators of urbanization in China's National New-type Urbanization Plan for 2014–2020 (Issued by the Central Committee of the Communist Party of China and the State Council, March 16, 2014).

Indicator	Sub-indicator	Real status in 2012	Planning objectives in 2020
Urbanization level	Urbanization rate of permanent urban residents (the proportion of permanent urban residents to China's total population)	52.6%	About 60%
	Urbanization rate of registered urban population (the proportion of registered urban population to China's total population; registered urban population are those who hold a “hukou” under China’s household registration system)	35.3%	About 45%
Basic public services	Rate of migrant rural workers' children achieving compulsory education		≥ 99%
	Rate of urban unemployed, migrant workers, and new comers to the work-force that received basic free vocational skills training		≥ 95%
	Rate of permanent urban residents that participate in basic endowment insurance	66.9%	≥ 90%
	Rate of permanent urban residents that participated in basic medical insurance	95%	98%
	Rate of permanent urban residents that live in indemnificatory apartment	12.5%	≥ 23%
Infrastructures	Share of public transport in cities with more than one million population	45% (in 2011)	60%
	Percentage of households coverage by water supply in cities and towns	81.7%	90%
	Percentage of urban domestic sewage treated	87.3%	95%
	Percentage of urban domestic garbage treated	84.8%	95%
	Broadband internet access of urban households	4 Mbps	≥ 50 Mbps
	Percentage of households having access to public service facilities in urban communities	72.5%	100%
Resources and environment	Urban developed land per capita (m^2)		≤ 100 m^2
	Percentage of urban renewable energy consumption	8.7%	13%
	Share of urban green buildings in all new buildings	2%	50%
	Ratio of urban green space to total urban space	35.7%	38.9%
	The percentage of cities (at and above prefectural level) where urban air quality attains the national standards	40.9%	60%

continue. National and local policies have always ‘guided’ urbanization (Table S1), but only recently a national urbanization policy has been formulated aiming to create less one-sided and more balanced urbanization. China’s official urbanization plan (The State Council, 2014), unveiled in March 2014, details ambitious goals for 2020 in steering the country's urbanization into a human-centered, urban-rural coordinated, and ecologically sound path (Table 1). However, an emerging phenomenon has arisen from this ceaseless urbanization, the sprouting of so-called “ghost cities/towns (or wasted cities)” across the country (Yu, 2014). The 2014 plan should also cope with an increasing number of ghost cities that have come into being along with rapid urbanization.

No generally accepted national inventory exists for the current and potential future wasted cities in China. The China Investment Times (*Tou Zi Shi Bao* in Chinese), a newspaper, has issued a 2014 Ghost City Index, listing 50 cities with a strong probability of becoming ghost cities (Su, 2014), while others have also listed existing ones (e.g. Table S2). In most countries (Thomsen, 2012) ghost cities are either *old* residential areas that had been constructed more than 30 years ago and were abandoned because the quality of life had deteriorated (Detroit, MI, USA being an important example), or rural villages – especially in poor, remote, and undeveloped regions – that have been depopulated following emigration to urban centers (Liu et al., 2011). Ghost cities in China are unique because they form a third type, which we label as wasted cities. Wasted cities are largely un- or under-populated and under-used *new* urban districts and towns that have generally never been inhabited after they were constructed. Only very rarely in other countries do a large number of new buildings (or complete neighborhoods/city districts) remain empty to the extent currently witnessed in China. In 2013, around 22.4% (49 million) of the newly constructed residential buildings in urban areas remained empty (China Household Finance Survey, 2014). Vacant apartments, buildings and neighborhoods come with poor or no public infrastructure, lack public services and therefore generate major economic, social, and environmental effects. The economic and social impacts include huge economic losses, property devaluation, governmental financial risks, deterioration in the investment environment, shrinking employment and labor markets, social injustice and protests, poor public health, and psychological effects (Batty, 2008; Chen and Wen, 2014; Lin and Chen, 2011; Yusuf and Saich, 2007).

Empty newly-built office buildings can be seen in many countries, especially after the financial crisis of 2007/2008. However, in very few countries one can identify large volumes of recently-built empty real estate. The rise of “wasted cities” in China has attracted global attention and incidental examples started to be reported in the Western media five years ago, with a fear that a collapse of the Chinese housing market may intensify the then-current world economic crisis and significantly prolong the world-wide recession, given China’s increasing role as an engine of global economic growth. While China’s leadership has placed Ecological Civilization on the top of its political agenda and aims to construct a “Beautiful China,” the emerging ghost cities contrast this as they come with severe environmental costs as “wasted cities.” In an unusual critical editorial, the official People’s Daily railed against the wasteful trend for building new cities, stating, “Empty towns and wasted cities are redundant developments that do not generate much economic benefit…. They are a huge waste of resources which create debt pressure onto local governments" (People's Daily, 2013).

While anecdotal evidence of Chinese wasted cities has been documented, a systematic investigation into the magnitude and environmental profile of wasted cities is lacking, as is a full understanding of the causes behind this phenomenon. This study aims to reveal the prevalence and geographical distribution of China's wasted cities, quantify the environmental losses and costs, identify the drivers and causes behind this phenomenon, and formulate short- and long-term mitigation and prevention strategies.

2. Materials and methods

Data related to wasted cities were derived from scientific literature, governmental (statistical) data and plans, and governmental working reports. Governmental data and information were collected from the following sources: (1) national and provincial statistical databases from 1992 to 2012, including from the China Statistical Yearbook, China City Statistical Yearbook, China Urban Construction Statistical Yearbook, China Environmental Status Bulletin, and the China Land and Resources Bulletin; (2) national and provincial (environmental) plans such as the latest National New-type Urbanization Plan 2014–2020, The National Land Use Planning Outline (2006–2020), the 12th Five-Year Plan on Land and Resources (2011–2015), the Medium- and Long-term Urban Plans at the prefectural level, the New District Construction Plans at prefectural level, Land Use Plans at the provincial and prefectural level; and (3) annual governmental working reports at the prefectural level. The spatial dataset generated for this study constitutes the most detailed available planned land area, investment, population, and vacancy rate estimates. The spatial distribution of wasted cities was mapped with the Arcmap module in ArcGIS V10.0 software (ESRI, Redland, CA, USA).

The total area of wasted cities in China covers 3643 km^2 (Table S2). The reported vacancy rate of wasted city buildings ranges from 23–90%. To calculate environmental effects we used average figures. We defined the average vacancy rate of wasted city buildings at 50%. During 2009–2013, an average of 21% of China's total construction land was used for residential buildings (Ministry of Land and Resources, 2014). The floor area ratio (FAR) was also considered because most buildings have multi-stories. The floor area ratio equals the total floor area of all the buildings in a certain plot (Gross Floor Area) divided by the area of the plot. The FARs vary with different types of residential buildings. According to the national Standard Calculation Specification on Floor Area of Construction Projects (GB/T 50353-2013), the FAR was as follows: independent villas, 0.2–0.5; Townhouses, 0.4–0.7; multi-story buildings with maximum of six floors, 0.8–1.2; multi-story buildings up to eleven floors, 1.5–2.0; multi-story buildings up to eighteen floors, 1.8–2.5; and multi-story buildings with more than nineteen

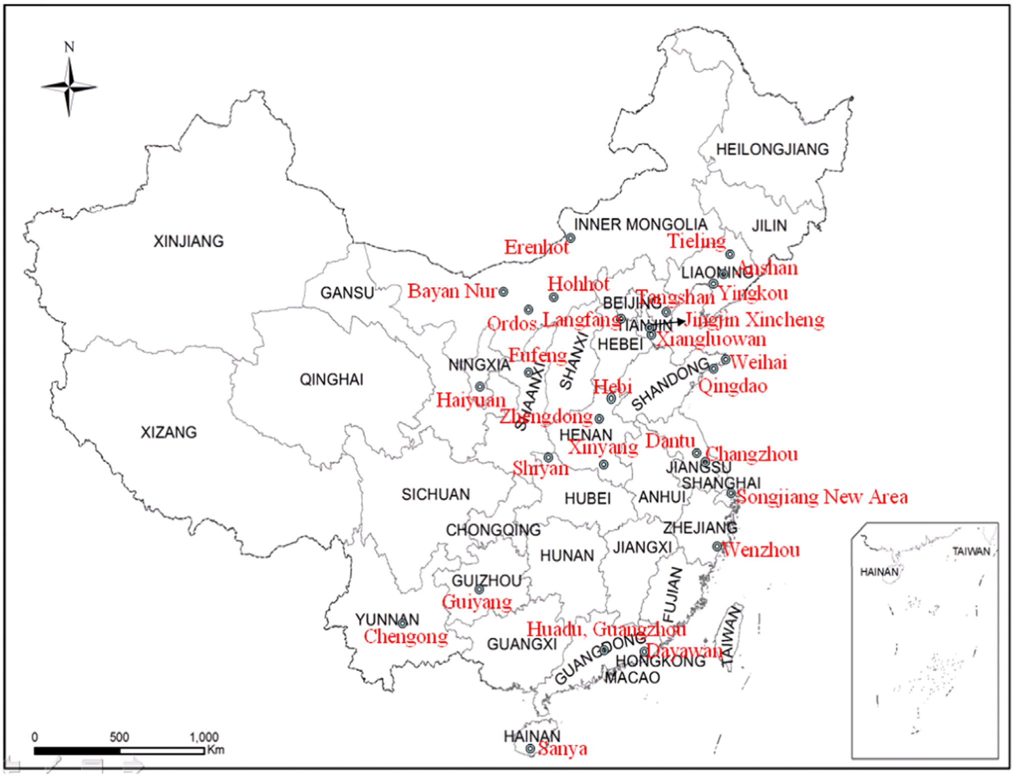

Fig. 1. Locations of wasted cities and towns in China during May 2014 (Sources: compiled by authors).

floors, 2.4–4.5. We selected an average FAR of 2. The gross floor area of vacant residential buildings in each city = total area of the wasted city × average residential land rate × FAR × average vacancy rate. The total vacant buildings in all wasted cities = $3643 \times 21\% \times 2 \times 0.50 = 765.09\ km^2$. We used this figure to estimate the environmental damage in all reported cities at the given time period for the construction of these buildings. The basis of the calculations was the scientifically reported environmental impacts per square meter floor area (see Section 4), using different environmental indicators including land use, resource consumption (e.g. energy, steel, cement, and water), air emissions, and waste generation. These cities were planned and constructed in different years, while an average construction period of a wasted city was five years.

Currently, no detailed first hand data are available for all the wasted cities in each province. In terms of data availability and quality in China, we have to use the government recognized/reported data and results at one location for an average figure for all the wasted cities in China. The metrics used here therefore have to be taken in this context, having been based on the limited data available. The deterioration of ecological systems was described qualitatively because of the complex environmental impacts and the limited existing data. Moreover, recycling of construction and demolition wastes is also affected by transportation distance and by degree of contamination from previous uses, which was not considered in our estimates.

Drivers and solutions were produced following a review and analysis of the current legal and institutional arrangements along with discussions with experts in China.

3. The size and geography of wasted cities

Following the institutional reform began in 1979, China has changed its urban housing policies from houses as welfare goods provided by the government to houses as commercial goods provided through the market. After 1998, urban housing development was further liberalized, all aimed at increasing the provisioning of and demand for urban houses (Cao and Keivani, 2014). In 2001, China announced plans to build 20 cities/towns of 1 million inhabitants every year, over a period of twenty years. These recently-built neighborhoods were expected to be busy palces swarming with people. But on closer inspection most sprawling cities with new public buildings, residential apartments, green parks, and parking garages are desolated and unpopulated in many urban areas; for example, consider the wasted cities in Jingjin Xincheng and Baodi District, Tianjin Municipality. No accepted national inventory of current and potential future ghost cities exists in China. Between 2008 and 2012, at least 28 wasted cities/towns had been documented, within 16 provincial juridical areas. Most of these wasted neighborhoods and towns occur in eastern China, both in large (e.g. Tianjin) and in small cities, especially in county level cities (Fig. 1 and Table S2). These wasted cities were planned to cover variously sized landscapes over different time periods, but were especially developed at the beginning of the 21st century and following the 2007/2008 global financial crisis (Fig. 2).

The major economic and social effects of wasted cities have been widely reported (Yu, 2014; Yusuf and Saich, 2007). Vacant apartments, buildings and neighborhoods create major problems for local governments and property owners, because property revenue is declining while investments have already been made and the interest on loans has to be paid. The infrastructure is deteriorating because there is often no money for public sewers, road maintenance and other public services. Although rarely reported in the scientific literature and Chinese media, these wasted cities have far-reaching environmental consequences (Yu, 2014).

4. Environmental impacts of wasted cities

Wasted cities generate a wide range of environmental impacts (Table 2). We analyzed and estimated these impacts for

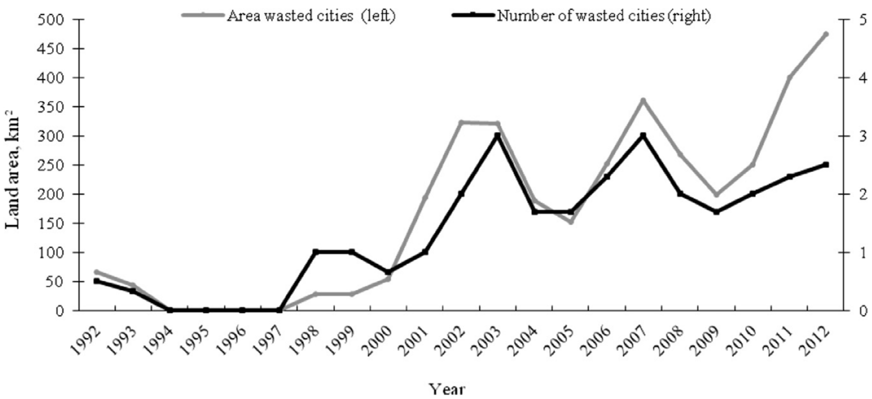

Fig. 2. Number and planned area of reported wasted cities in China, 1992–2012 (three year averages).

Table 2
Environmental consequences of developing housing and infrastructure in the wasted cities in China.

Source of environmental impacts	Physical environmental impacts (direct and indirect)
Built area extension	Urban sprawl Loss of farmland and green space Reduction of open space Damage of ecological system and biodiversity
Infrastructure design and construction	New infrastructure construction (water, sewage, solid waste, energy) New transport facilities and road networks Deterioration of ecological system
Building construction	Noise Air pollution Construction waste generation (Inefficient) energy use during construction
Building material	Natural resource depletion Energy use in manufacturing Industrial waste and pollution Energy in transport and distribution of materials
Housing and estate maintenance	Energy used for lighting, heating, air-conditioning Materials and energy used for building cleaning and maintenance Water supply Suboptimal waste water treatment

our set of wasted cities under four main headings: (1) inefficient land use and deterioration of ecological systems, (2) resource depletion (e.g. energy, steel, cement, and water), (3) air pollution (including climate change), and (4) waste generation (Table 3). The results show that the planned area of the 28 analyzed wasted cities was more than 3643 km². Wasted city development also causes direct and indirect, immediate and long-term ecological impacts (Cumming et al., 2014; Zhao et al., 2006). In China, the construction industry is one of the largest consumers of resources such as steel, timber, cement, clay, fresh water and energy (Zhao and Zhang, 2005; United Nations Environment Program (UNEP), 2006; Chang et al., 2010; Chui and Yang, 2006). The vacant buildings in the 28 wasted cities consumed over 1.5 billion tons of eight construction materials (aluminum, steel, wood, cement, brick, gravel, sand, and lime). The estimated total embodied energy of the vacant buildings is as much as 7.3E9 GJ. The buildings in the wasted cities also contributes to the discharge of air pollutants such as SO_2, NO_x, particulate matter (PM; the statistical data employed here did not separate in PM_{10} and $PM_{2.5}$ in the past; however, $PM_{2.5}$ has been monitored only over recent years; here PM indicates the total particulates) and greenhouse gases emissions.

Table 3
Main environmental impacts of 28 documented wasted cities in China.

Category	Quantitative estimation
Land use	• 3643 km^2 rural area lost for building wasted cities till 2015 • About 6% of farmland allowed for construction occupied by wasted cities in 2020
Resource and energy consumption	• Aluminum: 3.22 million tons • Steel: 52.91 million tons • Wood: 17.33 million tons • Cement: 174.86 million tons • Brick: 129.77 million tons • Gravel: 676.95 million tons • Sand: 468.97 million tons • Lime: 25.10 million tons • Water: 15.9 billion m^3 for wasted cities • Energy: total embodied energy 7.3E9 GJ for vacant buildings in wasted cities
Air emission	• 409.89 kg CO_2 equivalent per square meter floor area, total emissions 313.56 million tons CO_2-e • 0.20 kg CH_4 per square meter floor area, total emissions 1.51 million tons • 1.02 kg SO_2 per square meter floor area, total emissions 7.82 million tons • 13.93 kg CO per square meter floor area, total emissions 106.59 million tons • 0.78 kg NO_x per square meter floor area, total emissions 5.98 million tons • 0.30 kg NMVOC per square meter floor area, total emissions 2.32 million tons • 22.55 kg PM per square meter floor area, total emissions 157.20 million tons
Waste generation	• Waste generation 40–60 kg per square meter floor area of residential building construction • Total construction waste generation 38.25 million tons

4.1. Inefficient land use and impacts on ecosystems

The rapid conversion of land from low-density agriculture and light manufacturing to new high density urban zones and material-intensive commercial and residential buildings has irreversibly altered the Chinese landscape (Foley et al., 2005). Environmental concerns exist related to the effects of urban sprawl and scattered urban housing developments that have led to a large amount of farmland and sometimes nature reserves being converted into urban landscapes (Tan et al., 2005). The National Land Use Planning Outline (2006–2020) and the 12th Five-Year Plan on Land and Resources (2011–2015) ensure China maintains a minimum area of arable land at 1.8 billion mu (about 1.2 million km^2) in 2015, and cap has been placed on new construction land at 87.8 million mu (58.5 thousand km^2) in 2020. Based on the documented data sources related to wasted cities, we calculated the planned area of known/reported wasted cities to be over 3643 km^2 in 28 cities, with a planned population of more than 12.3 million in 21 cities; however, we could not find data related to the planned population in the other seven cities (Table S2). This means that over 6% of farmland allowed for construction until 2020 is already occupied by wasted cities and neighborhoods. This is also a substantial and unnecessary reduction of farmland and open space in and around cities.

Wasted city development, together with land use change and the accompanying road and infrastructure development, may fragment and disturb rural and native habitats, degrade semi-natural and natural habitats as well as wetlands, decrease biodiversity, and cause habitat heterogeneity (Cumming et al., 2014; Zhao et al., 2006; Seto et al., 2012). These types of disturbance affect important ecosystem processes and services. The land use and environmental effects of a building can reach far beyond its immediate site, leading to a decline in biodiversity and biotic homogenization (Wong, 2012; Zhao et al., 2006). Even where new buildings do not displace agricultural or natural ecosystems, excessive demand for the products/services of those types of ecosystems nearby can lead to overexploitation and landscape degradation. The conversion of farmland and forests into wasted cities reduces the amount of land available for food, timber and non-timber forest production.

4.2. High resource and energy consumption

Rapid urban construction has to include the development of infrastructure, such as water supply facilities, roads and bridges, wastewater and sewage pipes, energy transmission, waste (water) treatment facilities, electrical transmission lines, and communication networks. Also with low occupancy rates, buildings and apartments have to be maintained for future sale. Over time, operational maintenance increases steadily, causing inefficiencies and waste in the allocation and use of material and energy resources.

The construction industry is one of the largest consumers of natural resources (e.g. cement, steel, sand) and energy (Liu and Hu, 2006). According to the Worldwatch Institute, the construction of buildings accounts for 40% of the annual stone, sand and gravel use, 25% of timber, and 16% of water consumption worldwide (Arena and de Rosa, 2003). Chinese urban buildings consist of a range of architectural structures made of various types of construction materials. In China, the construction industry consumes about 50% of the steel (300 million tons per year), 40% of the timber, and 70% of the cement used nationally (Zhao and Zhang, 2005). Clay brick has been an important wall material in China's mass building stock, resulting in the loss of 800 km^2 of arable land. Insufficient local production and increased living standards generate a huge demand for the import of high quality building materials and components, such as cold rolled thin steel plates and pipes, bathroom fittings and facilities, escalators and elevators (Ganesan and Lau, 2000). In this study, we obtained the consumption intensity of building materials in urban areas by calculating the average value of each province, using material intensities for various types of buildings in each province in China (Table 4). The results showed that the vacant buildings of the 28 wasted cities consumed large amounts of materials, especially gravel, sand, and cement (Table 5). Many high quality materials and a large amount of equipment previously used in luxury office buildings or hotels are now employed in residential housing projects. Hence, wasted cities cause a significant increase of transportation, international trade, and inter-province resources exhaustion (Fernández, 2007; Ganesan and Lau, 2000).

The construction industry consumes an average of 30% of all fresh water consumption worldwide according to the United Nations Environment Program (United Nations Environment Program (UNEP), 2006). The overall water consumption required for constructing a building includes not only on-site water use for construction and operations, but also off-site water use to supply the necessary manpower, material and equipment required by the building. Direct water consumption is about

Table 4
Material use for residential buildings in urban China (Unit: kg/m^2).

Building structure	Aluminum[32]	Steel	Wood	Cement	Brick	Gravel	Sand	Lime
Brick-concrete[29]	2.2	23	24	172	705	657	778	32
Reinforced-concrete[29]	4.7	75	26	238	43	881	570	33
Shearing-force[24]	4.7	97	13	285	14	1205	579	33
Steel frame[30, 31]	4.7	100	6	172	14	881	570	33

Table 5
Material consumption used in vacant residential buildings in 28 wasted cities, China (million tons).

Building structure	Percent	Building area (km^2)	Aluminum	Steel	Wood	Cement	Brick	Gravel	Sand	Lime
Brick-concrete	20	153.02	0.34	3.52	3.67	26.32	107.88	100.53	119.05	4.90
Reinforced-concrete	60	459.05	2.16	34.43	11.94	109.25	19.74	404.43	261.66	15.15
Shearing-force	15	114.76	0.54	11.13	1.49	32.71	1.61	138.29	66.45	3.79
Steel frame	5	38.25	0.18	3.83	0.23	6.58	0.54	33.7	21.81	1.26
Total	100	765.09	3.22	52.91	17.33	174.86	129.77	676.95	468.97	25.10

12% of the total water demand during the construction of a building (Green Building Council of Australia (GBCA), 2008). The virtual water use of wasted buildings in China's waste cities is almost 15.9 billion m^3, equal to the virtual water consumption of 22.7 million people for one year based on a mean per capita water footprint of 700 m^3/yr (Meng et al., 2014; Hoekstra and Chapagain, 2007).

Buildings are an important component of China's total energy consumption mix. Energy consumption in building construction comes mainly from five sources: (1) manufacturing building materials; (2) transportation of building materials; (3) transportation of construction equipment; (4) energy consumption of construction equipment and processing resources; and (5) disposal of construction waste (Yan et al., 2010). By 2020, China's building sector is estimated to account for 30% of total final energy consumption (China Urban Research Committee, 2008; Liang et al., 2007). The increased use of imported materials also further contributed to building and operational energy consumption in recent years. Accurately assessing the total energy consumed in wasted buildings has proved to be difficult because of deficiencies in statistical and survey data in China. Embodied energy, which is the amount of energy used to manufacture, transport and install a material or component, has increased significantly in recent years. According to Chang et al. (2010), the embodied energy of Chinese construction projects accounted for nearly 16% of the total energy consumption in 2007, and may account for approximately 20–25% of the total energy use by 2015. In the reported wasted cities, the estimated total embodied energy of the vacant buildings is as much as 7.3E9 GJ (Chen et al., 2001), which equals to about 250 million tons of standard coal equivalents in mainland China.

4.3. Air emissions

Urban building construction creates an important source for air pollutant and greenhouse gases emissions (Yan et al., 2010). The major air pollutant emissions during the construction process (material manufacturing, transportation, construction, and operation and maintenance stages) are carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC) and particulate matter (PM) (Chang et al., 2010; Zhang et al., 2013). Emissions of SO_2, NOx, PM and CO_2 of the construction sector as part of the total national emissions are estimated to account for 11%, 10%, 10%, and 23% in 2007 and 32%, 33%, 25% and 37% in 2015, respectively (Chang et al., 2010). CH_4 and CO are released during the operation and maintenance stages of the buildings, and in the process of manufacturing building materials. PM emissions spread at different life stages of buildings: 35% during operation and maintenance, 43% during the transportation of building materials, 14% during construction waste disposal, and 8% at demolition (Zhang et al., 2013). Zhang et al. (2013) reported that total air emissions of a Peking project during the manufacturing and transportation of building materials, and the construction stages were 409.89 kg CO_2-e/m^2, 0.20 kg CH_4/m^2, 1.02 kg SO_2/m^2, 13.93 kg CO/m^2, 0.78 kg NOx/m^2, 0.30 kg NMVOC/m^2, and 22.55 kg PM/m^2. Based on the latest research, the estimated emissions of CO_2, CH_4, SO_2, CO, NOx, NMVOC, PM from the vacant buildings of wasted towns are 313.56, 1.51, 7.82, 106.58, 5.98, 2.32, and 157.20 million tons, respectively. Total air emissions were up to about 595 million tons.

4.4. Waste generation

Construction activities produce waste during the transportation and storage of building materials, construction of new buildings, and demolition of old buildings, while the majority of building wastes are released during demolition. In China, reinforced concrete structure is most popular in high-rise buildings. The major types of construction materials, such as concrete, timber formwork, and steel bars, dominate construction wastes. Urban construction waste has reached 30–40% of the total urban waste generation because of large-scale construction and demolition following accelerated urbanization and city rebuilding (Chui and Yang, 2006). This percentage is much higher than, for instance, in the European Union (EU) countries (25–30%). In some EU countries such as Denmark, Germany, Ireland, and The Netherlands, 80–90% of the construction and demolition waste is recycled (Fisher and Werge, 2009). However, in China only 5% of the 1.5 billion tons construction and demolition waste was recycled in 2012, according to statistical data of the Ministry of Industry and Information Technology of China.

Timber for formwork, concrete, and miscellaneous waste are the three largest components amongst the waste generated from on-going construction projects (Lu et al., 2011), and 50–60 kg/m^2 has been widely cited as representing the rate of

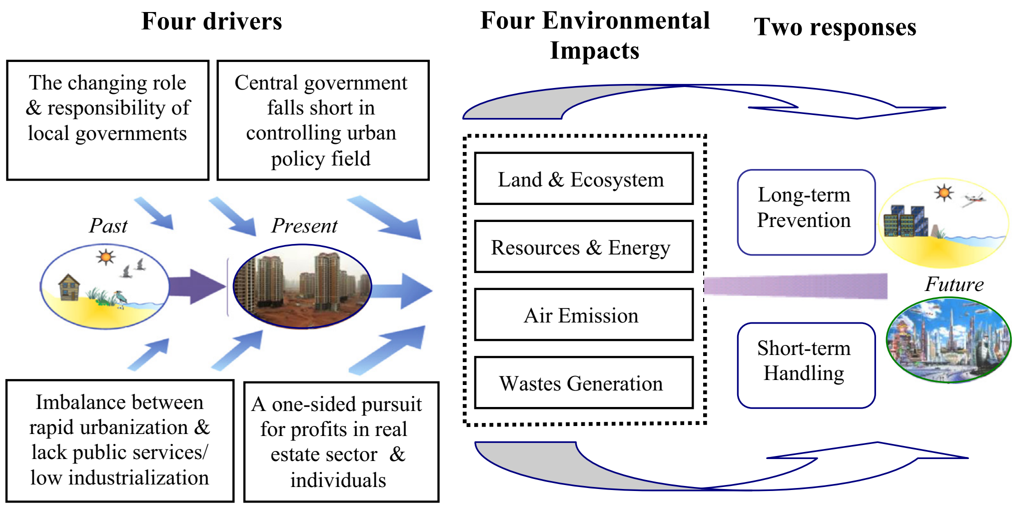

Fig. 3. Drivers and environmental impacts of wasted cities and policy interventions in China.

construction waste generation (Lu, 1999). Based on the mass balance principle, the generation of waste per gross floor area is 40.7 kg/m^2 for a newly constructed residential building in Shenzhen city (Li et al., 2013). This result is in line with 43.7 kg/m^2 in America (Cochran et al., 2007) and 47.8 kg/m^2 in Korea (Seo and Hwang, 2001), but higher than 30.7 kg/m^2 in Norway (Bergsdal et al., 2007). We selected the average rate of 50 kg/m^2 waste generation in residential building, and estimated the total construction waste generation of the vacant buildings in wasted towns as 38.25 million tons.

5. Drivers of wasted cities

With deregulation and liberalization of urban housing policies by the reforms of 1998 and 2003, the central government has reduced complexity and increased flexibility in urban housing development, resulting in an oversupply of urban houses versus a shortfall in demand. Indeed, the urban housing completion-to-sale ratio fell below 1.0 after 2004 (Cao and Keivani, 2014), especially in small cities and towns. An oversupply of large residential housing units does not emerge easily under market conditions. This is because housing demand remains high in major Chinese cities and housing prices did not experience an overall decline until 2013. Four main reasons can explain the unique emergence of wasted towns, especially oversupply in eastern China (Fig. 3).

First, the changing role and responsibility of local governments caused an artificial urbanization boom. In China's hierarchical administrative system, the central government and local governments (provincial, municipal, county/urban district, and township/street/community) play vital roles in developing and implementing urbanization policies and strategies. Reforms since the late 1980s have changed the role of local government in economic and fiscal management, and in the provisioning of public goods and services (including environmental protection). These reforms also changed the strength and structure of local administrative units (Wong, 2012). Local governments have acquired administrative powers and responsibilities over urban planning and land use, public works and services, investment approval, resource allocation, and the provisioning of social benefits. This all led to a decentralization of public spending responsibilities to local governments (about 80% in 2009, of which occurs 18% at the provincial level, 22% at the municipal level, and 40% at the county level) and centralization of revenues (more than 50%) to the central government (World Bank, 2002; OECD, 2006). The large fiscal gap at the local level between rising expenditures and stagnating revenue has led to a constant search by local governments for stable sources of revenue. Examples are the expansion of locally-owned township and village enterprises (TVEs) in the 1980 s/1990 s, and a wide range of sanctioned and unsanctioned fees and levies (Yusuf and Saich, 2007). This latter practice has come under increasing scrutiny from the central government and has induced local governments to search for alternative revenues. Land transfer – the sale of land use rights under local government jurisdiction, often by converting agricultural land to commercial or residential land – has proven to be an important source of new revenue for local governments (Wong, 2013). Local governments have a monopoly in allocating land to different users, controlling the land supply and overall planning of urban land. Most cities have established a Municipal Development and Investment Company to deal with the funding and operation of infrastructure projects. With accelerated urbanization and thus rapidly increasing land values, this has become an important source of extra-budgetary revenue for local governments. Local governments have increased land supply for residential and industrial projects, to an all-time high of 2910 km^2 in 2010. Local governments also have an interest in preparing land for special economic development zones, high-tech development zones, or residential housings at a significant distance from city centers, because it will increase land revenues through auctioning. While there have been some changes related to the rules regarding the sale of land use rights to reduce aggressive bidding and speculation and to include social and environmental conditions, generally the conversion of farmland to urban land has resulted in excessive quantities of scattered, low density, urban land, well beyond the level justified by demand. Studies consistently show that the current land use right transfer fees account for some 30–50% of total sub-provincial government revenues and in some developed regions even comprise 50–60% of total city revenue (Yusuf and Saich, 2007; World Bank, 2002). Revenue constraints also lead to local development plans that maximize short-term revenue over longer-term strategic planning and investment needs.

Second, the central government falls short in controlling this liberalized and decentralized urban policy field. Both China's spectacular achievements and its significant challenges in urban development are closely connected to the previously mentioned decentralized governance structure (Wong, 2013). Under the central government there are about 44,000 sub-national governments divided into four levels, and nearly two-thirds of these are local urban governments. National policies for urbanization, rural-to-urban land conversion, housing, industrial promotion, and environmental protection are all relevant to the issue of preventing wasted towns. However, inter-agency and inter-governmental conflicts of interest reduce effective policy coordination and implementation. China has, in theory, a relatively rigorously planned society, but the country faces two major problems. A) horizontal (between socio-economic, spatial and rural-urban planning and policies) and vertical (local-central) coordination in planning processes and policy making is not easy, because various governmental actors and agencies have distinct priorities and interests (Kostka and Mol, 2014; Lieberthal, 2003). B) during the process of implementation, the existing planning system lacks sufficient checks and balances to ensure that nationally approved plans are not arbitrarily modified, ignored, or incorrectly-reported upon by local governments. The large number of local land use changes, local self-interests, poor-reporting and information distortion often mean that central monitoring and supervision of policy/plan implementation is inadequate.

This is especially true as it relates to environmental protection (Carter and Mol, 2007). The central governments try to hold lower levels accountable, mostly through their control over the personnel appointment system and government contracts and evaluation systems, such as the various forms of Post Responsibility Systems and more recently Objective-oriented Responsibility Systems and Performance contracts (Burns and Zhou, 2010; Wang et al., 2010). These systems weaken flexibility and incentives of county, district, and township governments to promote place-specific comprehensive development. Officials from land administration agencies have noted that urbanization policies lead to wasteful, inefficient and often incompatible land use (Hu, 2012), and local governments have ignored or actively fought against central policies that were at conflict with local interests. Although nationwide priority targets are established, knowing how to translate them into contracts between the central and local government is still a question because the priorities are mainly oriented toward short-term development and with insufficient weight on long-term environmental quality and sustainable development (Kostka and Mol, 2014; Mol and Carter, 2006). Moreover, performance contracts focus on both quantitative targets and speed of task completion, with less attention paid to the quality of the finished product. The reward system thus encourages shoddy building and infrastructure, which has been part of China's urban building boom and the wasted towns.

Third, imbalance between rapidly growing "artificial" urbanization and lack public services/slow industrialization causes the creation of unattractive residential areas. The newly developed areas can provide limited job opportunities because the industrial and service facilities are inadequate. Some people are also unlikely to be willing to relocate producing a low housing demand. The lesson to be learned from wasted cities such as those of the Inner-Mongolian Ordos and Hebi, Henan Province for local governments is that a well-developed city needs to first have a well-developed industrial or service structure (Liu et al., 2012; Yu, 2014). A strategy for the local authorities of simply attracting a population by simply building houses does not work (World Bank, 2014). Many local governments are now trying to promote "real" secondary and tertiary industries in new development zones, rather than solely depending on a real estate-driven economy. However, many special industrial zones are designated as new investment areas/districts according to the logic/will of the governmental officials, rather than based on market laws and rules (Wong, 2013; World Bank, 2014). The resulting shortage of established secondary industries impedes the emergence of a developed service sector. Moreover, compared with the older cities and districts, many new cities/districts/towns hold far less attraction for the urban middle class who can afford houses because of a lack of necessary hospitals, schools, cultural institutions and enterprises.

Fourth, a one-sided pursuit for profits in the private real estate sector has contributed to this imbalance and thus wasted cities. The real estate market has become a vital opportunity for investment and speculation for households, state-owned enterprises, private firms, as well as commercial banks, because of the phenomenal rate of returns in this market (at least until 2010) and the shortage of asset supplies in the financial market. Housing investors in China consist of people from all walks of life, regardless of income level and profession, and enterprises of all types, regardless of size and ownership. The housing boom has rapidly transformed the landscape of China, facilitating urbanization and development processes and lifting the standard of living for hundreds of millions of people, but has also resulted in increasing speculation in the housing market and generated thousands of millionaires each year (World Bank, 2014; Wu et al., 2012). Rich, nationally operating development corporations, many of them still state-owned with easy credit access from state-owned banks, have aggressively bidded on local land for real estate projects. Property developers have strategically operated in this market by fake purchases, releasing misleading information on stocks, demand and prices, and illegal payments. The urban property sector has been allowed to focus on profits rather than on satisfying housing demand of a rapidly urbanizing society (Wong, 2013; World Bank, 2014; Wu et al., 2012). The consequence is overinvestment in housing projects where the housing demand is failing/absent, large numbers of bankruptcies in property development and investment companies, poorly planned new urban towns/neighborhood, and thus wasted cities.

In a word, the government's failure and market failure have both contributed to oversupply and un-occupied buildings in the reported cities.

6. Policies to rationalize urbanization with fewer adverse environmental impacts

China's official urbanization plan (2014) has set ambitious goals. However, the policy measures in this plan do not sufficiently address the issue of wasted cities. Given the diversity of causes, addressing the major environmental and sustainability problems of wasted cities requires an integrated policy response rather than simply addressing environmental measures. We suggest two areas for fundamental national and local policy improvement.

6.1. Preventing wasted estates

To prevent the construction of more wasted cities and towns entails three elements.

First, rethinking the central government's role in urbanization and public services provision is needed. As in the past, the trump card for China will be a diversity of (local) strategies and experiences for individual cities and regions. However, within this decentralized framework, the central government should refine its role in urbanization to provide policy direction and incentivize sustainable practices. A comprehensive set of policies is urgently needed to reduce the current heavy reliance on land use right sales to meet local fiscal expenditures, such as budgeting expenditures in compliance with local fiscal revenue, and managing land use right transfers and use in a more transparent and sustainable way. The central government needs to step in to realign incentives for local governments so that long-term public interests – rather than short term particular interests – prevail in local decision-making processes. In view of increased burden and weak financial capacity to deal with urban infrastructure and public services, local finances should be strengthened at the district level in urban areas to allow improved, long-term investment decisions to be made and redistributive mechanisms to be developed. Improving the current system of checks and balances is essential during urbanization (between sectoral interests, and between local and national interests) to ensure that sensible decisions are made on a broadly informed, transparent basis, and to ensure consequent implementation and enforcement of sustainable urbanization measures. Heavy local government reliance on land use right sales has to be limited to meet local fiscal expenditures. Incentives for local governments should be readjusted so that they can pursue long-term decision-making in the public interests. New mechanisms for land reallocation should be implemented such as the red line system for arable land and ecological preservation, develop public-private partnerships for green investment in land development and environmental conservation (KPMG International, 2012). Private sector capital should be catalyzed towards sustainable urban infrastructure and environmental improvement and protection (Wong, 2013). Only then, as in other countries, Chinese cities can develop sustainable municipal finances and become less financially dependent on land transactions and concessions.

Second, incentives as well as the development of a legitimate and accountable structure of local governments should be developed and the leaders of urbanization and environmental conservation should be changed. The 2014 Fourth Plenary Session of the 18th Central Committee of the Communist Party of China (CPC) highlighted "advancing the rule of law," "a lifelong liability accounting system for major [governmental] decisions…. to hold people accountable for poor decisions," and "promoting transparency of government." These elements for holding local governments accountable are essential in preventing the creation of wasted cities. The GDP-dominated performance evaluation system for local leaders should be replaced by a comprehensive set of sustainable development performance indicators. In addition, the municipal governments should not only be monitored and held accountable by higher level authorities, but also by citizens through local institutions (e.g. hearings, consultation, participatory plan development, elections) that represent the long-term interests of city residents and which are enabled by the new 2014 Environmental Protection Law (He et al., 2013; Zhang et al., 2015). Municipal decision-making and performance evaluation should become more transparent for citizens and society. Allowing, stimulating and facilitating public participation, media scrutiny, consultation, and "citizen-science" monitoring (Bonney et al., 2014; Lu et al., 2015) will increase local counter veiling powers that combat resource misuse and a dominance of private over public interests in land development. After more than a decade of rapid growth in off-budget financing for urban development, cities need to develop sustainable municipal finances, and become less dependent on land transactions and concessions. Only then can excessive investments in unnecessary urban buildings and facilities be prevented.

Third, the private sector needs to reorganize, and should be made responsible and accountable for wasteful investment projects. Real estate developers, private investors, housing speculators, and banks are major stakeholders in wasted cities/towns by their aim for quick and high return rates on housing investments. Setting environmental resource prices reasonably might help with the creation of sustainable building projects, but not much has been done to prevent wasted city development and construction. These private sector participants should be held commercially and personally responsible and accountable for wasteful housing investment projects. The recently developed green credit and green securities policies are useful tools that can be used to hold the private sector accountable for sustainable housing development, because this system relies heavily on bank credits and public equity (Li and Hu, 2014). The new Environmental Protection Law can hold private sector managers personally accountable because of the stiffer economic penalties for environmental violations. Most importantly, existing and new policies need to be strictly implemented through the rule of law.

6.2. Short term reform with long term vision – coping with existing wasted cities

Prevention does not offer a solution to the problem of existing wasted cities. The social, economic, and environmental situations of unoccupied buildings in different cities vary greatly, and they need to be treated differently. Different strategies are needed for existing wasted cities.

First, a full national investigation into the causes and problems related to wasted cities needs to be conducted. Responsible governmental agencies should coordinate to make a country-wide inventory and assessment of the scope and distribution of existing vacant estates (including incomplete buildings and unused but prepared or designated land for urbanization). This equips governments with data and information on the size, spatial distribution and distinct forms and specifics related to wasted cities. This type of an inventory should also include land use, vacancy rate, land ownership tax delinquency, demographics, housing market prices and conditions, and housing demand in the region. The data collection process should also include a forum for or hearing of community organizations, residents, homeowners, and other stakeholders to include their information and perspectives.

Second, a "land bank" and a "vacant house bank" could be established. Local governments that deal with vacant houses or land areas could use this land bank (in Chinese *tu di chu bei*) as a legal and financial mechanism to transform vacant, abandoned and tax-foreclosed property back to productive use. Priority should be given to properties that are the most feasible for re-use and that will have the largest economic impact. While a land bank provides short-term fiscal benefits, it can also act as a tool for planning long-term community development. A vacant-house bank needs to be established to provide information on vacant houses, combined with a package of measures to facilitate the re-use of existing buildings without a need for planning permissions, including the so-called "meanwhile" use of vacant commercial buildings (SQW Consulting, 2010). Under the vacant-house bank concept, houses are considered regional resources and officials can ask owners to either sell or rent at a lower price. The properties should be required to be entered into accessible databases via home pages of local governments. An important element in managing such banks is securing registered vacant houses. Moreover, authorities could adopt various administrative, tax, and voluntary measures to stimulate the use/reuse of vacant houses, such as by simplifying reuse applications, applying a Vacant Assets Tax, using Infrastructure and Support Services Construction Funds, and allowing the use of the buildings by cultural and charitable organizations.

Third, for some estates/towns land use rights need to be withdrawn and the function of vacant buildings could be changed so they can be used effectively. For vacant buildings with the smallest possibility for re-use, authorities should determine a standard procedure and compensation fund to allow them to be demolished and determine a new land use. This happened on a much smaller scale in Ireland in the 1990's and the Irish ghost areas have recently been demolished. This enables the withdrawal of urban land use rights and the development of a new land use plan, better adapted to the geography, demography, citizen demands and ecological functions.

Dealing with the wasted cities has been difficult when only one strategy or method is employed. A systematic solution to the problem depends on coordinated efforts of the national and local governments together with other major stakeholders, especially construction enterprises. Moreover, some of the information necessary to evaluate proposed solutions is not easily accessible in public documents or consistent across sources. A portfolio of governmental regulations and economic instruments are essential for China to prevent the creation of wasted cities while promoting sustainable urbanization. It may also establish an example for other developing countries that are experiencing a transition to a more urbanized society.

Acknowledgments

Funding: The Key Project of the Chinese Academy of Sciences (Grant no.KZZD-EW-TZ-12), the National Fundamental Field Investigation Program (Grant no. 2013FY111100), the National Natural Science Foundation of China (71103175).

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envdev.2015.12.003.

References

Arena, A.P., de Rosa, C., 2003. Life cycle assessment of energy and environmental implications of the implementation of conservation technologies in school buildings in Mendoza–Argentina. Build. Environ. 38, 359–368.
Batty, M., 2008. The size, scale, and shape of Cities. Science 319, 769–771.
Bergsdal, H., Bohne, R.A., Brattebo, H., 2007. Projection of construction and demolition waste in Norway. J. Ind. Ecol. 11, 27–39.
Bonney, R., Shirk, J.L., Phillips, T.B., et al., 2014. Next steps for citizen science. Science 343, 1436–1437.
Burns, J.P., Zhou, Z., 2010. Performance management in the government of the People's Republic of China: Accountability and control in the implementation of public policy. OECD J. Budg. 10, 1–28.
Cao, J.A., Keivani, R., 2014. The limits and potentials of the housing market enabling paradigm: an evaluation of China's housing policies from 1998–2011. Hous. Stud.

29, 44–68.
Carter, N.T., Mol, A.P.J., 2007. Environmental Governance in China. Routledge, London, UK.
Chang, Y., Ries, R., Wang, Y., 2010. The embodied energy and environmental emissions of construction projects in China: An economic input–output LCA model. Energy Policy 38, 6597–6603.
Chen, K.J., Wen, Y., 2014. The Great Chinese Housing Boom. Federal Reserve Bank of St. Louis. 〈https://research.stlouisfed.org/wp/2014/2014-022.pdf〉 (retrieved 25.06.15).
Chen, T.Y., Burnett, J., Chau, C.K., 2001. Analysis of embodied energy use in the residential building of Hong Kong. Energy 26, 323–340.
China Household Finance Survey, 2014. The Vacancy Rate of Urban Housing and Trend in the Housing Market 2014. Southwestern University of Finance and Economics, Chengdu (in Chinese).
China Urban Research Committee, 2008. Green Building. Chinese Construction Industrial Publish House, Beijing, China.
Chui, D., Yang, Z., 2006. C&D waste recycled for development of Circular Economy. Ind. Technol. Econ. 10, 35.
Cochran, K., Townsend, T., Reinhart, D., Heck, H., 2007. Estimation of regional building-related C&D debris generation and composition: case study for Florida, US. Waste Manag. 27, 921–931.
Cumming, G., Buerkert, A., Hoffmann, E.M., Schlecht, E., von Cramon-Taubadel, T.S. Tscharntke, 2014. Implications of agricultural transitions and urbanization for ecosystem services. Nature 515, 50–57.
Fisher, C., Werge, M., 2009. EU as a Recycling Society. Present recycling levels of Municipal Waste and Construction & Demolition Waste in the EU. European Environmental Agency, Copenhagen.
Foley, J.A., DeFries, R., Asner, G.P., et al., 2005. Global consequences of land use. Science 309, 570–574.
Fernández, J.E., 2007. Resource consumption of new urban construction in China. J. Ind. Ecol. 11 (2), 99–115.
Ganesan, S., Lau, S.S.Y., 2000. Urban challenges in Hong Kong: future direction for design. Urban Des. Int. 5, 3–12.
Green Building Council of Australia (GBCA), 2008. The Dollars and Sense of Green Buildings 2008: Building the Business Case for Green Buildings in Australia. GBCA, Melbourne, Australia.
He, G., Zhang, L., Mol, A.P.J., Lu, Y., Liu, J., 2013. Revising China's environmental law. Science 341, 133.
Hoekstra, A.Y., Chapagain, A.K., 2007. Virtual waters of nations: water use by people as a function of their consumption pattern. Water Resour. Manag. 21, 35–48.
Hu, C.Z., 2012. Problems in land administration in urbanization. Adm. Reform 11, 25–31.
Kostka, G., Mol, A.P.J., 2014. China's Local Environmental Politics. Routledge, London, UK.
KPMG International, 2012. Cities Infrastructure: A Report on Sustainability. New York.
Li, J.R., Ding, Z.K., Mi, X.M., Wang, J.Y., 2013. A model for estimating construction waste generation index for building project in China. Resour. Conserv. Recycl. 74, 20–26.
Li, W., Hu, M., 2014. An overview of the environmental finance policies in China: retrofitting an integrated mechanism for environmental management. Front. Environ. Sci. Eng. 8, 316–328.
Liang, J., Li, B.Z., Wu, Y., Yao, R.M., 2007. An investigation of the existing situation and trends in building energy efficiency management in China. Energy Build. 39, 1098–1106.
Lieberthal, K., 2003. Governing China: From Revolution to Reform, 2nd ed. W. W. Norton & Company, New York/London.
Lin, Y., Chen, B., 2011. Understanding urbanization and urban-rural inequality in China: a new perspective from government's development strategy. Front. Econ. China 6, 1–21.
Liu, T., Hu, D., 2006. Environmental impact of residential building construction in Beijing. J. Grad. Sch. Chin. Acad. Sci. 23, 231–241.
Liu, Y., Yin, G., Ma, L.J.C., 2012. Local state and administrative urbanization in post-reform China: a case study of Hebi City, Henan Province. Cities 29, 107–117.
Liu, Y.S., Long, H.L., Chen, Y.F., Wang, J.Y., 2011. Research Report on Rural Development in China: Hollowed Village and its Renovation Strategy. Science Press, Beijing.
Lu, K.A., 1999. Status quo and comprehensive utilization of refuse produced from construction and removal of building in China. Constr. Technol. 28, 44–45.
Lu, W.S., Yuan, H.P., Li, J.R., et al., 2011. An empirical investigation of construction and demolition waste generation rates in Shenzhen city, South China. Waste Manag. 31, 680–687.
Lu, Y., Nakicenovic, N., Visbeck, M., Stevance, A.S., 2015. Five priorities for the UN sustainable development goals. Nature 520, 432–433.
Meng, J., Chen, G.Q., Shao, L., et al., 2014. Virtual water accounting for building: case study for E-town, Beijing. J. Clean. Prod. 68, 7–15.
Ministry of Land and Resources, 2014. China Land and Resources Bulletin 2013. Beijing, China.
Mol, A.P.J., Carter, N., 2006. China's environmental governance in transition. Environ. Polit. 15, 149–170.
OECD, 2006. Challenges for China's Public Spending: Toward Greater Effectiveness and Equity. OECD, Paris, France.
People's Daily, 2013. "City-building Movement" Virtual Fire Disease Should be Treated. The fifth edition, August 28, 2013, Beijing. (in Chinese).
Seo, S., Hwang, Y., 2001. Estimation of CO_2 emissions in life cycle of residential buildings. J. Constr. Eng. Manag. 127, 414–418.
Seto, K.C., Güneralp, B., Hutyra, L.R., 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proc. Natl. Acad. Sci. USA 109, 16083–16088.
SQW Consulting, 2010. Meanwhile Use: Business Case and Learning Points. SQW, Cambridge, UK.
Su, X., 2014. The Chinese mainland cities ghost town index ranking 2014. Investment Times, Wuhan (in Chinese).
Tan, M.H., Li, X.B., Xie, H., Lu, C.H., 2005. Urban land expansion and arable land loss in China-A case study of Beijing, Tianjin, Hebei region. Land Use Policy 22, 187–196.
The State Council, China, 2014. The National New-type Urbanization Plan 2014–2020. The State Council, Beijing. (in Chinese).
Thomsen, C., 2012. Ghost Towns: Lost Cities of the Old West. Shire Publications, Westminster.
United Nations Environment Program (UNEP), 2006. Eco-house Guidelines. UNEP, Nairobi.
Wang, L., Jang, C., Zhang, Y., Wang, K., et al., 2010. Assessment of air quality benefits from national air pollution control policies in China. Part II: evaluation of air quality predictions and air quality benefits assessment. Atmos. Environ. 44 (28), 3449–3457.
Wong, C.P., 2012. Performance, Monitoring, and Evaluation in China. World Bank, Washington, D.C.
Wong, C.P., 2013. Paying for urbanization in China: challenges of municipal finance in the twenty-first century. In: Bahl, R., Linn, J., Wetzel, D. (Eds.), Financing Metropolitan Governments in Developing Countries, Lincoln Institute of Land Policy, Cambridge.
World Bank, 2002. China: National Development and Sub-National Finance-A Review of Provincial Expenditures. World Bank, Washington, D.C., USA.
World Bank, 2014. Development Research Center of the State Council, China. Urban China – Toward Efficient, Inclusive, and Sustainable Urbanization. World Bank, Washington, DC.
Wu, J., Gyourko, J., Deng, Y.H., 2012. Evaluating conditions in major Chinese housing markets. Reg. Sci. Urban Econ. 42, 531–543.
Yan, H., Shen, Q.P., Fan, L.C.H., Wang, Y.W., Zhang, L., 2010. Greenhouse gas emissions in building construction: A case study of One Peking in Hong Kong. Build. Environ. 45, 949–955.
Yu, H., 2014. China's "ghost cities". East Asian Policy 6, 33–43.
Yusuf, S., Saich, T., 2007. China Urbanizes: Consequences, Strategies, and Policies. World Bank, Washington, DC.
Zhang, L., He, G., Mol, A.P.J., 2015. China's new environmental protection law: a game changer? Environ. Dev. 13, 1–3.
Zhang, X.L., Shen, L.Y., Zhang, L., 2013. Life cycle assessment of the air emissions during building construction process: a case study in Hong Kong. Renew. Sustain. Energy Rev. 17, 160–169.
Zhao, S.Q., Da, L.J., Tang, Z.Y., Fang, H.J., Song, K., Fang, J.Y., 2006. Ecological consequences of rapid urban expansion, Shanghai, China. Front. Ecol. Environ. 4, 341–346.
Zhao, X., Zhang, R., 2005. Saving building materials for the interest of future generations. Hous. Ind. 8, 4.