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Garden waste biomass for renewable and sustainable energy production in China: Potential, challenges and development

Yan Shi [a,b], Ying Ge [a], Jie Chang [a,*], Hongbo Shao [b,c,**], Yuli Tang [d]

[a] College of Life Sciences, Zhejiang University, Hangzhou 310058, PR China
[b] Key Laboratory of Coastal Biology & Bioresources Utilization, Yantai Institute of Costal Zone Research (YIC), Chinese Academy of Sciences (CAS), Yantai 264003, PR China
[c] Institute of Life Sciences, Qingdao University of Science and Technology (QUST), Qingdao 266042, PR China
[d] Qianjiang Administration Offices, Hangzhou West Lake Scenic Area, Hangzhou 310008, PR China

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ABSTRACT

Garden waste biomass is a potentially underutilized renewable biofuel feedstock, which is increasing dramatically with rapid urbanization worldwide. China has experienced fast-paced urbanization over the past three decades: the settlement area has increased at a rate of 6.1% annually, with greenspace increasing by 12.7% annually from 1996 to 2008. This paper provides a synthesis of literature and experimental data to trace the potential of garden waste biomass for green renewable energy production in China. Our results show that the total potential biofuel produced by garden waste biomass was estimated at 260 petajoules (PJ), accounting for 20.7% of China's urban residential electricity consumption, or 12.6% of China's transport gasoline demand in 2008. Thus the use of garden waste biomass for energy production will contribute to the construction of low-carbon cities. However, there are still many difficulties—the main challenges are how to quantify the available garden waste biomass accurately, and technical and financial issues with the exploitation of garden waste biomass for energy production. Finally, we provide several practical suggestions for the future development of garden waste biomass for energy production. The use of garden waste for energy production in urban areas could be a win–win approach for mitigating both the burden of disposed costs and the energy crisis.

Contents

1. Introduction

Sustainable energy resources have become important for world stability, and biofuels may offer promising alternative energy sources [1]. Biomass for energy generation has attracted much attention at global and national scales [2–4]. Renewable biofuel feedstock should neither compete with food crops nor cause carbon debt and negative environmental impacts [5]. Biofuel made from waste biomass can offer advantages in reducing greenhouse

* Corresponding author. Tel./fax: +86 571 8820 6465.
** Corresponding author at: Institute of Life Sciences, Qingdao University of Science and Technology, Zhengzhou Road 53, Qingdao266042, PR China. Tel.: +86 53284023984; fax: +86 53284028798.
E-mail addresses: jchang@zju.edu.cn (J. Chang), shaohongbochu@126.com (H. Shao).

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gas emissions [6]. Wood wastes are one biomass in this category [5]. Generally, much of this wood waste biomass comes from forests or plantations [7–9]; the availability of biomass from urban trees has not been much discussed.

Woody biomass from urban areas is a potentially large, underutilized resource [10]. This type of resource has been increasing with the expansion of urban and greenspace areas [11]. The definition of greenspace in this paper follows the Chinese national standard according to which it is a kind of urban land which is mainly composed of vegetation, for the use of the improvement of urban ecology, environmental protection, providing residents with recreation space and beautifying the city [12]. Currently, greenspace vegetation has no production function and is not used by humans or even by animals. However, the management of greenspace has costs for labor and other expenses. This suggests that utilizing garden waste for biofuels could not only reduce waste disposal costs, but also increase energy yields. At the same time, it could avoid the generation of greenhouse gases by the processes of landfill, gas capture from which is inefficient [13]. Compared with forest residues, garden waste is well suited for energy production because it has already been collected and transported, and has no effect on the balance of natural ecosystems. Moreover, garden waste may have higher yields; for example, in the USA the amount of garden waste is higher than the total annual harvest from National Forests [14].

Garden waste biomass for energy production has been suggested to be more environmentally friendly [15,16]. Net greenhouse gas emissions for production of biochar from garden waste are negative, and they are only half of emissions for switchgrass biofuel production [17]. Life-cycle assessment for garden waste management scenarios suggests that incineration of garden waste will result in large benefits on a seasonal basis [18]. We are aware of only one study that has been carried out on estimating the potential of garden waste for biofuel production. Biofuel produced from garden waste can offset 1.6–6.5% of the city's transport gasoline demand in Singapore [19]. The potential and feasibility of using garden waste biomass for energy production should be explored further.

China has experienced the world's fastest urbanization since the 1980s [20]. Its urbanization rate (ratio of the urban population to the total population of a given region) increased from 21% in 1982 to 46% in 2008 [21], and it is still rising rapidly. Land use and land cover changed dramatically in the process of urbanization, and the amount of garden waste biomass is increasing quickly with the urban expansion. Garden waste offers a modest, yet substantial and reliable amount of biomass that could contribute significantly to regional bio-based energy. It could be conveniently cleared and gathered every day in most cities of China. Addressing air pollutants and climate forcing agents in Chinese cities, China is striving to build more low-carbon cities [22]. Garden waste for energy in urban area could offer a win–win approach.

There are no previous studies on energy production from garden waste in China. In this paper, the amount of garden waste biomass required and its energy utilization potential are estimated to determine whether garden waste has potential as biomass for renewable energy production. Challenges and strategies for developing the use of garden waste for energy are also discussed. The conclusions could also provide a potential alternative option for solving environmental and energy problems in other developing countries.

2. Garden waste feedstock in China

2.1. Development of greenspace in China

From 1996 to 2008 in China, the built-up area increased at a rate of 6.1% annually, with greenspace area increasing by 12.7% annually. During this period, the percentage of greenery coverage in built-up area increased from 24.4% to 37.4% (Fig. 1). In 2008, the total greenspace area reached 1,771,847 ha. To meet the growing demand for greenery, the amount of planting area for ornamentals has also been steadily increasing in China. In 2008, the total area of ornamental nursery stocks was about 424,925 ha, an increase of 5.1% than in year 2007 [24].

The climate of China varies greatly, and the country is abundant in ornamental tree species. North of the Qinling Mountain–Huaihe River line (about 35°N latitude), which is the boundary of temperate and subtropical climatic zones, dominant ornamental trees are deciduous broad-leaved tree species such as *Sophora japonica*, *Populus tomentosa*, *P. nigra*, *P. bolleana*, *Fraxinus chinensis*, *Salix matsudana* and *Ulmus pumila*. There are also some evergreen coniferous species in this area, mainly *Pinus tabuliformis*, *Sabina chinensis*, *Picea asperata* and *Platycladus orientalis*. South of the Qinling Mountain–Huaihe River line, the dominant ornamental trees are evergreen broad-leaved tree species, including *Cinnamomum camphora*, *Elaeocarpus sylvestris*, *Magnolia grandiflora* and *Ficus benjamina*. The mainly deciduous tree species are *Platanus acerifolia*, *Liquidambar formosana*, *Sapindus mukorossi*, *Ginkgo biloba* and *S. babylonica*. Some ornament tree species are also energy plants, such as *Sapiam sebiferum*, *Xanthoceras sorbifolia*, *Pistacia chinensis*, *Populus* spp. [25].

Greenspace vegetation is well managed and conserved in China. Gardening practices (pruning, fertilization, irrigation) reduce the detrimental effects which urban plants tend to suffer during the growing period. Urban vegetation generally grows more quickly

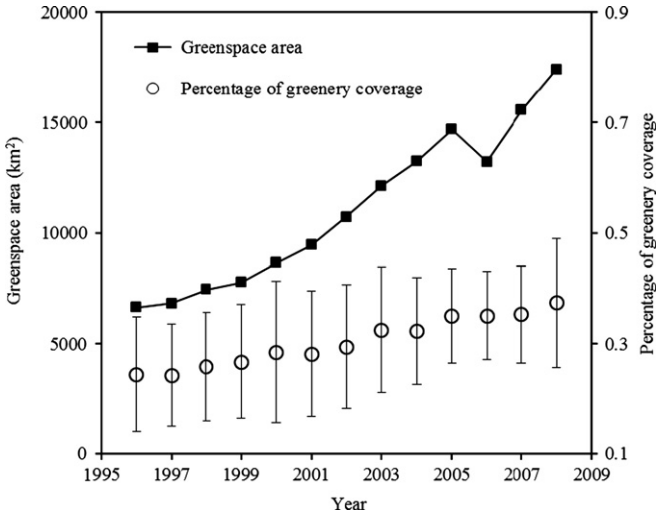

Fig. 1. Changes in greenspace area and percentage of greenery coverage in built-up areas in China from 1996 to 2008. The percentage of greenery coverage in built-up areas is from six regions of China; values are means ± SE [21,23].

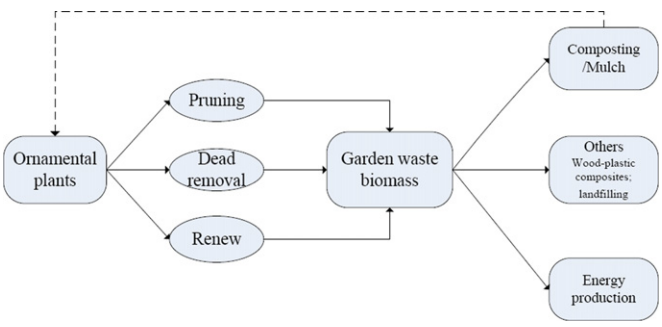

Fig. 2. Garden waste biomass resources and utilization types.