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Research paper

Availability, supply technology and costs of residual forest biomass for energy – A case study in northern China

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ABSTRACT

In theory, China has vast potential forest resources for production of energy, but utilization on an industrial scale has been negligible. We assessed the practical possibilities and barriers for a forest energy business in a case study in northern China. The specific objectives of the study were 1) to assess the availability of forest biomass for energy production, 2) to determine feasible supply chains, and 3) to estimate the biomass fuel supply costs. Based on the case study results, the stand-level removals of the intended feedstock were low and the supply costs were relatively high. Suggestions for increasing the raw material basis, lowering the costs and further research and development were given. We conclude that although the case study area may not be promising from the feedstock point of view, the development could be started with small steps and proven technology. In order to avoid expensive mistakes further research for transfer of know-how and technology is needed.

1. Introduction

1.1. Background and objectives

Due to its huge population and fast-growing economy China has become the number one energy consumer in the world [1]. As a net importer of oil, gas and coal there is interest in China to develop bioenergy production as a domestic energy source. Use of modern bioenergy would also help China in reaching the recently announced target to cap its rapidly growing carbon emissions by 2030.

Forest energy, i.e., bioenergy produced from the residues of wood production of the forest industry, has drawn the attention of SFA (Table 1). SFA is motivated by the following facts:

- Forest energy is considered green and environmentally friendly,
- There is a need for heat production in the north of China,
- Use of forests for energy production could improve the public image of state forests, and
- Increased wood harvesting would offer work opportunities for the declining population in remote areas.

At the national level, forest energy or bioenergy generally does not currently play a major role. China's 12th Five-Year Plan sets a binding target to increase the use of non-fossil fuels in primary energy consumption by 3.1% between the years 2010 and 2015 [2]. Although biomass energy is mentioned, hydro power and solar energy are clearly prioritized as renewable energy sources.

According to China's energy policy, however, power generation using woody biomass in forested areas is promoted, as well as distributed energy production [3]. Also another government white paper discusses power generation using biomass, but heat generation is not mentioned [4]. Nevertheless, Kahrl et al. [5] argue that bioenergy development policies have so far focused on large-scale, centralized biomass conversion for transport fuels and electricity. Yet, focussing on the local scale and utilizing forests for producing clean energy with modern technology for the rural population might be a wiser way [5].

According to China's Medium- and Long-term Development Plan for Renewable Energy, the raw material base for woody biomass based energy is large: of about 900 million tonnes of dry waste from forestry and forest product processing available every

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Table 1
Nomenclature and abbreviations.

SFA	State Forestry Administration of China
m^3	Solid cubic metre
RES8	Supply chain of logging residues (the minimum top diameter of a roundwood bolt 8 cm)
RES12	Supply chain of logging residues (the minimum top diameter of a roundwood bolt 12 cm)
WHT	Supply chain of whole trees

year, nearly 300 million tonnes could be used for energy production [6]. A specific objective in the plan was to raise the share of all renewable energy to 15% of total primary energy consumption by 2020. In 2012, the share of renewables was 9% [7]. Of this, hydropower accounted for nearly 90%.

The potentials given in the plan may, however, be rather optimistic: Qiu et al. showed that for crop residues, when taking the competing uses and the economic viability of bioenergy plants into account, the real availability could be less than half of the potential stated in the plan [8]. Zhou et al. estimated the total forest residue potential – including both primary and secondary residues – at 197 million tonnes [9]. Even this estimate could be questioned as the competing use of residues was apparently not considered.

Gosens studied the economical prerequisites for biomass power projects in China [10]. He concluded that without increasing the feed-in-tariffs from the current level of 90.9 € MWh^{-1} the economic viability of future projects cannot be guaranteed.

The results of a survey carried out among the heads of bureaus of forestry and county leaders responsible for forest programmes indicated that training and education in forest bioenergy should be increased [11]. The attitudes among these professionals were positive towards renewable energy in general, but less positive towards forest bioenergy. The professionals also felt that future development in the implementation of forest bioenergy requires cooperation between the government and enterprises.

It seems, therefore, that although the theoretical potential and general prerequisites for forest energy in China have been evaluated there is a lack of knowledge about the realistic possibilities of starting energy production based on residual forest biomass. Before making a decision on starting a biomass-fuelled plant, it is crucial to find out how much feedstock would be available, how it could be harvested and what would be the supply cost. These questions cannot be evaluated with a nation-wide assessment, but one must start in a carefully selected location with a more thorough case study.

The objectives of this study were 1) to assess the availability of logging residues for energy production, 2) to determine feasible supply chains, and 3) to estimate the biomass fuel supply costs. As the interest of SFA lay in Daxing'anling prefecture, the study was solely focused there. Within Daxing'anling Mohe county was determined as the target area.

1.2. General operating environment in the study area

Daxing'anling prefecture is located in the northernmost corner of China (Fig. 1). It mostly belongs to Heilongjiang province, but also partly to Inner Mongolia province. Daxing'anling is a special forestry area and administratively directly under SFA meaning that all the forests in the prefecture are owned by the state. The total area of the prefecture equals 83,000 km^2. The topography in the area is characterized by undulating, eroded mountains with slope angles mostly between 15° and 30°. The mean altitude in Daxing'anling region is 573 m, ranging from 180 m to 1528 m. The soil is mainly brown forest soil. According to the local forest authorities about 80% of the forest area is dominated by Dahurian larch (*Larix gmelinii*), 10% by white birch (*Betula platyphylla*) and 4–5% by Scots pine (*Pinus sylvestris* L. var. *mongolica* Litv.).

The climate in Daxing'anling is continental, and in Mohe county subarctic (Dwc in Köppen climate classification system [12]). The winters in Mohe are cold (average temperatures in January −36.2 to −21.5 °C) and long, and summers short and warm (average temperature in July 11.7–25.8 °C). The frost-free period lasts only approximately three months, which keeps tree growth low. Long winters also mean that the heating season is long, at least eight months. Currently, households in Daxing'anling are heated with charcoal.

Forestry and the forest industry are vital for the economy and employment of the region. In 2010, the production of sawn wood in Daxing'anling was 275.6 dam^3 [13]. There are no specific figures on the forest industry in Daxing'anling, but in the whole Heilongjiang province there were approximately 2000 wood processing enterprises with a total annual processing capacity of 9.6 hm^3 at the end of 2012. The main products include solid wood furniture, wooden doors and windows, floors, laminated wood, chipboards, fibreboards and wooden craft products. Due to the small size of harvested trees, the wood-products industry carefully utilizes the scarce resources. In addition to harvests from its own forests, Heilongjiang province imports annually around 10 hm^3 timber from Russia.

Currently, the use of forest chips in energy production in Daxing'anling is limited. Wood processing residues such as sawdust, bark and offcuts are partly utilized as energy, but part of the residues is treated as waste. At the end of 2013, there were two energy production facilities which were able to utilize woody biomass as feedstock.

One of the plants was located in Tahe city and was established in 2012. The main products of the plant were electricity and activated charcoal. The heat was utilized for drying the chips and heating the premises. The target was to raise the level of power production to 10 MW. The consumption of fresh wood chips amounted to 100,000 t, while the targeted use was even 250,000 t. Supply of chips was outsourced to 4–5 companies delivering the feedstock at a price of 37–39 € t^{-1} (average rate of RMB 8.165 in 2013).

The other plant, located in Songling, was built in 2011. The main product of this plant was charcoal, but the aim was to purify and sell the process gases as well. The daily feedstock consumption totalled 24 t which equals 6000–9000 t annual consumption depending on the utilization rate of the plant. The raw material cost at plant was 24–32 € t^{-1}.

2. Material and methods

The assessment of the availability of forest chips (chips made from logging residues) for energy was based on the SFA's statistics on the area, the growing stock and harvesting quota in Mohe county and on two thinning trials with the following steps: 1) estimation of thinning removals of stemwood, 2) estimation of stand-level removal of residues, and 3) combining the results of the former two to estimate the technical harvesting potential for forest chips.