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Low Carbon City Development in China in the Context of New Type of Urbanization

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Abstract

Urbanization is an important part of economic development in China which directly related to industrial development. Industrial development is based on energy production, consumption, and trade. A new type of urbanization with low carbon city development is an urgent matter in the researcher community for developing an appropriate strategy, policy, technology, and action. The aim of this study is to explore the status and assess the strategy and policy of low carbon city development in the context of urbanization. It also finds out the effects of new type of urbanization on low carbon city development by finding out constraints and providing recommendations. An extensive literature review with meta-analysis has been done considering various indicators of low carbon city development. This study reveals that most of the large cities are already under the pilot projects of low carbon city development. It also finds out some major indicators of low carbon city like economic growth, energy using pattern, social and lifestyle factor, carbon and environment, urban mobilization, solid waste management, and water management in the context of urbanization. Rapid urbanization requires more building construction and energy which emits more GHG. It suggests that an assessment index system should be introduced by the government to control, monitor and motivate people to use low carbon technology. It further suggests that rules and regulations, awareness building, locality-based technology and practices, and participation of all stakeholders in policy making should be maintained by the government for sustainable low carbon city development in China.

Keywords

Low Carbon City, Urbanization, Sustainable Development, GHG Emission

1. Introduction

Urbanization is an important part of social and economic development in China. The process of urbanization in China is faster than other countries. The urban people of China will be 500 million by 2050 [1]. There are so many challenges in China due to the fastest urbanization which characterized by suffering world's pre- and post-urbanization like air pollution, water pollution, expansion of urban sprawl, traffic congestion and high carbon emission. People-centered and the eco-friendly urban environment is necessary to lead a comfortable urban life in China. Rapid urbanization requires high energy consumption for high production in the industry as well as people's daily life [2]. By 2030, the carbon emission will be 8 tonnes per capita in China due to carbon using pattern in the industry and urban life [3]. China's per capita energy consumption is more than global average but China can reduce its energy consumption by adopting low carbon technology and strategic pattern of energy consumption which helps to reduce 20% GHG emission by 2030 [4].

The term and concept of "low carbon city" were introduced in 2008 in China by a non-government organization, World Wildlife Fund (WWF) [5] [6]. The carbon emission bears 88% aluminum, 80% energy, 86% iron, 75% cement and 92% copper [4]. Some strategic plannings like the restructuring of industry, transport efficiency, lifestyle change, more efficiency in building and electricity, industrial endues and developing energy sector should be adopted by the Chinese authority to reduce carbon emission [7]. Chinese people prefer urban area for their living and it is one of the causes of social transformation which challenges low carbon practices in China. According to City Metabolize statistics, urban population consumes and emits Green House Gas (GHG) about 46% of the total population which deserves special attention for research and practice for low carbon city development [1]. Rapid urbanization and industrialization in China require promoting low city development and tackling rapid rural-urban migration, limited resources, and large population. It also causes some negative effects of air pollution, water pollution, increasing noise, traffic congestion, solid and liquid waste. GHG emission rate in city areas in China is larger than rural areas due to more fossil fuel use and its growing demand. Though China initiated low carbon city development project in 79 cities it faces challenges due to the traditional pattern of carbon practices, institutional rigidness and less finance [8]. The negative effects of urbanization may cause a serious problem for human settlement [6]. The article tries to fill the gap in the literature by exploring the answer to the questions like i) what is the extent of low carbon city development in China? ii) what strategies and policies are necessary for low carbon

city development in the context of urbanization? iii) what are the barriers to low carbon city development? These questions lead the research team to determine the specific objectives like i) to explore the status of low carbon city development in China; ii) to assess the strategy and policies of low carbon city development in the context of urbanization; iii) to explore the effects of new type of urbanization of China on low carbon city development; iv) to find out the constraints of low carbon city development in the perspective of new type of urbanization in China; v) to suggest some measures to overcome the constraints of low carbon city development based on findings.

This article depicts research methodology section after introduction including data collection and treatment and data analysis method. The third and fourth section describes a review of related literature and status of low carbon city development in China respectively. The fifth section describes the policy implications for facilitating the low carbon city development in the perspective of the new type of urbanization. The final section concludes the article.

2. Methodology

2.1. Research Design

The study mainly focuses on concept, indicators and implementation challenges and opportunities of low carbon city development in the perspective of fastest urbanization in China. A conceptual model is developed for low carbon city development in China through extensive literature review [9]. The research is descriptive in nature based on some indicators of low carbon city development (**Figure 1**).

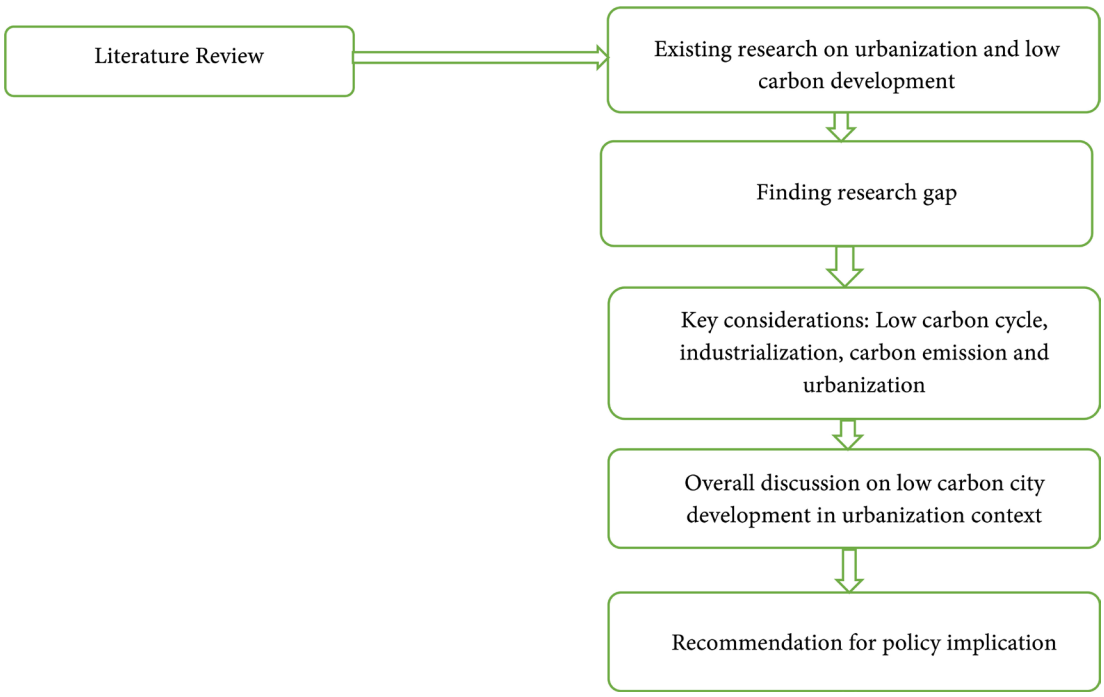


Figure 1. Research design for low carbon city development in China.

2.2. Sources of Data

This study has been extensively used secondary sources related to the concept, indicators and practices of low carbon city development, adoption of modern eco-friendly technologies, low carbon governance, climate change effects, air and water pollution and the adverse effect of the unplanned future economy. Some developed and developing countries are in the stage of rapid urbanization and low carbon city development is a prior issue to them. Though this study has been confined to China but it is applicable for other developed and developing countries.

2.3. Search Strategy

This study has been extensively searched some renowned databases like Google scholar, a web of science, science direct, Springer link, researchgate website using important keywords like "low carbon city, technology, urbanization, eco-friendly city, climate change, and China for securing reliable information" [10]. The data collection and analysis for this study has been done from November to December 2017. According to Liu & Qin, a literature review is a significant part of the development of a field [1]. It offers an opportunity to synthesize and reflect on previous research, and thus providing secure grounding for the advancement of knowledge [9]. Finally, 75 journal articles and books are selected for qualitative content analysis for this study. The supporting data has been taken from government statistics and other sources on the internet with due verification (**Figure 2**).

2.4. Data Analysis

Data is analyzed from different perspectives of low carbon practices, technologies,

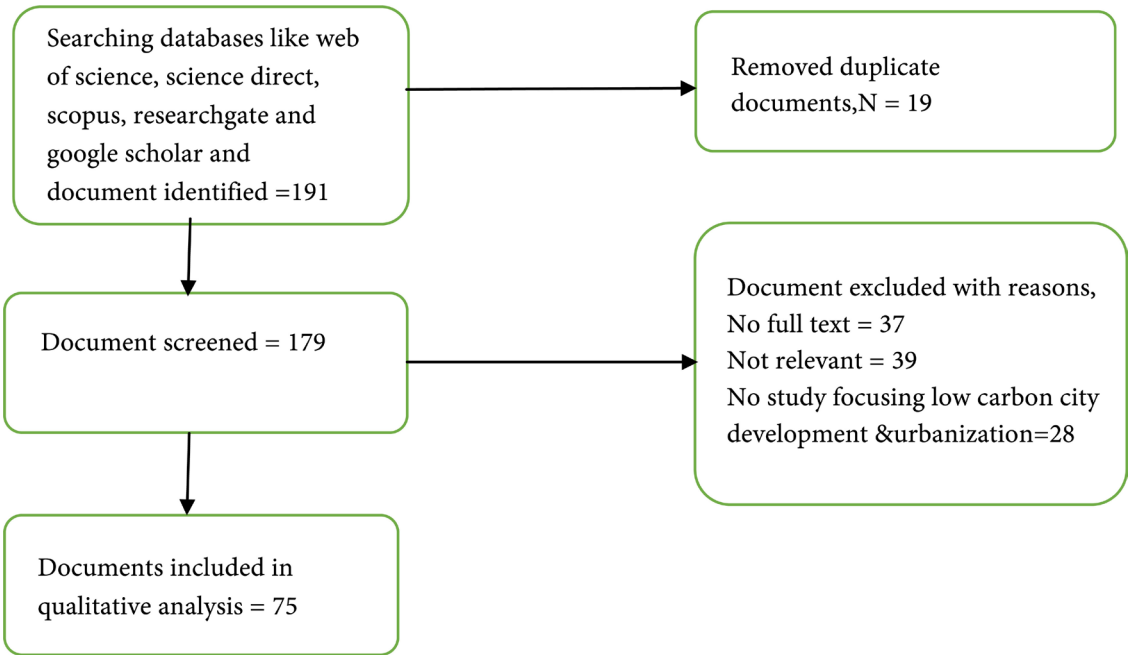


Figure 2. Flow diagram of study selection.

indicators, challenges and opportunities of technology adoption, climate change effect and environmental governance.

3. Review of Related Work

The rate urbanization in China is increasing rapidly as the urbanization rate was about 36% in 2000 but increased to about 53% in 2012 [11]. The rapid and new type of urbanization faces an acute pressure for infrastructure, urban resources, land, real estate, pollution and economic development due to making new cities adjacent to old cities, urban expansion, and migration [12]. About 18% of the total population is living in 35 largest cities in China [13]. The percentages of urbanized people are increasing due to the fastest rate of a new type of urbanization. The more people require more energy, more building construction and more resources which lead to more Greenhouse Gas Emission (GHG), air and water pollution. Global warming and climate change are the effects of Greenhouse Gas Emission (GHG). About 40% - 78% GHG emissions are originated from cities due to the cause of fastest urbanization [14]. The rate of GHG emission is increasing gradually with increasing urbanization. Traditional urbanization follows energy-intensive development patterns which require increased energy consumption along with rising living standards [15]. China is undergoing fastest urbanization on an unbalanced scale as a largest developing country.

The scarce natural resources, overpopulation pressure and limited climate and urban finance, make the cities of China vulnerable to climate change impacts. Some cities of the northern and western part of China have already faced some climate change impacts like a sandstorm, drought, and smog while the cities of eastern and southern part of China are experiencing rainstorm and frequent flood [12]. According to Liu and Deng [16], cities of northern China is experiencing decrease at 2% to 10% while flood-prone cities of southern China faces more than 20% average annual precipitation. Some cities of China viz Shanghai, Guangzhou already faces some climate change effects like rainstorms in every summer. Since urbanization creates so much pressure on energy, environment and carbon emission, so a decarburization strategy should be taken by the policy makers irrespective of regional and national level for saving the citizen and developing low carbon city [12].

Low-carbon city program was initiated in China in 2008 and subsequently, the low-carbon city experimental project was launched in eight cities viz Chongqing, Xiamen, Nanchang, Tianjin, Guiyang, Shenzhen, Baoding and Hangzhou in 2010 [13]. Low carbon pilot project included another 29 provinces and cities in 2012 which covers 57% of total GDP, 42% of total population and 56% of energy-related CO_2 emissions [12]. The goals of the new development strategy of China are sustainable urbanization, ecological civilization and scientific development which can be achieved by low-carbon city development through integration of low-carbon society and low-carbon economy [6] [17]. So, low carbon city development is not only for better lifestyle but also for the better economic development of the city (**Table 1**).

Table 1. Major research on low carbon economy.

Researcher & duration	Summary of finding	Journal or source
Zhang *et al.*, 2017 [18]	China's cities also must ensure sustainable development in line with national efforts to transition to a less carbon-intensive economy.	Sustainable Low-Carbon City Development in China
Cai *et al.*, 2017 [19]	The spirit of a "Low Carbon City" is not consistently understood by the society.	Journal of Cleaner Production
Chen *et al.*, 2017 [20]	Data on greenhouse gas (GHG) emission are vital for the reduction of carbon emissions and the development of low-carbon strategies.	Resources, Conservation and Recycling
Adenle, Manning, & Arbiol, (2017) [21]	Developing countries participation is necessary to encourage low-carbon development pathways.	World Development
Chen *et al.*, (2017) [20]	China has a target to reduce 65 percent carbon intensity by 2030 through the adoption of modern energy technology.	Resources, Conservation and Recycling
Zhang, Li, & Zhou, (2017) [18]	Developing low-carbon buildings has become a communal trend in the world in the perspective of energy consumption and carbon emissions.	Journal of Cleaner Production
Liu *et al.*, (2017) [22]	Target Responsibility System (TRS) is a vital key to the reduction of CO_2 per unit GDP.	Journal of Cleaner Production
Lo, K [23] [24]	Policies related to low-carbon cannot be implemented properly due to the poor scoring system, weak targets, energy intensity, and lack of reliable local energy statistics.	Environmental Science & Policy
Han *et al.*, (2018) [25]	The local and neighboring cities in China emit more carbon due to specialization and diversification industry.	Journal of Cleaner Production
Yang *et al.* (2018) [26]	The intensive energy consumption in urban sectors is infuriating global warming.	Journal of Cleaner Production
Fu & Zhang, (2017) [15]	The eco-new towns are more concerned with the promotion of a sustainable way of life in GHG emission context.	Habitat International
Wang, Engels, & Wang, (2017) [27]	Strong structural changes in existing development pattern are essential for short and long-term low carbon development.	Renewable & Sustainable Energy Reviews
Guo *et al.*, (2017) [28]	The approach of carbon balance analysis can help for monitoring policy effectiveness for sustainable carbon economy.	Resources, Conservation and Recycling
X. Ma, Wang, & Wang, 2017 [29]	China will have difficulty in realizing its carbon reduction target by 2020 if the present rate of GHG emission exists in the thermal power industry.	Renewable and Sustainable Energy Reviews
Cheshmehzangi, Xie, & Tan-Mullins, 2017 [30]	Participation of Chinese and international partners for low carbon occurs in the ways of the type of involvement, the level and timeframe of involvement and the level of Influence on the project.	Cities
Dong *et al.*, 2013 [13]	Low-carbon city strategy in China launched for responding global climate change and sustainable urbanization.	Energy Policy
Fu, and Zhang, (2017) [15]	A sustainable city, eco-cities, and low-carbon cities concepts have received a national endorsement in China.	Habitat International
Guo *et al.*, 2017 [28]	Urbanization advances great challenges for global sustainability with the increasing carbon constraints in the context of carbon emission and climate change.	Resources, Conservation and Recycling
Kedia, 2016 [4]	Domestic policies and international partnerships are successfully engaged for low carbon city development in China.	Advances in Climate Change Research
He, 2016 [31]	China is being implemented green and low-carbon development strategy.	Advances in Climate Change Research

Continued

Lv & Qin, 2016 [32]	Low-carbon technology mainly includes carbon reduction technology, carbon-free technology, carbon removal technology, carbon management technology, resource saving and recycling technology.	Low Carbon Economy
Yuan, 2016 [33]	Carbon finance not only provides a number of means for the development of low carbon economy but also offers a new development space for the innovation of the financial system.	Low Carbon Economy
Liang *et al.*, 2014 [34]	The low carbon development roadmap is extremely important for China's lack of energy resources, serious environmental pollution, and huge greenhouse gas (GHG) emission.	Energy Procedia
Liu, and Qin, 2016 [1]	China has largely formed a multilayer and multi-actor policy-making process for developing low-carbon cities.	Cities
Lo, 2014 [24]	China has already disseminated a wide variety of low-carbon initiatives to reduce energy consumption and carbon emissions in the cities.	Habitat International
Su *et al.*, 2012[5]	Many cities in China have been dedicated to the expansion of low-carbon city construction nowadays.	Procedia Environmental Sciences
Su *et al.*, 2016 [35]	Low-carbon city in China is necessary for reducing huge cost of climate change particularly for city's greenhouse gas emissions.	Energy Procedia
Tan *et al.*, 2017 [7]	Many cities are pursuing the low-carbon practices to reduce CO_2 and other environmental emissions.	Applied Energy
Yang *et al.*, 2017 [26]	The intensive energy consumption in urban sectors is stimulating global warming, which prompts thinking on energy-carbon nexus and low-carbon city actions.	Journal of Cleaner Production
Yang & Li, 2013 [36]	The development of low carbon city is required to cope with global climate change and sustainable development of economic society.	Sustainable Cities and Society
Yu, 2014 [2]	The application of low carbon eco-city strategy should be contributed to the solution in addressing upcoming challenges.	Habitat International
Zhang *et al.*, 2017 [18]	The current pattern of low-carbon buildings in China's urban area is still dissatisfactory.	Journal of Cleaner Production
Zhou *et al.*, 2018 [37]	China is in a period of rapid urbanization, which has led to increased demands for energy. Approximately 85% of China's CO_2 emissions are related to urban energy consumption.	Journal of Cleaner Production
Zhou *et al.*, 2015 [38]	China is pursuing the development of low-carbon eco-cities to limit carbon dioxide and other greenhouse gases emissions.	Ecological Indicators

The major strategy of sustainable urbanization requires a low carbon city development planning, policy, and development pattern since Chinese cities are facing various constraints in implementing a new type of urbanization.

4. Current Status of Low Carbon City Development in China

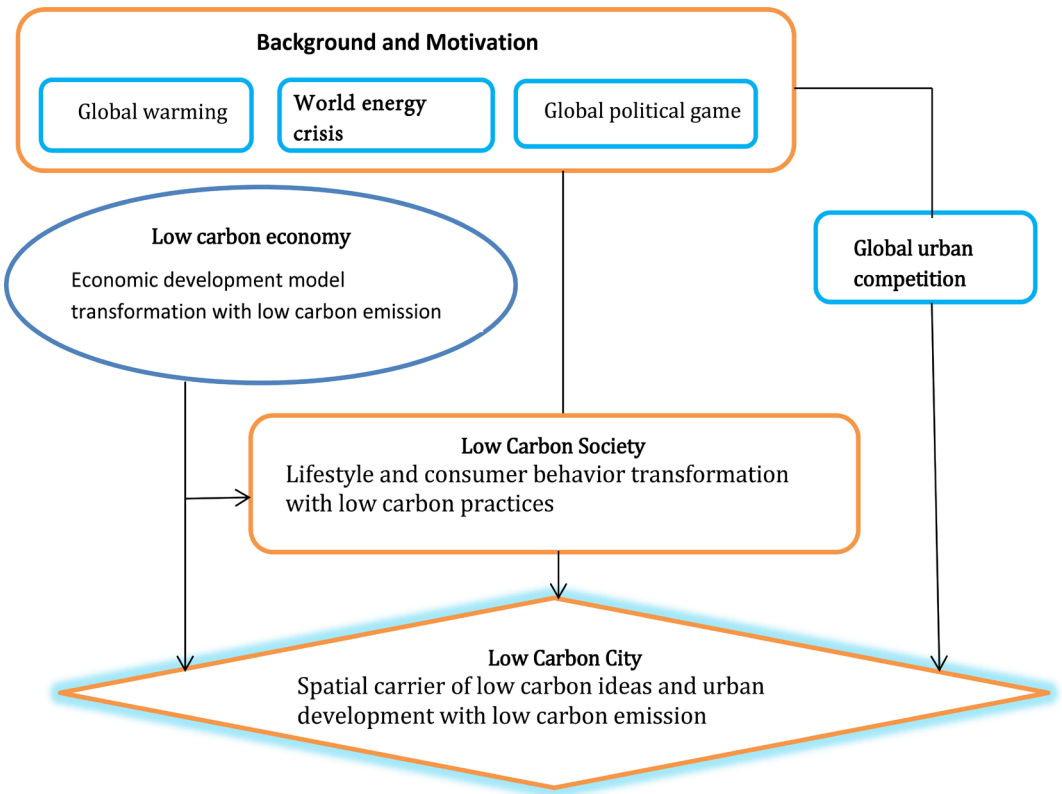
Sustainable urbanization is a new challenge for Chinese cities due to the continuous migration of people from the countryside to urban areas, environmental pollution, and energy consumption. A continuous and new approach is necessary for sustainable low carbon city development in order to cope with the con-

tinuous challenges and pressures of social and environmental factors.

4.1. Concept of Low Carbon City

A low carbon city is an approach to the transformation from industrial civilization to ecological civilization which covers the challenges of urbanization considering low carbon practices. Energy saving and low carbon emission are the priority sector in the economic development process which faces the challenges driven by global politics, climate change, energy consumption & crisis, and urbanization. In 2003, the British government first proposed low carbon economy through Energy White Paper entitled to "Our Energy Future: Creating a low carbon economy". A low carbon economy can be achieved through practicing low carbon city development. One of the major purposes of low carbon city is to reduce energy consumption and carbon emission *i.e.* low carbon energy is related to low carbon city development. Low carbon city is also an urban development model which stimulates the initiation and development of new type of urban economics for reducing energy consumption and carbon emission (Figure 3).

The challenges of urbanization in the process of city development are meeting up with the similar concepts of low carbon city, eco-city, and low carbon eco-city development in China. This low carbon city concept was decided by the Fourth Plenary Session of the 16th Chinese Communist Party Central Committee



Source: Adapted from [39].

Figure 3. The origin of low carbon city.

for developing eco-friendly, energy saving and self-dependent model. The major purpose of this model is to reduce poverty, developing an eco-friendly environment and promoting renewable energy sources. This plan was further strengthened through the 18th National Congress of the Communist Party of China [40]. The concept also explained in last few years as sustainable or eco-city development. Some other scholars described the eco-city from various perspectives. According to Feng *et al.* [41], eco-city usually saves energy, water, and other natural resources by reducing pollution and waste. As a result, an eco-city is an approach to saves fossil resources and provides an attractive place for living and working. According to Zhang [42], an eco-city is a city which includes harmonious human development, synchronization of ecological, economic and social factors, economic and environmental components. Yu [2] mentioned that eco-city is a process which stimulates environmental, economic and social development through transforming traditional production patterns and improving lifestyles (Table 2).

4.2. Introducing Low Carbon Policy

The National Development and Reform Commission (NDRC) selected 6 provinces and 36 cities for low carbon cities pilot projects for reducing carbon emission in the industry and promoting eco-friendly development as a responsible body of government [2]. The Ministry of Environmental Protection (MEP) of China has also played a vital role in reducing GHG emission and low carbon city development. The MEP also conducting other related works like controlling polluters, monitoring, supervising and licensing industrial bodies, reviewing the

Table 2. Similar concepts to Low carbon city.

Terms	Definition	Researcher	Examples
Sustainable City	It stimulates social equity, economic productivity, and environmental quality to meets the needs of the present without compromising the ability of future generations to meet their own needs.	Riviere *et al.*,2013 [43] Liu *et al.*, 2016 [44]	1) Malmö, Sweden
Eco-city	A city where human beings can exist in harmony with nature therefore greatly reducing ecological footprint. A city that creates economic opportunities for their citizens in an inclusive, sustainable, and resource-efficient way, while also protecting and nurturing the local ecology and global public goods, such as the environment, for future generations.	Suzuki *et al.* 2010 [45] World Bank, 2015 [46]	1) Sino-Singapore Tianjin Eco-city, China 2) City of Copenhagen, Denmark 3) Stockholm, Sweden 4) Yokohama, Japan
Smart city	The safe, secure, environmental and efficient urban center of the future with advanced information and communication technologies (ICT) to stimulate sustainable development in the economic growth and a high quality of life	UNESCAP, 2012 [47] Sarker, 2017 [48]	1) Barcelona, Spain 2) Luxembourg
Carbon neutral city	Similar to "LCC" except defined more strictly as a city which has zero carbon emissions.	Adelaide City Council, 2015 [49]	1) Melbourne, Australia
Zero carbon city	More specifically to a city which produces no GHG and is run exclusively on energy from renewable sources	Urban World, 2009 [50] Hannallah & Faragallah, 2009 [50]	1) Masdar City, United Arab Emirates 2) Dongtan, China

progress of pollutants through local government [2]. In 2012, the MEP provided an award to 38 National eco-cities (or counties) and 1559 National eco-towns for best practices in environmental protection [12].

Urban and rural human settlement sector is under the Ministry of Housing and Urban-Rural Development (MoHURD) of China which assess the best practices of urban settlement by some standard indicators and contribute to low carbon city development in the new type of urbanization [51] (**Figure 4**) (**Table 3**).

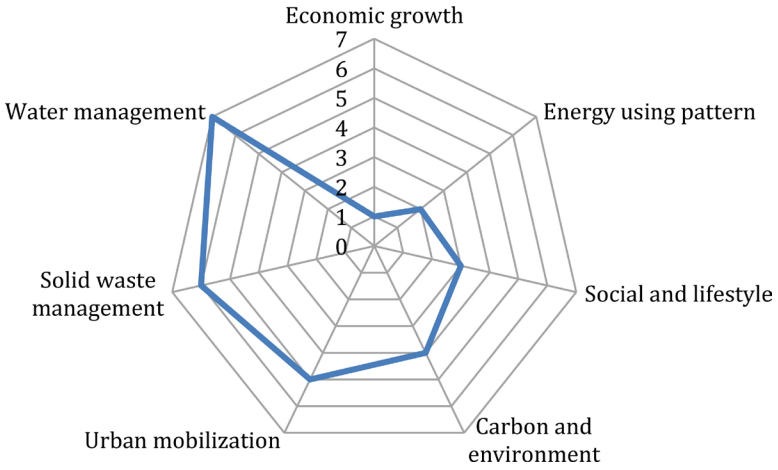


Figure 4. Dimensions of low carbon city (LCC) development.

Table 3. Dimensions of low carbon city (LCC) development.

Category	Indicator	Researcher
Economic growth	• Per capita GDP • Proportion of tertiary industry to GDP • Carbon productivity	World Bank, 2015 [46] Cheng *et al.*, 2012 [39] EIU, 2012 [52] Suzuki *et al.*, 2010 [45]
Energy using pattern	• Proportion of renewable energy • Energy intensity	EIU, 2012 [52] Tan *et al.*, 2017 [52] [7]
Social and lifestyle	• Proportion of public green space • Population density Population/km^2	Tan *et al.*, 2017 [7] UN-Habitat, 2011 [14]
Carbon and environment	• CO_2 emission/capita ton/person Nitrogen dioxide emission/capita lg/m^3 • Daily sulfur dioxide levels lg/m^3 • daily suspended particular matter levels lg/m^3	Zhou *et al.*, 2015 [38] Garcia, 2017 [53]
Urban mobilization	• Public buses per capita Public buses/million persons • Rail length per capita km/million persons • Cars per capita Private cars/persons	EIU, 2012 [52] WHO, 2014 [54]
Solid waste management	• Solid waste generation per Capita kg/capita/day • Share of waste collected and adequately disposed • Share of waste energy • Share of material recycling	Hoornweg & Bhada, 2012 [55] Shen *et al.*, 2018 [56] Baeumler *et al.* 2012 [57]
Water management	• Share of wastewater treated • Water consumption intensity L/capita/day	Zhou *et al.*, 2015 [38] Suzuki *et al.*, 2010 [45]

4.3. Manufacturing Sector and Carbon Emission

Rapid industrialization in China stimulates manufacturing industries, especially iron and steel, cement and chemical industry. Most of them are established in the cities which are located in the newly established industrial parks [58]. It provides a great opportunity for Chinese cities to encourage industrial symbiosis as well as low-carbon strategy, demanding a systematical evaluation so that quantitative evidence can be provided for future policymaking. However, comprehensive study focus on this topic remains challenging, due to model limitation and data unavailability.

4.4. Transportation Sector and Carbon Emission

Electricity production, industrial fuel use, and ground transportation are the major source of carbon emission in Chinese cities. The average rate of emission is higher than cities of other developed countries of the world [18]. This study analyzes the sources of carbon emission in various Chinese cities and finds three major GHG contributing sectors like energy consumption, industrial system, and transportation. Some major sectors are considered by some researcher with transportation like energy supply and consumption, construction of the building, agriculture, industry, and planning of new urban areas [59]. Some others mentioned that economic and policy instruments are the major effective keys for low-carbon development [1]. Major instruments are labeling and certification of energy, beginning inner carbon markets and inspiring energy pricing reforms [22] [13]. The main low carbon practices for city development are upgrading industrial structure, relocation of industry, energy savings, energy friendly technology, and transportation of low carbon [60] [61]. Establishing energy standard, urban planning, and public transportation are the major instruments for achieving goals of CO_2 reduction which must be considered by the concerned authority [1] [62].

4.5. Building Sector and Carbon Emission

One of major GHG emission sector is building sector which covers 14.11% of total emission with other sectors like 41.36% by transport and communication sector and 10.41% education and recreation sector [12]. Most of the big cities are suffering from poor land use. The development of low-carbon cities has been encouraged worldwide because cities are key drivers of energy consumption and related carbon emissions [63]. Regulation and technological improvements will play an important role in mitigating GHG emissions in some Chinese cities. Carbon reductions require a transformation of the city's lifestyle, social and economic development pattern which includes clean energy policies to encourage change in its energy system [28]. Knowledge, expertise, science, and technology from foreign countries are considered to be a key component of developing low-carbon cities [19]. Some researchers have suggested that low carbon development of China's cities need to learn from and collaborate with successful

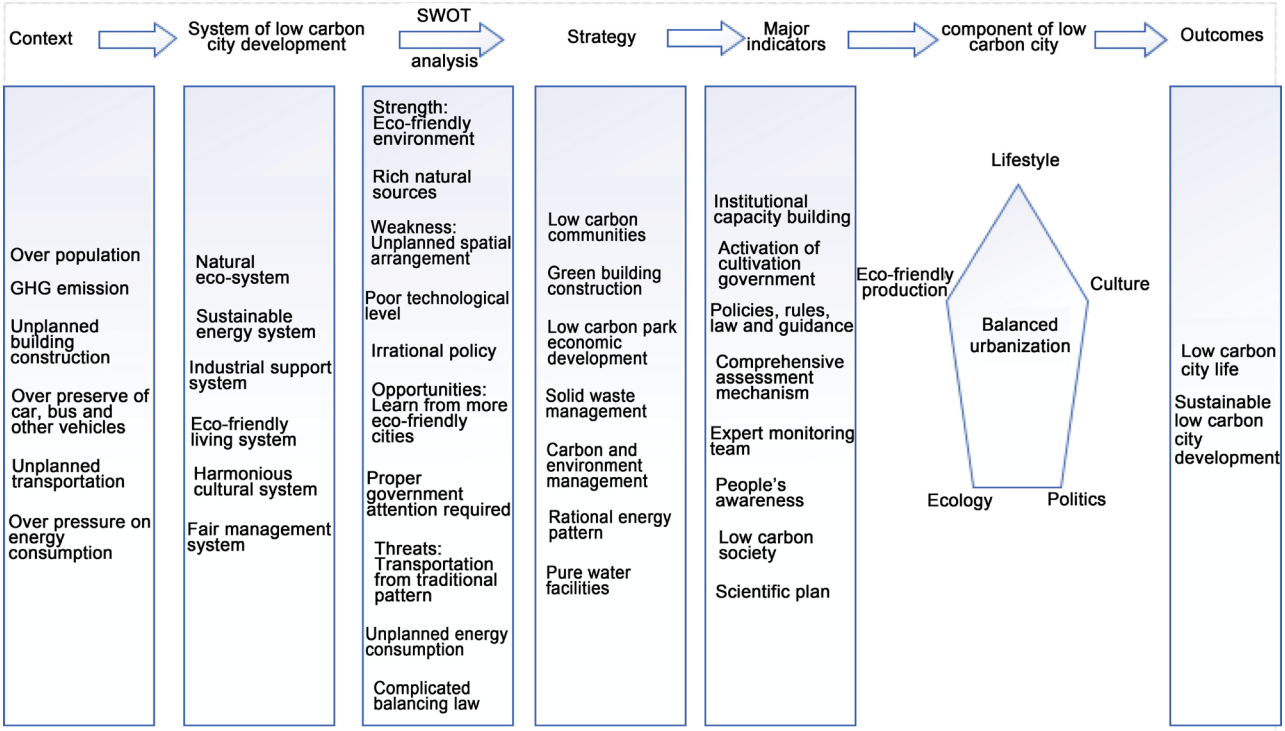


Figure 5. Conceptual framework of the low carbon city in China in the context of urbanization.

low-carbon cities in developed countries. The carbon-related regulations can improve emission reduction awareness and behaviors of policymakers and other related stakeholders [64] (**Figure 5**).

5. Recommendations

- Governments should make an assessment index system and incentive mechanisms which will encourage low-carbon production to provide low-carbon products to the market.
- The research centers need to focus on low-carbon technologies for providing technological support for the development of low-carbon cities in China.
- Awareness building program should be taken by the concerned authority on the importance of low-carbon consumption and low-carbon lifestyles.
- Local feasibility should be considered for designing, planning and implementing Low-carbon policy, practices and technology development for sustainable low carbon city development in the context of the new type of urbanization.
- The targets of government for low-carbon city development are not enough understanding to different stakeholders. So necessary steps should be taken by the concerned authority for implementing real works instead of just showing the achievements of local officials. Moreover, medium-sized or small cities should be taken into consideration for gross achievement in low carbon city development over the country. Additionally, building construction should be considered for low carbon city development irrespective of large, medium or small cities.

- Governments should be taken the initiative to design proper rules and regulations for providing legal insurance for the development of low carbon industries, raising environmental awareness among people for promoting low-carbon practices, measuring and assessing emission reduction achievements, encouraging enterprises for focusing on innovative low-carbon technologies, improving industrial structures and energy structures.

6. Conclusion

The traditional urbanization pattern in China is a challenge for maintaining low carbon because of its relation to industrial development. Since industrial development is basically based on energy production, consumption, and trade. Low carbon city development in the process of the new type of urbanization is an academic debating matter in the researcher community particularly on developing an appropriate strategy, policy, technology, and action. This study reveals that most of the large cities are already under the pilot projects of low carbon city development. Some major indicators of low carbon city like economic growth, energy using pattern, social and lifestyle factor, carbon and environment, urban mobilization, solid waste management, and water management are related to urbanization. It also finds out some constraints like the traditional pattern of urbanization, the traditional pattern of industrial development, huge pressure on energy consumption, unawareness of the people about GHG emission, unavailability of low carbon technology, unequal emphasis on medium and small cities, and lack of proper assessment system. This study suggests that a standard assessment indicator system should be introduced by the government to control, monitor and stimulate people to use low carbon technology. It further suggests that rules and regulations, awareness building, local-oriented technology and practices, and stimulating participation of all stakeholders in the policy-making process should be maintained by the government for sustainable low carbon city in China. Further research should be done to address the performance of China's low-carbon city pilot projects and determining the role of government agencies for the development of low-carbon cities in China.

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