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Prospect of briquetting biomass fuel by forest residues in Tibet

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Abstract−Tibet, a region that lacks fossil energy resource, mainly depends on traditional biomass to meet its rising energy demand. Irrational use of traditional biomass affects the local environment as burning of straw and animal dung as fuel pollutes the air and destroys vegetation and ecological environment. The rich forest resources and hydropower resources in the south and east of Tibet, however, hold out the hope of biofuel utilization industrialization, an innovative solution to the Tibet energy issue. Renewable hydropower may be used for briquetting biomass fuel by forest residues, which has higher energy efficiency than traditional biomass and is easier to store and transport. In so doing, the energy demand of Tibet will be better met with least damage to the environment. It also means less reliance on outside supply of fossil fuel even after the opening of the Qinghai-Tibet railway. In addition, it means more job opportunities for local residents as people will be hired to collect forest residues and transport them to the plants.

Key words: Briquette Fuel, Forest Residues, Sustainable Development

INTRODUCTION

Lying south-west of China, Tibet has vast land but sparse population. It covers an area of 1.22 million sq·km. It had a population of only 2.63 million in 2004, 95.7 percent of which being Tibetans. The population density is about only 2 persons/sq·km.

Tibet has unique features in geography, environment and ecology. The average altitude is more than 4,000 m, making Tibet the source of large and major rivers in China. The region ecological environment is very fragile and faces degradation of pasture and soil erosion.

The power grid in Tibet is supported mainly by renewable energy, with about 86 percent of power generation coming from hydroelectricity. In 2004, total installed generating capacity of Tibet amounted to 469 MW, including 404 MW of hydropower. Power generation in Tibet reached 1,206 gWh in 2004, of which 1,088 gWh was hydropower [China Electric Power Press, 2005].

Although there is abundant hydropower resource in Tibet, power shortages occur in certain periods of time. As the peak supply of hydropower is in summer while the maximal demand is in winter, Tibet experiences a surplus electricity supply in summer but power shortage in winter. Due to the vast land but sparse population, the investment is not cost-effective and several times higher than that of other places per kW.

Tibet is short of fossil energy resources. Until now, most of the coal, oil and LPG have been transported from elsewhere, at least 1,000 km away by road or pipeline. The coal is mainly used for the cement industry, the oil for transportation, and LPG for cooking. Due to the long distance transportation and the high cost of the fossil energy, energy consumption in Tibet is dominated by traditional biomass. In 2003, the total amount of energy consumption was about 2 million tons of coal equivalent (tce), of which the traditional biomass accounted for 70 percent.

At present, utilization of the biomass in Tibet is of low efficiency and proceeds in a way that rapidly degrades the environment and causes desertification. The local residents almost entirely depend on the traditional biomass for cooking and space heating. Most of the biomass is directly burned as fuel for cooking. Due to shortage of oxygen in Tibet and use of outdated stoves, the burning efficiency is very low, utilizing less 10 percent of the potential energy of biomass [Junfeng et al., 2005].

Meanwhile, there is no district heat supply in winter in Tibet and most of the local residents depend on the individual traditional space heating. Due to the cold winter's long duration, traditional space heating consumes a great deal of traditional biomass, which includes straw, firewood and animal dung. The cattle dung and straw, in particular, are used as the main fuels in the rural areas as well as in towns. Excessive utilization of straw and animal dung has degraded the local environment. In 2003, about 2.43 million ha of grassland was degraded by desertification, accounting for 3% of all grassland in Tibet. As the vegetation cover rate has dropped greatly, sandstorms and droughts occur more frequently.

Tibet faces difficulty in the energy supply. In the "Yijianglianghe" district in the southern part of Tibet, for instance, most of the straw is used as fodder and there is not much animal dung. About one quarter of the firewood and animal dung used in the area comes from elsewhere, 800 kilometers away.

In conclusion, the overuse of traditional biomass as fuel in partial areas damages the fragile environment. There exists an urgent need to utilize biomass energy in a rational way, which can be done through using surplus hydropower in summer to produce briquette biomass fuel from forest residues. This will not only improve energy efficiency, but also reduce pollution and damage to the ecological environment.

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1. Forest Residues Resource and Hydropower Resource

With a sparse population in a vast territory, the energy supply is provided as nearby as possible currently, the straw and cattle dung and some sparse shrubs and pasture as fuel are overly exploited in some areas, while the rich forest resource is little used. Tibet has abundant forest resources, mainly in the south and east, with a forest area of 7.17 million ha and an accumulation of 2 billion cubic meters of live stumpage. But little firewood and forest residues are utilized and much forest residue is decomposed and wasted in vain.

The rich forest resource coexists with hydropower in the south and east of Tibet. The potential hydropower in Tibet is about 110 GW in technology, which is the second largest hydropower resource in China and about 11 GW is small hydropower resource. About 90 percent of these are in south and east of Tibet, which holds out the possibility for biomass fuel utilization industrialization by forest residues.

2. The Biomass Briquetting Technology

Biomass has become an important renewable alternative energy resource and considered as one of the most promising candidates for a substitute for fossil fuel in the future. Besides the traditional combustion by family stoves, through carbonization, liquefaction, and gasification, biomass can also be converted into charcoal, liquid product and fuel gas. For example, rice bran oil is used to produce bio-diesel oil [Bak et al., 1996]. Food waste, rice husks and corn are also used as the biomass feedstock for fluidized bed combustors [Ko et al., 2001; Chyang et al., 2005]. Even the used vegetable oil can also be converted into liquid fuel [Charusiri et al., 2006]. It is an efficient combustion way of coal-biomass mixture in a circulating fluidized bed [Rodjeen et al., 2006].

The study focuses on the abundant forest residues in Tibet to meet its energy demand. Forest residues consist of bark, sawdust, wood shavings, and other wood wastes. Little forest residue in Tibet is utilized because of the bulk of these untreated materials and long transport distances, making the transportation cost high. In short, there exists a "high cost bottleneck" arising from collection, transportation and storage of forest residues fuel.

Production of briquette biomass fuel, including biomass pellet fuel, is a promising solution as it can increase volumetric heat content, decrease transportation costs, and make cooking and space heating more convenient in winter. Its heat caloric value and density are very close to coal with much fewer pollutants such as SO_2, NO_x, etc.

Biomass briquetting technologies include two approaches. The first is based on a lignin plasticization mechanism named Hot Briquette Technique (HBT) and a series of biomass HBT systems already have been widely developed and widespread in Japan, EU and USA. Generally, these systems are complicated, space demanding, energy consuming and involve high investment and cost. They are also very sensitive to biomass moisture content and the life of key abrasion-resistant components. Hence, the cost of bio-fuel by them is high and promotion of them heavily relies on government subsidies [Tripathi et al., 1998; Paulrud and Nilsson, 2001; Husain et al., 2002].

The second approach is the room temperature briquette technique for biomass with original moisture content, which is named Cool Briquette Technique (CBT). The CBT is simple and mobile, processing on the spot of raw material with small investment and low maintenance and operation cost and low energy consumption [Zhanbin, 2005]. The detailed comparisons are shown in Table 1.

Table 1. Comparisons of the briquetting technologies [Zhanbin, 2005]

Process step	HBT system	CBT system
Crushing	Diameter<10 mm	Diameter<10 mm
Drying	Moisture: 6-14%	Not necessary Moisture: natural (8-35%)
Briquetting	Pressure: 4-60 Mpa Temperature: 160-280 °C	Pressure: below 6 MPa Temp.: room temperature
Cooling	Below 50 °C	Not necessary
Storage	Water Proof	Not necessary

Compared with the HBT system that is complicated, expensive and space demanding, the CBT system is more promising and feasible in Tibet, which can make the forest residues briquette fuel enter the commercial fuel market to replace untreated traditional biomass fuel and fossil fuel imported by long distance transportation maximally.

Some people debate the suitability of biomass briquette as a substantial amount of energy is required for the briquetting process [Purohit et al., 2006]. As mentioned above, abundant forest resources coexist with the rich renewable small hydropower in south and east of Tibet; hence, the briquette fuel by forest residues is an energetically viable option. Therefore, the technology may play an important role in the Tibetan energy supply in the future.

3. The Biomass Briquette Fuel Industrialization Frame

As discussed above, the rich forest resources coexist with hydropower in the south and east of Tibet, which holds a possibility for biomass briquette utilization industrialization.

First, the biomass briquetting technology and formation forest residues are developed into briquette fuel by surplus hydro generation in the summer, products of which will be easier to transport and store. Secondly, they are used as residential fuel for cooking and space heating in high efficiency to displace the traditional biomass, especially straw and cattle dung. Finally, such biomass briquette will also be used as the fuel for district heat supply and generation. The industrialization frame is shown in Fig. 1.

As shown in the above figure, the briquette fuel of forest residues can be produced through making full use of the surplus and abundant hydropower in summer in the south and east of Tibet. This will reduce the straw and animal dung consumption as fuel and the space heating load by electricity in winter, increase the generation in winter if the processed products are used for power generation or CHP. It will be an innovative solution to the Tibet energy supply and mismatch between the hydropower peak supply and the power demand peak, and also avoid the pollution from burning fossil fuel. At the same time, an opportunity will be provided to increase local residents' income because most of the fuel collection and distribution cost will be converted into the local income, which will be discussed in detail in the next section.

4. The Cost of Biomass Briquette Fuel

Generally, the cost of the biomass briquette fuel is higher than that of the fossil fuel. Although such a system is not feasible from the standpoint of cost, it should be possible to reduce the CO_2 emissions by utilizing forest residues as alternative energy resources,

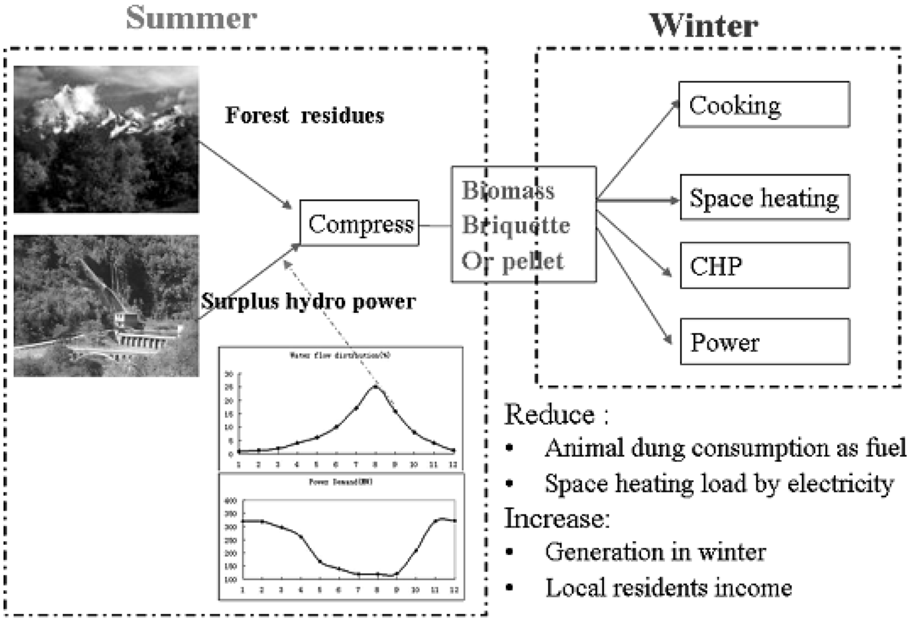

Fig. 1. Biomass briquette fuel industrialization in Tibet.

which is discussed in detail in the feasibility of a harvesting and transporting system for logging residues [Yoshioka and Aruga, 2006].

The cost of biomass briquette made from forest residues includes the cost of collection, briquetting, transportation and stove update. To discuss the cost in detail, it is necessary to make the scenario assumption:

Make use of the forest residues from Linzhi Prefecture forest industries in east of Tibet, briquette them on the spot of raw material, then transport to Lhasa city by road for cooking and space heating in winter.

Baseline scenario: The Qing-Zang railway (or Qinghai-Tibet railway), which has put into operation, will facilitate coal transport to Tibet. Therefore, the comparable object is coal imported by train and the traditional biomass. It is estimated that, the price of coal arriving in Lhasa City by train is about 450 yuan/t, the traditional firewood is 400 yuan/t and the cattle dung as fuel is 250 yuan/t.

If the biomass briquette fuel is used for cooking and space heating in winter, the combustion efficiency will be at least double that of the traditional firewood and cattle dung. Therefore, it will be competitive with the traditional firewood if the sale price of biomass briquette fuel is within 800 yuan/t. Detailed information is furnished as follows:

4-1. Collection Cost: 100 yuan/t

Currently, in the Linzhi Prefecture region, the south and east of Tibet, the annual amount of logging is about 120,000 cubic meters and at least 300,000 cubic meters forest residues will be produced and available at low collection cost. In this paper, the collection target is such forest residues from forest enterprises due to three reasons. One is to avoid exploiting the forest resource excessively and out of order; the second is to create new job opportunities for forest enterprises, which are losing business due to the national forest protection policy; and the final is the low collection cost and the easy availability of forest residues. It is estimated that the collection cost will be about 100 yuan/t.

4-2. Briquetting Cost: 110 yuan/t

The equipment investment is only 60 thousand yuan, and production capacity is 300 kg per hour; the electricity consumption is only 100 kWh/t and the total process cost is 110 yuan/t; the production bulk is only 20 percent of the original bulk, and the density and heat value is similar to the coal [Zhanbin, 2005].

4-3. Transport Cost: 240 yuan/t

The distance from Linzhi Prefecture to Lhasa City is 425 km. Considering the location of process sites, the distance is assumed to be at 500 km. Because the density of briquette fuel is similar to coal, a 10 t capacity truck may be used to transport with diesel consumption of about 40 litres per 10 t-100 km. Therefore, the trip to Lhasa City will consume diesel oil of 200 litres, plus other cost and the driver payment, the total cost is 2,400 yuan/10 t. Therefore, the transport cost is about 240 yuan/t [Wei and Oi, 2005].

4-4. The Total Cost and Sale Price

From the above analysis, the total cost of briquette fuel delivery to Lhasa City is about 450 yuan/t. plus other costs (national tax, enterprise profit and other uncertain fees), the sale price will reach to 630 yuan/t, which is summarized in Table 2.

Compared with coal transported to Tibet from other areas, the briquette fuel is less competitive obviously. But it enjoys much competitiveness over traditional firewood and cattle dung due to its greater

Table 2. Sumary of the biomass briquette fuel cost and sale price

	(yuan/t)
Collection cost	100
Briquetting cost	110
Transport cost	240
Total production cost	450
other cost	180
sale price	630

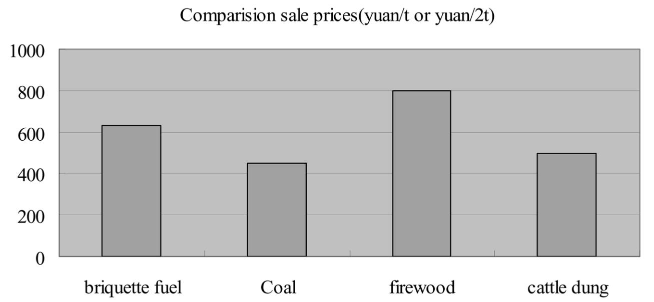

Fig. 2. Comparison of sale prices among the fuels in Tibet.

convenience and cleanness, which is shown in detail in Fig. 2.

Note: the combustion efficiency of briquette fuel approximately equals that of the coal and two times the traditional firewood and cattle dung.

In fact, the transport cost accounts for half of the total cost, which may be changed in the future. A new railway will be built from Linzhi Prefecture to Lhasa City, and the cost of railway transport is only 30 percent of that of road transport. By then, the total cost will drop down to 290 yuan/t and sale price will drop to 400 yuan/t, which will be fully competitive even compared with the price of coal.

Even if the sale price is 630 yuan/t, considering the CO_2 emission reduction, it is estimated that about 2 tons of CO_2 will be reduced from one ton of briquette fuel displacing the coal, assuming the revenue is 80 yuan per tonne of CO_2 emission reduction, according the recent carbon trade price of CDM project. The cost of briquette bio-fuel will drop by 160 yuan/t and sale price will drop to 470 yuan/t, which is similar to the coal price arriving in Lhasa city.

In the above analysis, the most uncertain thing is the collection cost. Through making good use of the forest industry residues, the collection cost will be further reduced and be more acceptable.

5. Benefit to Local Environment and Local Sustainable Development

In view of the energy shortage and CO_2 emission, bio-fuel is now being considered as an inexhaustible and clean energy resource all over the world, which can displace the fossil fuel consumption and reduce its pollutants emission and CO_2 emission to improve the climate and maintain an ecological balance.

In this case, if 80 percent of the forest residues from Linzhi Prefecture enterprises are processed to become briquette of bio-fuel, then 180,000 tons of bio-fuel will be available per year, which will substitute about 360,000 tons of traditional firewood or cattle dung or 180,000 tons of coal transported from 1,000 km away, reducing 2,100 metric tons of SO_2, 2,000 metric tons of NO_x, 1,230 metric tons of TSP and 360,000 tons of CO_2 separately.

For the local sustainable development, some studies have been carried out and in-depth discussions held on the drivers for implementing bioenergy projects from the viewpoints of potential economic benefits of commercial biomass e.g. employment/earnings, regional economic gain, contribution to security of energy supply and all others [Domac et al., 2005].

The approach will also promote local sustainable development. Assuming the sales price is 630 yuan/t, total output value will reach 110 million yuan. Assuming per capita output value will be 20,000 yuan, which is about 3 times the average per capita GDP of Tibet, this provides at least 5,500 job opportunities. Currently, the total employment is only 3,000 in Linzhi Prefecture forest industries and such an option will provide promising new opportunities for local forest enterprises [Gong and Wang, 2002; Zou, 2001].

In addition, most of the bio-fuel production cost will be directly converted into the local residents' income. The collection cost, briquetting cost and transport cost will reach 81 million yuan annually, which will increase the local income and improve lifestyles greatly.

CONCLUSION

In a word, producing briquette bio-fuel from forest residues is a promising option for energy supply in Tibet. It will produce the following benefits:

1. Displace the traditional biomass of straw and cattle dung and protect the local fragile environment, substitute for the fossil fuel consumption transported from at least 1,000 km away and avoid pollutants emissions, such as SO_2, NO_x, TSP and CO_2.
2. Make good use of the abundant forest resources and hydro power in the south and east of Tibet cost-effectively.
3. Provide an innovative solution to the Tibet energy supply and mismatch between the hydro peak supply and the power demand peak.
4. Facilitate the local sustainable development through increase of the local income and job opportunity.

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NOMENCLATURE

sq·km : squre kilometers
MW : megawatt
gWh : giga watt hours
tce : tons of coal equivalent which equals 7 giga-cal
ha : hectare
CHP : combined heat and power
SO_2 : doxide sulfur
NO_x : nitrogen oxides
TSP : total suspended particles
CO_2 : doxide carbon

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