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Renewable energy leapfrogging in China's urban development? Current status and outlook

Patrick M. Schroeder[a,b,c,*], Ralph B. Chapman[a]

[a] Victoria University of Wellington, Wellington, New Zealand
[b] China Association For NGO Cooperation, Beijing, China
[c] Collaborating Centre on Sustainable Consumption and Production, Wuppertal, Germany

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ABSTRACT

Cities in China will be crucial for deciding the direction of China's transition to a low-carbon economy and will play a key role in China's sustainable future. Over the next two decades over 325 million people will migrate to China's cities and by 2030 they are expected to house about 1 billion people. Will these cities be able to 'leapfrog' conventional high-carbon development? Many cities in China have put forward low-carbon city development plans and China's National Development and Reform Commission has designated five provinces and eight cities as low-carbon development zones. The challenge will be on-the-ground implementation of these low-carbon development plans based on sound indicator systems for monitoring and evaluation of emission reductions. The paper analyses one key sector for urban development issues in Chinese cities, namely the application and use of renewable electricity technologies in cities as a crucial element of low-carbon city development. Several city case studies are presented which show that flexibility at the local level has allowed several cities in China to adopt and implement support policies and targets for renewable energy technologies such as solar PV and geothermal heat pumps. Through the application of solar water heating technologies, in particular, significant progress has been achieved, resulting in electricity savings in the building sector. The analysis concludes with an assessment of how these ongoing initiatives in Chinese cities may contribute to leapfrogging in urban environmental outcomes, particularly in terms of urban carbon emissions.

1. Introduction: leapfrogging opportunities in China's urban development

China's rapid urbanization represents a major opportunity to reduce the carbon emissions of the world's largest carbon emitting country. The opportunity arises partly because China's cities are expanding rapidly, new residential developments are being constructed and new industries are being created for the first time. This offers potential for 'leapfrogging', defined as skipping stages of development and generations of technologies to avoid pollution-intensive stages of development and bypass environmental impacts (Goldemberg, 1998; Munasinghe, 1999).

China's renewable energy technologies have developed significantly since the introduction of China's Renewable Energy Law in 2005. Since then renewables, particular wind and solar power, have grown rapidly and have made China the world leader in installed non-hydro capacity with 70 GW at the end of 2011 (REN21, 2012). Moreover, it is clear empirically that with certain low-carbon technologies such as solar water heating, leapfrogging has been occurring in China (Schroeder, 2011). Local 'bottom-up' initiatives and strategies at the city level could enable fast low-carbon transitions (Bulkeley et al., 2011) or even leapfrogging of conventional high-carbon urban development. However, there are reasons for doubting that leapfrogging is easy across the energy technology spectrum, including in areas where technologies are not mature or still expensive, such as solar PV cells for urban application (Unruh & Carrillo-Hermosilla, 2006).

It remains unclear, therefore, how widespread leapfrogging may become in China, and whether the rapid growth and reconfiguration of China's economy and cities will allow carbon emissions to be reduced at the rapid rates necessary if the world community as a whole is to achieve the 50% reduction by 2050 target that many analysts consider essential in order to keep within the 2 °C guardrail (Rogelj et al., 2010; Hansen et al., 2013).

As part of China's strongly planning-oriented economy, in contrast to the market-led, government-incentivised western approach, city-level development is also strongly planned. Low-carbon city development and renewable energy applications are

* Corresponding author at: Collaborating Centre on Sustainable Consumption and Production, Wuppertal, Germany. Tel.: +49 20245958-12; fax: +49 20245958-30.
E-mail addresses: patrick@cango.org, patrick.schroeder@scp-centre.org (P.M. Schroeder).

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promoted through government plans and targets. For this reason, this paper first introduces some of China's low-carbon city development plans and indicator systems which are being employed to guide progress towards the low-carbon goals set by municipal governments. The second part presents a number of case studies of Chinese cities which have set strong targets for renewable energy development or have already experienced fast growth in renewable energy technologies in recent years.

2. China's low-carbon city development plans

The concepts of a 'low carbon economy' and 'low carbon city' were introduced to China as recently as 2008 in the run-up to the Beijing Olympics. Since then the concepts have moved from being merely political slogans to concrete development approaches for Chinese cities. In 2010 China's National Development Reform Commission (NDRC) announced a programme for five low-carbon pilot provinces and eight low carbon pilot cities. The five provinces taking part in the pilot project are Guangdong, Liaoning, Hubei, Shaanxi and Yunnan; the eight cities are Tianjin, Chongqing, Shenzhen, Xiamen, Nanchang, Guiyang, Baoding and Hangzhou (see Fig. 1).

In addition, a large number of other Chinese cities have announced goals to become low-carbon cities. Of China's more than 600 major cities, more than 200 have adopted the goal of low-carbon development. Common elements of these local development plans are CO_2 emission intensity targets and energy consumption targets for buildings, transport or industry sectors for 2015 or 2020. A representative selection of Chinese cities' low-carbon development plans, highlighting not only common elements but also the diversity of indicators used, is presented in Table 1 below.

China's cities are now frequently being compared in "low-carbon city rankings". An example is a nationwide assessment and ranking of major Chinese cities in terms of their low-carbon development by the China Low-carbon Economy Media Federation, in cooperation with the State Council Research Institute, published in December 2011 (CLEMF, 2011). The ten leading low-carbon cities, ranked on the basis of a set of 18 indicators, were, according to the report, Suzhou, Beijing, Tianjin, Yichun, Lhasa, Liaoyang, Yinchuan, Liupanshui, Xining and Chengde. The report also identified 89 cities which had not taken any action towards becoming low-carbon cities.

In the public debate about low-carbon cities, significant voices disapprove of the current promotion of Chinese cities as low-carbon. For example, Jiang Kejun, director at the National Energy Research Institute, publicly stated that no city in China is yet a low-carbon city, particularly not the ones ranking top in the surveys mentioned above (Chinadialogue, 2010). This is supported by a number of research studies, for example by the Global Carbon Project (Dhakal, 2009), which shows that the 35 largest cities in China represent less than 20 percent of China's population but produced about 40 percent of the nation's GDP, consume 40 percent of the total commercial energy of the nation and emit CO_2 at similar levels. The wide disparity between these cities and the rest of the country in per capita GDP, per capita energy consumption, and per capita CO_2 emissions shows the influence of large cities in shaping national energy and carbon profiles.

To make more transparent whether cities are indeed "low-carbon", quantitative indexes are being developed to assess action and progress towards the low-carbon goal (Su, Liang, Chen, Chen, & Yang, 2012; Zhu, 2011). However, although developed with great detail, these indicator sets do not adequately reflect the current status of the cities. For example, the indicator system of Su et al. (2012) consists of 16 indicators for assessing levels of low-carbon urban development. A comparison of 12 cities applying this indicator set ranks Shenzhen, Beijing and Guangzhou first, second and third.

One of the main reasons for the high ranking of cities like Beijing or Tianjin as being "low-carbon" is the use of aggregated data on energy use or CO_2 emissions per unit of GDP or per capita. Major cities tend to have high GDP per capita, so rank well in terms of being "low carbon" using metrics such as energy intensity (tce/GDP) or carbon intensity (tCO_2/GDP), but rank poorly if per capita emissions are taken as an indicator: in 2008 Beijing had 8.7 tCO_2/person, Tianjin 10.8 tCO_2/person, and Shanghai 11.9 tCO_2/person (Price et al., 2011).

Indicator sets are clearer if adjusted for population, but placing a strong weight on GDP per capita or GDP per capita growth does not give a particularly meaningful measure of whether a city or province is "low carbon". Price et al. (2011) propose indicators based on energy end-use sectors (industry, residential, commercial, transport, electric power) for defining low carbon cities or provinces. For example, residential energy use per capita by city and province would be reported. This approach would also be useful for identification and evaluation of concrete interventions for emission reductions.

However, no Chinese city, not even the low-carbon pilot projects designated by NDRC, has adopted a comprehensive set of low-carbon city indicators. Given the limited development of international methodologies for accurately evaluating urban carbon emissions (Kennedy et al., 2009), it is not surprising that in China, also, robust methodologies for establishing carbon emissions inventories at the city level are not yet mature. A difficulty in establishing emission indicators is to consistently calibrate city emissions, in order to accurately allocate emissions generated outside a city's boundary, but consumed inside the city. For example, the coal consumption cap set for 2015 by Tianjin Municipality will only restrict direct coal burning within the city's boundaries, but not the city's consumption of electricity generated by coal-fired power stations located outside Tianjin. Moreover, in line with China's national carbon commitments to date, which are based on carbon intensity, only a few Chinese cities are currently targeting absolute carbon emissions as opposed to carbon (or energy) intensity (The Climate Group, 2010). A further problem is that the surveys only compare Chinese cities amongst each other, not internationally.

One key sector indicator important for determining whether a city is low-carbon or not, is the share of renewable energy of the city's primary energy generation and use.

Renewable energy generation technologies and energy saving technologies such as solar water heating (SWH) or ground heat pumps will play an important role in the low-carbon transition of China's cities. A number of cities in China are using renewable energy as indicators, such as square metres of solar PV installed. While these may not in themselves be robust indicators of desired outcomes, they are intermediate steps to indicate the increase in renewables' share of electricity used. The advantage of renewable energy indicators for urban development is that they link energy related issues to the cities' environmental, economic and social attributes. Furthermore, they are relatively easy to measure and data are more easily available, compared to other indicators such as energy use of buildings or use of low-carbon urban transport. The cities in China which have already demonstrated significant achievements in renewable energy development have all applied either one or more indicators relating to renewable energy (Table 2).

However, it needs to be noted, when it comes to the use of renewable energy industry consumption as an indicator, that there may be a discrepancy between being a "low-carbon" city and having (or planning to have) large manufacturing capacity in renewable energy equipment (e.g. PV panels or wind turbines). The cities with