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ABSTRACT

This paper evaluates the potential production of non-food biofuels in China. The evaluation is conducted for ethanol and biodiesel. The ethanol production is predicted based on the available amounts of energy crops, agricultural and forest residues and waste molasses, while the biodiesel is predicted to be produced from wood energy plants and waste cooking oil. The results indicate that China's potential capacity on non-food biofuels from 2015 to 2030 will be in the range between 75.60 and 152.13 million metric tons. In order to exploit this potential capacity, there is a long way to march.

1. Introduction

China's rapid economic growth has resulted in a supply constraint on the country's energy consumption, especially its crude oil consumption. China's dependence on crude oil imports keeps increasing since it began to import crude oil in 1993. Moreover, China surpassed the United States as the largest energy consumption country in the world (IEA, 2011). In 2013, China's apparent consumption in crude oil was evaluated at 514 million metric tons[1], and the net imports reached 289 million metric tons. This means that China's dependence ratio on imports was 56.23% in the year. Therefore, the development of biofuels might be an effective manner to relieve the crude oil supply constraint.

However, the limited production of biofuels may not be enough to fill the gap between energy demand and supply. In 2012, China's ethanol and biodiesel production were 1.66 million metric tons, and 0.5 million metric tons, respectively. These amounts were too small comparing to the apparent consumption of petroleum product, which were 278 million metric tons in that year. Hence, for the sake of energy security, China's biofuel production should increase remarkably.

China enjoyed a historical high of food production in 2013. The food production reached 602 million metric tons in that year. However, given the threat of arable land decreasing, lack of irrigating water, and difficulty in increasing yields, it is a long-term challenge for China to maintain its food security strategy. Massive population, dearth of arable land, and food security strategy restrict China from using food and vegetable oil to produce biofuels.

In addition to food products, non-food agricultural products like straw, forest residues and wood waste, waste cooking oils can be used to produce biofuels. As a country abundant in non-food agricultural products, China has a great potential to transfer these products into biofuels to complement its crude oil supply [6,12,14]. Therefore, an accurate quantitative evaluation on China's potential to transfer non-food agricultural products to biofuels is very critical for China to design policies on biofuel production and biofuel crops' distribution.

This paper is designed to conduct such quantitative evaluation. In Section 2, the evaluation starts from studying the amounts of raw materials for biofuel production. Such raw materials include marginal land for non-food biofuel plants, and agricultural and forest residues. In Section 3, the amounts of such raw materials are converted into potential production of ethanol and biodiesel for the next fifteen years. Section 4 is for conclusion. The technology in biofuel production is critical but not be covered in this paper. For people, who are interested in biofuel technology, they can find good discussion in Refs. [1,2,9].[2]

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[1] 1 metric ton = 1000 kg.

[2] Ethanol can be produced from corn and sugarcanes, and biodiesel can be produced from soybean oil, rapeseed oil and animal fats. Since the production of the first generation biofuels demands for food products as inputs and it competes with people's food consumption, the expansion of the biofuel production based on these inputs cannot be sustainable in long-term. Hence, in this paper we do not discuss such biofuel inputs.

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Table 1
The regional distribution of the three-rank marginal land for non-food biofuel crops and plants in China, unit: ten thousand hectares.

Region	Area	Rank I	Rank II	Rank III
Northeast	222.46	21.46	50	151
North China	79.02	19.02	25	35
Loess Plateau	200.24	47.91	25	127.33
Middles-and-Downstream of Yangtze River	178.64	33.64	75	70
Inner Mongolia and Xinjiang	760.43	193.37	292.46	274.6
South China	75	15	25	35
Southwest	641.27	75	168.4	397.87
Qinghai-Tibet	22.73	16.26	4.99	1.48
Total	2371.81	421.66	774.02	1176.13

Sources: Investigations of ministry of land and resources and ministry of agriculture.

2. The potential production of raw materials for biofuels in China

Stable and abundant supply of raw materials is indispensable for China to increase its biofuel production. Because of China's food security strategy and limited supply of arable land and water resource, corn, wheat, rapeseed and soybeans cannot be used as raw materials to produce biofuels in China. Increasing biofuel production requires more supply of non-food crops [13]. To achieve this goal, China can produce ethanol by reclaiming marginal land for non-food energy crops like cassava, sweet potato, and sweet sorghum, and building projects to make use of straw and forest residues. As to increase biodiesel production, China can also plant energy plants like Jatropha curcas (Barbados nut), Pistacia chinensis (Chinese pistache), Vernicia fordii (tung oil tree), Xanthoceras sorbifolium (shiny leaf yellowhorn), Swida wilsoniana (Chinese dogwood), Triadica sebifera (Chinese tallow tree) on barren hills and mountains. The nuts and seeds of these plants are abundant in oil, which can be used to produce biodiesel. Additionally, waste cooking oil can also be collected for producing biodiesel in China too [7].

2.1. Marginal land for non-food biofuel crops and plants in China

Ministry of Land and Resources and Ministry of Agriculture conducted investigation on the area, quality, style and utilization of the marginal land for non-food energy crops and plants in China in 2003 and 2007, respectively. Their investigations indicate that the total marginal land for non-food energy crops and plants reached 23.72 million hectares. The marginal land is categorized into Rank I to Rank III in a quality degeneration order.[3] Among the total 26.8 million hectares, Ranks I to III are 4.22, 7.74 and 11.76 million hectares, respectively. The distribution of the marginal land for non-food energy crops and trees in different regions are listed in Table 1.

Because wood plants' advantage in being adaptive to environment, part of Rank II and all of Rank III can be used for energy plants (Jatropha curcas, Pistacia chinensis, Vernicia fordii, Xanthoceras sorbifolium, Swida wilsoniana, Triadica sebifera) in biodiesel production. The other marginal land can be used to other energy crops (cassava, sweet potato, and sweet sorghum) for ethanol production. Moreover, according to the consumption ratio between diesel and gasoline, it is presumed that total Rank I and one thirds of Rank II marginal land will be used to produce ethanol and total Rank III and two thirds of Rank II marginal land will be used to produce biodiesel. The distribution of the marginal land for ethanol and biodiesel across different regions in China is listed in Table 2.

2.2. Agriculture and forest residues

2.2.1. Crop straw

In 2010, China's grain production was 570 million metric tons. The hay to grain ratio[4] indicates that the straw production was evaluated at 700 million metric tons. Deducting the amount that is used as fertilizers, feeds and inputs of other industrial products, around 350 million metric tons of the total straw production can be used to produce bioenergy, which is equal to 180 million metric tons of standard coal [4]. The conversion ratio from straw to ethanol is 20%. Given the large amount of straw production, China can increase its bioenergy production by making ethanol from straw.

Using the average growth rate of China's grain production from 1996 to 2013, we project China's straw production in 2015, 2020, 2025 and 2030. The projection indicates that China's straw production will grow stably and reach 802.79, 841.00, 882.14 and 926.43 million metric tons in 2015, 2020, 2025 and 2030, respectively (Table 3).

2.2.2. Forest residues and wood waste

Forest residues and wood waste are supplied from three sources in China: forest harvesting and forest metabolism, timber processing, and urban wood waste [11]. evaluates that around 35–40% of the total forest residues and wood waste are not collected or utilized. This unutilized volume can be used as fiber inputs for ethanol.

Every year, forest harvesting and forest metabolism generates around 900 million metric tons forest residues and wood waste. According to the Seventh Forestry Resource Check, the forest harvesting in China is around 379 million cubic meters every year, out of which merchantable and non-merchantable timbers are 239.53 and 139.47 million cubic meters, accounting for 63.2% and 36.8%, respectively. Given that the ratios of forest residues of merchantable and non-merchantable timber are 35% and 50%, the total forest residues from harvesting can be 154 million cubic meters. This can be used to produce biofuel in China.

In addition to the forest residues from forest harvesting, the

[3] The rank of marginal land is determined by grade, effective soil depth, soil quality, degree of salinization-alkalinization, moisture content, and temperature. Rank I has the best quality while Rank III has the worst.

[4] The hay to grain ratio is a ratio between the yields of the grain and straw. This ratio is normally stable.

[5] In addition to supporting policies, the progress in technology is also critical for achieving the potential production. For example, forest and wood residues contain enormous amounts of lignocellulosic waste. This work predicts that the potential ethanol production from forest and wood residues can reach 34.08 million metric tons by 2030. However under the current technologies, to convert lignocellulosic biomass to alcohol is much more difficult than to convert starch based feedstocks [9]. In the process, how to increase the efficiency of xylose fermentation strains is especially difficult. More technological details and a new improvement are discussed in Ref. [15].

Table 2
The regional distribution of the three-rank marginal land for ethanol and biodiesel production in China, unit: ten thousand hectares.

Region	Ethanol		Biodiesel	
	Rank I	Rank II	Rank II	Rank III
Northeast	21.46	16.67	33.33	151
North China	19.02	8.33	16.67	35
Loess Plateau	47.91	8.33	16.67	127.33
Middles-and-Downstream of Yangtze River	33.64	25	50	70
Inner Mongolia and Xinjiang	193.37	97.49	194.97	274.6
South China	15	8.33	16.67	35
Southwest	75	56.13	112.27	397.87
Total	405.4	256.34	512.69	1176.13

Source: Authors' calculation using survey data of ministry of land and resources and ministry of agriculture.

Table 3
The projection of China's agricultural straw production, 2015, 2020, 2025, and 2030, unit: million metric tons.

Year	Grain straw	Bean straw	Yam straw	Oilseed straw	Cotton straw	Total
2015	576.34	30.00	78.92	50.86	65.62	802.79
2020	604.50	29.35	75.43	58.23	72.44	841.00
2025	633.62	28.71	72.10	66.68	79.98	882.14
2030	663.73	28.08	68.91	76.35	88.31	926.43

Sources: Authors' calculation using data from Ref. [3] and Handbook of Technological Economics in Agriculture (1993) [5].

residues from timber processing are also inputs for ethanol production. The harvestings of merchantable and non-merchantable timbers are 239.53 and 139.47 million cubic meters. The final timber production rates for merchantable and non-merchantable timber are 65% and 50%, respectively. Hence, every year the production of final merchantable and non-merchantable timbers are 155.7 and 69.7 million cubic meters. Because 80% and 20% of the final merchantable and non-merchantable timber are processed in timber mills, and the utilization rates are 70% and 30%, the wood waste produced in timber mills is

$$155.7 \times 80\% \times (1 - 70\%) + 69.7 \times 20\% \times (1 - 30\%) = 47.1$$

million cubic meters. Then the total forest residues and wood waste from timber processing is 201.1 million cubic meters.

China's forestry resource is increasing in recent years. The growth rate of China's forestry reserve is 1.85% per year. The projections of the forest residues and wood waste for year 2015, 2020, 2025 and 2030 are calculated using a growth rate of 1% and the projections are listed in Table 4.

2.2.3. Waste molasses

Waste molasses left from sugar production accounts for 30% of raw sugar. Every year, around 25% of the waste molasses is used to produce ethanol. Based on the production of sugar crops in recent years, we project the amount of waste molasses for the period from 2015 to 2030 (Table 5).

2.2.4. Waste cooking oil

The available amount of waste cooking oil is positively correlated with the consumption of edible oils and animal fats. Normally, the ratio of the waste cooking oil to the consumption of edible oils and animal fats is around 20%. In China, it is not economically efficient to collect cooking oil in rural area, but might be efficient in urban area. In 2010, per capital consumption of edible oils was 23 kg and the annual growth rate was 3%. This growth rate will be stable until 2020. Per capita consumption of meat and poultry are 35 kg. The content ratio of fats in meat is around 20%, and the ratio of waste cooking oil to animal fats is also around 20%. Moreover, the Sixth National Population Census indicates that in 2010 China's total population was 1.34 billion, and the urbanization rate was 49.68%. China's population growth rate was 0.5% and the growth rate of urbanization was 1%. By using China's demographic data and the data of consumption of edible oil and animal fats, we can project the waste cooking oil amount in urban China from 2015 to 2030 (Table 6).

The projection implies that in 2015, China's waste cooking oil production will reach 5.09 million metric tons, which can be converted into 4.58 million metric tons of biodiesel. This means that

Table 5
The projection of China's waste molasses, 2015–2030, unit: million metric tons.

Year	Production of waste molasses	Year	Production of waste molasses
2015	6.09	2023	8.16
2016	6.33	2024	8.43
2017	6.58	2025	8.71
2018	6.84	2026	9.00
2019	7.11	2027	9.30
2020	7.39	2028	9.62
2021	7.64	2029	9.94
2022	7.89	2030	10.28

Source: Authors' calculation using data in Ref. [3].

Table 4
The projection of China's forest residues and wood waste, 2015, 2020, 2025, and 2030.

Year	Forest residues from harvesting (million cubic meters)	Wood waste from processing (million cubic meters)	Forest residues and wood waste (million metric tons)
2015	164.6	50.5	130.5
2020	173.0	53.1	137.1
2025	181.9	55.8	144.1
2030	191.1	58.7	151.5

with appropriate encouraging policies, waste cooking oil can be utilized to produce biodiesel to relieve the problem of energy deficiency in China. From the perspective of economic efficiency, big cities, especially provincial capitals should be given priority in China's biodiesel production by using waste cooking oil. In 2015, 31 provincial cities (including four cities directly under the central government) will produce 1.57 million metric tons of waste cooking oil, and in the big- and middle-size cities, the waste cooking oil production will reach 3.20 million metric tons.

3. Evaluation of potential production capacity of biofuels

3.1. Ethanol

Energy crops, straw, forest residues and wood waste, and waste molasses will be the major sources of China's ethanol production in near future. Energy crops include cassava, sweet potato, sweet sorghum, which have characteristics good for ethanol production [10]. The cassava is feasible to plant in tropical and subtropical areas, and the content ratio of starch is around 30–35%. In 2005, China's cassava planting area was 0.6 million hectares, and the production was 11 million metric tons. Cassava has accounted for around 35% of China's total bioethanol production capacity [2]. The world's first large-scale cassava ethanol plant was built in Guangxi Zhuang Autonomous Region in China by China National Cereals, Oils and Foodstuffs Corporation (COFCO) in 2007. The designed annual production capacity is 200,000 metric tons [8]. The Ministry of Agriculture plans to increase the planting area of cassava to 1 million hectares in 2015. Today, China is the world largest country in sweet potato planting. The planting area is around 5 million hectares, and the annual production is around 100 million metric tons. Sweet sorghum is high in photosynthetic efficiency and can be planted in various regions, and it is also a good energy crop.

As to the plating regions, cassava is suitable for South China and Southwest China. The increase in the ethanol production from cassava must rely on the increase in the yield. Sweet potato is suitable for North China, Loess Plateau, Middles-and-Downstream of Yangtze River and Southwest China. Sweet sorghum is suitable for Northeast, North China, Loess Plateau and Inner Mongolia and Xinjiang. The seeds of sweet sorghum will also benefit the grain output.

Energy crops to produce ethanol can be planted in Rank I and Rank II marginal land. The formula for ethanol production from energy crops, E_{ac}, is

$$E_{ac} = \sum_{i=1}^{n} (q_{1i}Q_{1i}\mu_1 + q_{2i}Q_{2i}\mu_2) \tag{1}$$

The idea behind this equation is simple. We first evaluate how many metric tons of the three crops can be harvested from Rank I and Rank II marginal land every year. Then the fixed conversion ratios are used to evaluate how many tons of ethanol can be produced from the crop harvests. In Equation (1), q_{1i} is the conversion ratio to ethanol of crop i planted in Rank I marginal land, q_{2i} is the conversion ratio to ethanol of crop i planted in Rank II marginal land, Q_{1i} is the planting area of crop i in Rank I marginal land, Q_{2i} is the planting area of crop i in Rank II marginal land, μ_1 is the cultivation ratio of Rank I marginal land, and μ_2 is cultivation ratio of Rank II marginal land, and there are n types of energy crops for ethanol production.

Because of the different quality, cultivation rates are also different across different kinds of marginal land. Rank I marginal land can be cultivated directly. If the land is used for planting energy crops now, the cultivation rate can increase to 40%, 60%, 80% and 100% in 2015, 2020, 2025 and 2030, respectively. The planting cost of Rank II marginal land is higher and the increase in the cultivation rate is slower. The rate can increase to 30%, 50%, 65% and 80% in 2015, 2020, 2025 and 2030, respectively. Moreover, the yields of Rank I and Rank II is evaluated to increase 1% every year. The yield of Rank II is around 80% of Rank I for a same energy crop. Combining these facts, we can evaluate China's ethanol production from crops planted in marginal land (Table 7). From the perspective of energy crops, sweet sorghum, sweet potato and cassava are ranked in a decreasing order for ethanol production in each hectare. The projection of China's ethanol potential production from these three crops are displayed in Table 8.

Table 9 contains the potential projection of ethanol in China. The potential production will reach 63.6, 88.8, 107 and 118 million metric tons in 2015, 2020, 2025 and 2030, respectively. The major sources are energy crops, straw and forest residues and waste wood. All three account from 97.5% of the total potential production. Energy crops, like Cassava, sweet potato and sweet sorghum, can make use of marginal land. Straw and forest residues and waste wood have great potential and should be treated as primary sources.

3.2. Biodiesel

3.2.1. Wood energy plants

China can use two-thirds of Rank II and all Rank III marginal land to plant wood energy plants. The cultivation rate of Rank II marginal land can reach 30%, 50%, 65% and 80% in 2015, 2020, 2025 and 2030. The rate of Rank III can reach 20%, 35%, 50% and 65% in those years. From the perspective of planting regions of the energy trees, Northeast and Inner Mongolia and Xinjiang are suitable for Xanthoceras sorbifolium, North China is suitable for Pistacia chinensis, Vernicia fordii and Swida wilsoniana, Loess Plateau is suitable for Pistacia chinensis and Xanthoceras sorbifolium, Middles-and-Downstream of Yangtze River is suitable for Swida wilsoniana and Triadica sebifera, South China is suitable for Jatropha curcas, Pistacia chinensis and Triadica sebifera, and Southwest China is suitable for Jatropha curcas, Pistacia chinensis and Vernicia fordii. For the region that is suitable for more than one wood energy plants, the marginal land in this region is equally divided for all these plant.

Using the data of the wood energy plants, the formula for potential production of biodiesel from wood energy plants,E_{bc}, is

Table 6
The projection of China's waste cooking oil, 2015, 2020, 2025, and 2030.

Year	Urban population (million)	Waste cooking oil production (million metric tons)	Waste cooking oil production in big- and middle-size cities (million metric tons)	Waste cooking oil production in provincial capitals (million metric tons)
2015	755.46	5.09	3.20	1.57
2020	844.94	6.41	3.79	1.86
2025	929.17	7.49	4.22	2.08
2030	1015.74	8.71	4.72	2.33

Source: Authors' calculation.

Table 7
The projection of the regional distribution of China's ethanol production from three energy crops, 2015, 2020, 2025 and 2030, unit: ten thousand metric tons.

Region	2015	2020	2025	2030
Northeast	54.49	88.93	123.50	161.61
North China	36.89	59.49	82.88	108.61
Loess Plateau	81.27	129.43	180.88	237.46
Middles-and-Downstream of Yangtze River	65.18	106.25	147.67	193.10
Inner Mongolia and Xinjiang	436.23	705.33	981.77	1286.49
South China	32.64	52.78	73.49	96.17
Southwest	161.50	263.06	365.67	478.08
Total	868.19	1405.28	1955.86	2561.51

Source: Authors' calculation.

Table 8
The projection of China's ethanol potential production from three energy crops, 2015, 2020, 2025 and 2030, unit: ten thousand metric tons.

Year	Ethanol from cassava	Ethanol from sweet potato	Ethanol from sweet sorghum
2015	121.32	189.53	557.34
2020	197.13	307.37	900.78
2025	274.16	427.45	1253.95
2030	358.5	559.76	1643.24

Source: Authors' calculation.

Table 9
The projection of China's ethanol potential production from four sources in 2015, 2020, 2025 and 2030, unit: million metric tons.

Year	Energy crops	Straw	Forest residues and waste wood[5]	Waste molasses	Total
2015	8.68	24.08	29.36	1.52	63.64
2020	14.05	42.05	30.85	1.85	88.80
2025	19.56	52.93	32.43	2.18	107.09
2030	25.62	55.59	34.08	2.57	117.85

Source: Authors' calculation.

$$E_{bc} = \sum_{i=1}^{m} (q_{2i}Q_{2i}\eta_2 + q_{3i}Q_{3i}\eta_3) \tag{2}$$

where q_{2i} is the conversion ratio of wood energy plant i planted in Rank II marginal land, q_{3i} is the conversion ratio of wood energy plant i planted in Rank III marginal land, Q_{2i} is the planting area of plant i in Rank II marginal land, Q_{3i} is the planting area of plant i in Rank III marginal land, η_2 is the is the cultivation ratio of Rank II marginal land, and η_3 is cultivation ratio of Rank III marginal land, and m is the types of wood energy plants for ethanol production.

The projection using the above formula and data indicates that in 2015 China's potential production of biodiesel from wood energy plants will be 6.87 million metric tons. This level will increase to 14.60 and 25.57 million metric tons in 2020 and 2030, respectively (Table 10).

Table 11 contains the biodiesel potential production of every major energy plant. The potential production prioritizes the planting of Pistacia chinensis, Xanthoceras sorbifolium, Jatropha curcas and Vernicia fordii. Xanthoceras sorbifolium has the largest potential production and is suitable for Northeast and Inner Mongolia and Xinjiang. Pistacia chinensis can be planted in more regions than the others and is suitable for North China, Loess Plateau, Southwest and South China. Vernicia fordii has the longest planting history and is suitable for North China and Southwest. Jatropha curcas is suitable for Southwest and South China.

3.2.2. *Waste cooking oil*

The formula for biodiesel production from waste cooking oil, W_t, is

$$W_t = p_t u_t o_t \tag{3}$$

where p_t is China's population in year t, u_t is the rate of urbanization, and o_t is the production of waste cooking oil per capita. The biodiesel potential production from waste cooking oil is displayed

Table 10
The projection of the regional distribution of China's biodiesel potential production from wood energy plants, 2015, 2020, 2025 and 2030, unit: million metric tons.

Region	2015	2020	2025	2030
Northeast	0.89	1.55	2.16	2.76
North China	0.22	0.57	0.78	0.99
Loess Plateau	0.33	1.27	1.78	2.30
Middles-and-Downstream of Yangtze River	0.69	1.17	1.59	2.01
Inner Mongolia and Xinjiang	2.69	4.58	6.22	7.85
South China	0.17	0.47	0.65	0.83
Southwest	1.87	4.98	6.91	8.83
Total	6.87	14.60	20.08	25.57

Source: Authors' calculation.

Table 11
The Projection of China's biodiesel potential production from wood energy plants, 2015, 2020, 2025 and 2030, unit: ten thousand metric tons.

Wood energy plants	2015	2020	2025	2030
Pistacia chinensis	0	283.28	393.17	503.06
Jatropha curcas	94.51	162.57	224.98	287.39
Vernicia fordii	113.34	194.96	269.81	344.66
Xanthoceras sorbifolium	392.2	670.78	918.26	1165.73
Swida wilsoniana	52.4	89.29	121.36	153.44
Triadica sebifera	34.93	59.52	80.91	102.3

Source: Authors' calculation.

Table 12
The projection of China's biodiesel potential production from waste cooking oil, 2015, 2020, 2025 and 2030, unit: ten thousand metric tons.

Year	East region	Middle region	Northeast region	Southwest region	Northwest region
2015	116.95	65.25	32.48	48.39	24.34
2020	138.42	77.23	37.69	56.71	28.59
2025	154.65	86.28	41.28	62.73	31.71
2030	172.92	96.47	45.25	69.45	35.19

Note: East region includes Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong and Hainan. Middle region includes Shanxi, Henan, Hubei, Hunan, Anhui and Jiangxi. Northeast includes Liaoning, Jilin, Heilongjiang. Southwest includes Sichuan, Chongqing, Guangxi, Yunnan, Guizhou and Tibet. Northwest includes Shanxi, Gansu, Inner Mongolia, Xinjiang, Ningxia and Qinghai.

Table 13
The projection of China's biodiesel potential production, 2015, 2020, 2025 and 2030, unit: million metric tons.

Year	Wood energy plants	Waste cooking oil	Total
2015	6.87	5.09	11.96
2020	14.60	6.41	21.01
2025	20.08	7.49	27.57
2030	25.57	8.71	34.28

Source: Authors' calculation.

in Table 12. The potential production is evaluated across regions in China.

Combining biodiesel from wood energy plant and waste cooking oil, we can get China's total biodiesel potential production (Table 13). From 2015 to 2030, the potential production will increase from 11.96 million metric tons to 34.28 million metric tons. The potential production from wood energy plants will dominate China's biodiesel production and should be treated as a primary source. The potential production of waste cooking oil is relatively small but has positive impacts on China's food safety and should play important role in China's biodiesel production.

4. Conclusions

The projections in this paper indicate that from 2015 to 2030 China's potential capacity of ethanol will be from 63.64 to 117.85 million metric tons, and the biodiesel production will be from 11.96 to 34.28 million metric tons. However, this potential capacity cannot be achieved unless agriculture and forest residues can be collected efficiently for biofuel production. Currently, the biofuel price and production cost indicate that it might not be economically efficient to produce biofuels from non-food crops.

Hence, in order to foster the growth of biofuel production, encouraging policies are necessary. First, the growth of the biofuel industry in China requires subsidies from the government. These subsidies should not only focus on the biofuel production, but also benefit the procedures like planting, harvesting and transportation. This will improve the economic efficiency for China's biofuel industry. Second, as to the subsidies on the production, the policies should encourage the enterprises' efforts on R&D in biofuel technologies, especially those can increase the conversion ratios from raw inputs to final products.

The critical issue of these supporting policies is to prolong the biofuel industrial chain, which includes the planting, harvesting and transportation of inputs like the non-food energy crops, forest residues and wood waste. Additionally, the utilization of the by-products is also important. The longer the industrial chain, the more sectors can be benefited from the expansion of biofuel production. The development of the biofuel industrial chain will benefit the all participants including farmers, production enterprises and distributors. These benefits will provide incentives for investors to enter biofuel industry.

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