Liquid Biofuels for Transportation

Chinese Potential and Implications for Sustainable Agriculture and Energy in the 21st Century

Assessment Study

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Abbreviations & Acronyms

APERC	Asia Pacific Energy Research Centre
ASTM	American Society of Testing and Material
BMVEL	German Ministry for Consumer Protection, Nutrition and Agriculture
BTL	Biomass–to–Liquid
BX	Brix Value
CAAE	Chinese Academy of Agricultural Engineering
CAS	Chinese Academy of Sciences
CBH	Chinese Business Handbook
CFPP	Cold Filter Plugging Point
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corporation
CSY	China Statistical Yearbook
DDGs	Distillers Dried Grains
EC	European Commission
EPP	Environmental Preferable Product
ERI	Energy Research Institute
EU	European Union
FAO	United Nations Food and Agriculture Programme
FNR	Fachverband nachwachsende Rohstoffe (German Association for renewable prime material)
FT	Fischer-Tropsch process (Biomass-to-liquid, developed in Germany and South Africa)
GMO	Genetically Modified Organisms
GTZ	Deutsche Gesellschaft fuer technische Zusammenarbeit / German technical Cooperation
IBC	Investing Business with Knowledge, Asia Branch, Singapore
IEA	International Energy Agency
IEEP	Institute of Energy and Environmental Protection
IFEU	Institut fuer Energie– und Umweltforschung
LAMNET	EU-Latin America Thematic Network on Bio-energy
LCA	Life-cycle assessment
LPG	Liquid Petrol Gas
MDG	Millennium Development Goals
MES	Methyl Esters
MOA	Chinese Ministry of Agriculture
MOF	Chinese Ministry of Finance
MOST	Chinese Ministry of Science and Technology
nd	No data available
NDRC	National Development and Reform Commission / before SDPC
NYBOT	New York Board of Trade
PRC	People’s Republic of China
R&D	Research and Development
RE	Renewable Energies
SCF	Supercritical fluid technology
SDPC	State Development and Planning Commission / now re-named in NDRC
SEA	State Energy Administration
SETC	State Economics and Trade Commission / now re-named in NETC-National …….
SINOPEC	China Petrochemical Corporation
SOE	State Owned Enterprise
SPC	State Planning Commission
SSTC	State Science and Technology Commission
STA	State Tax Administration
TCM	Traditional Chinese Medicine
UFEP	Union zur Foerderung von Oel- und Proteinpflanzen e.V.
ULSD	Ultra Low Sulphur Diesel
UNCTAD	United Nations Conference on Trade And Development
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USDOE	United States Department of Energy
USA	United States of America
WDG	Wet distilled grain

WHO	World Health Organisation

Units & Currencies

EUR	Euro
US $	Us Dollar (1 $ = 0.83 €)
RMB	Chinese currency YUAN (10 RMB = 1 €; 8 RMB = 1 USD)

BN	Billion (USA)
b/d	Barrel per day
GJ	Giga Joule = 10^9 Joule
ha	hectare, hectares
Kg	Kilogram
Kwh	Kilo watt hour
l	litre, litres
Mio	Million
MT	Metric tons
mu	1/15 ha
Mwh	Mega Watt hours
PJ	Peta Joule = 10^{15} Joule
t	Ton, tonnes = 1000kg
t/a	Tonnes per year
TOE	Tons-oil-equivalent
TCE/SCE	Tons-coal-equivalent (1 KWh = 0.1229 kg CE/SCE / 1 TCE= 29.3076 GJ)

Key Issues

Renewable energy, fossil fuel, fuel substitution, fuel security, liquid biofuel, biodiesel, bioethanol, transportation, environmental protection, biomass, energy crops, energy agriculture, energy forestry, food security, rural development, industrial development, employment opportunity

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1 Introduction & summary

1.1. Background and Rationale of the Chinese Biofuel Assessment Study

China's share of world Carbondioxide (CO_2) emissions will increase from 12% in 2000 to 18% in 2025, rapidly approaching the today USA share of 22%[1]. In view of this trend, the problem of Greenhouse Gas (GHG) emissions cannot be seriously addressed without engaging China[2]. The country has officially accepted that climate change is a potential problem, and is a signatory of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

Besides, the country has many high priorities, which need to be addressed urgently and one way could be the promotion of liquid biofuel and its related feedstock production:

a) To maintain rapid economic growth[3],

b) To provide employment for large numbers of people leaving traditional agriculture, and those released from state owned enterprises (SOEs),

c) To assure political stability,

d) To reduce floods and water and air pollution, while preserving energy and food security.

To cover the national demand of its fast growing economy, China is already the second largest buyer for crude oil worldwide. The country is in need for solutions to reduce the dependency on imports and high oil prices. Likewise it also is under pressure to reduce CO_2 and sulphur emissions from transport and agricultural machinery; therefore both, the public and the private sectors are looking into alternative fuels. The government tends to promote the development of technologies that can be applied to quick and large-scale production, but needs also to map out an overall applicable and effective energy strategy[4]. In October 2005 Chinese Communist Party leaders approved the national blueprint for economic development between 2006 and 2010. It calls for improving energy efficiency, environment protection, strengthening infrastructure, and gives priority to energy and agriculture with a top priority to solve rural income and development problems in the five-year plan.[5]

Worldwide, there is an increasing dynamic in the use of liquid biofuels blending or replacing fossil fuels. Supported by the international conferences for renewable energy 2004 in Bonn, Germany[6], and 2005 in Beijing[7], there is evidence for a rising interest in the use of alternative fuels. While the production in the USA and in Europe is accelerating quickly, a growing number of industrialised and developing countries is looking for the most appropriate way how to promote the production and use of liquid biofuel.

Currently, several initiatives with different motivations have been started. Some of the countries (like Brazil and Malaysia) expect growing export opportunities to Europe, Japan and the USA markets whereas others have been driven by ecological aspects, the reduction of the oil import dependency (like China, India, South Africa) or by internal economic problems (like Tanzania). At the same time sound information of costs, potentials, chances and risks are only available in a limited range. The current patterns of the liquid biofuel markets are diverse and unclear.

GTZ therefore has been commissioned to comprehensively survey the issue of "liquid biofuels for transportation" in a global environment guided by the principle of sustainable agriculture, energy and

[1] IEA 2004
[2] and Brazil and India and other rapidly growing economies
[3] Cooper 2004: the official aspiration is to quadruple its GDP between 2000 and 2020, implying average annual growth of 7.2%
[4] Zhou Fengqi, deputy director Institute of Energy, NDRC, Business Watch Magazine/China Daily Sept. 30,2005
[5] The Wall Street Journal, November 11-13, 2005, page 15
[6] International Conference for Renewable Energies, Bonn, June 2004, Germany (www.renewables2004.de)
[7] Beijing International Energy Conference, November 2005, China (www.birec2005.cn)

transport, and to bring the results of the analysis in the international debate. The global survey is carried out by the Worldwatch Institute, Washington, USA[8]. As a basis for the formulation of an international policy approach also country-specific considerations have to be analysed and to be taken into account.

Regional studies are being undertaken in Brazil, China, India, Tanzania, USA and Europe to act as a basis for the global survey. GTZ took the responsibility for organising and executing regional workshops and the concluding international conferences in Berlin and Washington as well as providing regional forums for further political consultation. One of them took place in Beijing, China on November 16th, 2005, directly related to the "World Biofuel Symposium 2005 in China"[9]. The overall project period will end in July 2006.

To reach the above-mentioned objectives, the following contributions have been identified:

- Assessment studies
- Expert workshops and political discussion

Depending on the decision of the German Ministry of Consumer Protection, Food and Agriculture (BMVEL)[10], closely after the final conferences in Berlin and/or Washington, regional events may be held in order to discuss the results with local decision makers.

This report presents the Assessment Study on Chinese liquid biofuels for transportation, potential and implications for sustainable agriculture and renewable transport energy.

Liquid biofuel produced from biomass[11] analysed in the present assessment study are related to:

- Biodiesel & Vegetable oil or Pure Plant Oil
- Bioethanol
- Fischer-Tropsch technology for BTL (biomass-to-liquid)

1.2. Objectives and methodological approaches

1.2.1 Objectives

The objective of this assessment study is to analyse the local and national experiences, the actual and potential relevant markets and conditions for the production, use and marketing of liquid biofuel in the Chinese transport sector. This includes a close look into actual and potential agricultural and forestry developments like energy crop varieties as feedstock[12] for biofuel production, technical skills, Research and Development (R&D) stakeholders, and available land for energy crop plantation.

1.2.2 Methodological approaches

According to the Terms of Reference, which GTZ-China provided, a multi-disciplinary team of 9 experts, supported by 8 research assistants, has carried out an intensive working program between July

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8 Worldwatch Biofuels Project (www.worldwatch.org/features/renewables)

9 www.worldbiofuelsymposium.com

10 Frank Wouters, Implications of the European Biofuels Directive – a German Perspective (www.german-renewable-energy.com////downloads/pdf/biomasseverordnung_wouters.pdf?PHPSESSID=66a6848ec121f955 4998c72f5c28857f)

11 A distinction can be made between the use of dry biomass (such as wood) and the use of wet biomass sources such as the organic fraction of domestic waste, agro-industrial wastes and slurries, and wastewater. Two kinds of conversion process: biochemical and thermo chemical. Current production costs of liquid biofuels depend on the prices of the biomass used and the size and type of the production plant.

12 Feedstock is defined as harvested biomass used for the production of biofuel, with exception of waste cooking oil

and November 2005, also exchanging experiences with the Tanzanian and Indian Assessment Study teams.

The assessment work has been organized in 9 subsequent phases:

First phase: July 4th –Aug. 24th, 2005: experts in the fields of biodiesel, bioethanol, plant-oil, BTL, agriculture and forestry completed their analysis, field visits.

Second phase: Aug. 1st – Aug. 24th, 2005: experts in the fields of energy, socio-economic, and environmental aspects completed their analysis, expert for policy completed his analysis and proposal report, field visits.

Third phase: Aug. 24th –Sept. 12th, 2005: compilation of the first draft of the study report in English, including first synthesis and initial recommendations from the study team.

Fourth phase: Sept. 12th, 2005: discussion of the first draft of the study report with GTZ.

Fifth phase: Sept. 12th – Sept. 30th, 2005: compilation of second draft of the study report.

Sixth phase: Oct. 1st – Oct. 24st, 2005: collection comments on the first draft version from GTZ and external experts in China and Germany.

Seventh phase: Oct. 24st – Oct. 31st, 2005: integration of GTZ's and other comments and recommendations into the study report, handing over of draft final report.

Eighth phase: Nov. 1st – Nov. 6th, 2005, preparing publicity and strategy for country study workshop.

Ninths phase: Nov. 16th, 2005: country study workshop: presentation of the findings of the report, discussion of recommendations, preparing workshop summary report.

Tenth phase: Nov. 25th – Dec. 7th, 2005, integrating workshop results in the final report version.

The data collection was carried out through

- Intensive literature research in Chinese, English and German langueges, reviewing national and international internet websites, scientific and country specific literature, conference and workshop proceedings, laws, yearbooks and other statistical material,
- Visits to liquid biofuel producing factories and research laboratories,
- Interviews with national and international experts and companies in the field of liquid biofuels.

The data processing was integrated within the teamwork process. In 16 internal meetings, the findings of each team member have been presented and discussed in order to come out with a synthesis and recommendations that consider all liquid biofuel related aspects.

Expert team

Considering the complexity of the Assessment Study, the research content of the relevant liquid biofuels and the urgent time schedule, the expert team has been composed by 9 experts from different research fields and institutions:

a) Expert team leader: Prof. Wang Gehua, Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing: responsible for organization of group activities and completion of the draft and final report of the study project, and preparation of the presentations for the country workshop.

b) Expert in the field of biodiesel/BTL: Prof. Liu Dehua, Department of Chemical Engineering, Tsinghua University, Beijing: responsible for supply of relevant information to techniques and market of biodiesel and BTL.

c) Expert in the field of bioethanol: Prof. Li Shizhong, Center of Bio-energy, China Agricultural University, responsible for supply of relevant information to techniques and market of bioethanol.

d) Agricultural expert: Mrs. Zhang Yanli, Chinese Academy of Agricultural Engineering, Beijing, responsible for supply of relevant information to energy plant oriented agriculture (energy crops) and food security.

e) Forest expert: Mrs. Dr. Fu Yujie, Northeast Forestry University Harbin, responsible for supply of relevant information to energy biomass oriented forestry.

f) Energy analyst: Mrs. Prof. Dr. Zhao Lixin, Chinese Academy of Agricultural Engineering, Beijing, responsible for forecasting analysis of biomass, liquid biofuels and general analysis of other energy resources, based on available statistical information.

g) Socio-economic expert: Mrs. Elisabeth-Maria Huba, international social scientist consultant of the Chinese Academy of Agricultural Engineering, in charge of social and economic analysis.

h) Environmental expert: Mr. Liu Dongsheng, Chinese Academy of Agricultural Engineering, Beijing, in charge of analysis of environmental aspects and greenhouse gas emission.

i) Energy policy expert: Mr. Heinz-Peter Mang, Institute of Energy and Environmental Protection, Beijing, in charge of policy analysis under macro-economic and global policy aspects; actual and potential markets for relevant liquid biofuels esp. direct use of plant oil; suggestions on policies.

Staff members of the involved institutions have supported each of these experts: Tsinghua University Beijing, Northeast Forestry University Harbin, China Agricultural University Beijing, and Chinese Academy of Agricultural Engineering.

1.3. Ongoing liquid biofuel related activities in / with China

1.3.1 Conferences

Since recent years, the production and use of liquid biofuels are promoted through international conferences in China, with the following table stating some of the most relevant events.

Table 1: National Conferences related to liquid biofuels

Date	Topic	Organizer	References
Nov 2001	EU – China Biofuel	LAMNET[13]	www.bioenergy-lamnet.org
Dec 2001	Clean Bio-Fuel	MOST	
Sep 2003	International Bio-energy Forum - Conference on Bio-energy Utilization and Environment Protection	LAMNET	www.bioenergy-lamnet.org
Nov 2004	Shanghai International Industry Fair - renewable energies China	Arno A. Evers Fair-PR	www.fair-pr.com/china2004/index.php

[13] www.bioenergy-lamnet.org

Date	Topic	Organizer	References
Nov 2004	Biodiesel for Hongkong Region	University of Hongkong	www.biodiesel.at
Dec 2004	EU-China Workshop on liquid biofuels, Beijing	EU, MOST	http://europa.eu.int/comm/research/energy/gp/gp_events/China/article_1738_en.htm
May 2005	2nd Asian Renewable Energy Fair and Conference (REAsia 2005)	Grace Fair International Limited	www.re-asia.com
Sep 2005	China Biofuel and Ethanol Outlook 2005, Beijing	IBC – Asia	www.ibc-asia.com/Bio-Fuel/BioFuelIntro.htm
Nov 2005	World Biofuels Symposium, Beijing	Department of Agriculture, Minnesota USA & Tsinghua University	www.worldbiofuelssymposium.com
Nov 2005	International Seminar on Promoting Bio-Diesel Development and Application in China	Global Environmental Institut, Natural Resources Defense Council, Worldwatch Institute	www.worldwatch.org
Nov 2005	Beijing International Renewable Energy Conference	NDRC	www.birec2005.cn
Mar 2006	3rd international exhibition on New Energy 2006, Shanghai	Coastal International Exhibition Company	www.coastal.com.hk/renew/renew.html
May 2006	RE Asia 2006, Beijing	Grace Fair International Limited	www.gracefair.com/reasia_home.htm
Oct 2006	Asia Biofuels Conference & Expo IV	The Stratton Group	www.asiabiofuels.com

1.3.2 Examples of related regional events where Chinese professionals participated:

Several regional events related to liquid biofuels in Asia have taken place in the last years, of which the following are among the most important ones:

- Asia Biofuels Conference & Expo, Manila Philippines, 2005
- Biofuel 2004 – challenges for Asians future, Thailand
- Asian Biomass-Symposium 2004, Japan
- Sino-German Workshop on Energetic Utilization of Biomass, Beijing 2003

1.3.3 Examples of international visits of Chinese decision-makers and professionals

May 2003: first delegation of the Chinese Ministry of Agriculture (MOA) and the Chinese Academy of Agricultural Engineering (CAAE) visited the Choren Company in Freiberg, Germany, the leading company in clean transport fuel research and development.

July 2005: Chinese delegation of high ranking officials, including the director of the renewable energy division of the National Development and Reform Commission (NDRC), together with representatives of the SPC and from different Ministries, visited the German company Choren Industries[14] to be informed about the state of art in biomass-to-liquid technologies.

1.3.4 Examples of Chinese participation in international R&D programs

In recent years, many Chinese scientific institutes have been engaged in the research on agricultural development and have selected plant varieties and hybrids with high yield, suitable for liquid biofuel production and for dissemination in different areas of the country.

One of the first international events was the Chinese participation in the Latin America Thematic Network on Bio-energy (LAMNET), a global bio-energy network, which consists of 48 partners and 150 associate partners from more than 35 countries. The European Commission funded the programme in 2001-2004.

Chinese LAMNET members:

(1) *Chinese Association of Rural Energy Industry (CAREI)* is a non-governmental organization of different regions, departments and disciplines for the whole rural energy industry after examination and approval by the Ministry of Civil Affairs for registration. CAREI is under the professional guidance of the State Planning Committee, the State Commission of Economy and Trade, the State Commission of Science and Technology as well as the Ministry of Agriculture and the Ministry of Electricity. CAREI has already established priorities areas and action plans with Europe in the biomass sector in the framework of a project supported by the EU Commission DG1 (EU-China Local Authority Link).

(2) *Chinese Renewable Energy Industries Association (CREIA)* is a business-led, independent, and self-financed association, working in the interests of its industry members. In maintaining an open information network, CREIA will share the latest technology developments and market information nationwide, and provide an effective channel for industry training programmes. CREIA will also link investment-grade projects with potential sources of financing (national and international) through an investment opportunity facility (IOF). In the context of limited in-country investment information, CREIA aims to raise awareness of renewable energy investment opportunities, to provide a business network for professionals in the renewable energy industry, and to provide key policy advice to the Government. Membership fees and other independent funding mechanisms will increasingly provide the financing for CREIA's activities.

(3) *Beijing Green Energy Institute:* The research focus of the Beijing Green Energy Institute is to find new crops and breed new cultivars of energy crops. Experiments showed that sweet sorghum is the most promising crop for China due to its high photosynthetic efficiency.

(4) *Shenyang Agricultural University (SAU)* was founded in 1952. SAU is one of the key universities in China built jointly by the Ministry of Agriculture and Liaoning Provincial Government and operates directly under the Ministry. In the university, there are eight colleges, one separate department and three divisions. The university offers twenty-six undergraduate programs, twenty-six master degree programs and seven doctorate programs. Since 1978, SAU has undertaken 1,819 research projects and achieved ideal results in 596 items. Among them, 251 items attained advanced international and domestic levels. The Department of Energy and Environment Engineering at the Agricultural Engineering College of Shenyang Agricultural University was founded in 1984. It offers undergraduate, master, and doctorate degree programs. In addition, it has worked on biomass energy research for twenty years, including many international research projects.

(5) *Ministry of Agriculture, China (MOA)* is a function body under the State Council, which is responsible for the administration of agricultural economy and comprehensive management of crop planting, animal

[14] http://213.174.34.155/de/choren_industries/aktuelles/?nid=50

husbandry, agricultural land reclamation, township enterprises, animal feed industry and agricultural mechanization.

(6) *Ministry of Science and Technology, China (MOST)* is the central government agency under the State Council, responsible for the nation's science and technology activities. Some major activities are the research on important issues of science and technology for promoting the development of economy and society, promotion of national scientific and technological innovation system and upgrading the national capacity of innovation. Another main target is the establishment of science and technology innovation mechanisms, which adapts itself to the socialist market economy, and the inherent law of development of science and technology.

Under the framework of the European Commission FP6 Priority "Sustainable Energy Systems" a project concept has been elaborated in cooperation with Choren Industries (Germany) and the Chinese Institute of Coal Chemistry. The objective of this project is to demonstrate the technical and economic feasibility of a unique combined production of bioethanol and BTL-fuel using biomass, i.e. *Sorghum bicolor (L.)*, as feedstock[15]. Cooperation between Jilin Light Industry Design Institute and Risø, Denmark has been established for the optimization of pre-treatment methods of substrate such as corn stover, which is an important substrate for ethanol production in China[16]. In April 2004, Guandong Institute of Energy Conservation (GIEC) and Japanese Toyama University signed a cooperation protocol on a Sino-Japan biomass synthesis fluid fuel (including BTL) and hydrocarbon project[17].

1.4. Findings of the Assessment Study (Executive Summary)

The biofuel sector has just begun to develop in China: R&D is still in the initial phase, and processing and the development of energy-oriented agriculture and forestry need the corporate effect of multiple strategies, investments and mechanisms, especially the support from the different level of governmental decision makers. Based on the findings of the present Assessment Study, six recommendations are proposed[18]:

1. Perform research and investigation on agricultural and forestry resource potential in species and land
2. Strengthen technology R&D
3. Extend industrial demonstration
4. Expand support policy scope
5. Enable fair trade and open market environment
6. Cooperate in the international know-how exchange

China's crude oil import bill may rise by 10 BN EUR in 2005 because of higher global prices and the increasing fuel demand (2004 imports: 30 BN EUR)[19]. Private vehicle ownership has increased six-fold in 10 years, expanding fossil gasoline and diesel use. The facts:

- Total fossil diesel consumption in 2004: 95.5 Mio t/a[20]
- Total fossil gasoline consumption in 2004: 45 Mio t/a[21]

[15] LAMNET, 2004
[16] http://www.risoe.dk/bem/Bioethanol.htm
[17] CAS, 2004
[18] Chapter 6.3 explains in detail these recommendations
[19] China Daily 2005-10-20, http://www2.chinadaily.com.cn/english/doc/2005-10/12/content_484367.htm
[20] CSY 2004, http://english.people.com.cn/200406/28/eng20040628_147782.html
[21] CSY 2004, http://english.people.com.cn/200406/28/eng20040628_147782.html

- In 2020, the fossil fuel demand only by motor vehicles will range about 256 Mio t: 85 Mio t of gasoline and 171 Mio t of diesel. If 10% of bio-ethanol (E10) is added up to gasoline, the demand for bio-ethanol in 2020 will reach 8.5 Mio t. If 10% of diesel demand is met by bio-diesel (B10), the demand for bio-diesel in 2020 will reach 17.1 Mio t.

Table 2: Forecast of China's dependence on oil import

	2010	**2020**
Crude oil import forecast Mio Barrel/day	4.6	8.5
Dependence on import	61 %	76.9 %

- Total biodiesel production nationwide in 2004 is estimated at 38,000 to 60,000 t[22], mainly from grease trap waste and waste cooking oil.
- Total bioethanol production is given with 4 Mio t/a, including 3 Mio t/a of edible ethanol. Today, fuel ethanol production uses mainly overtime crops and corn as feedstock[23].

Scenarios calculating the agro-forestry and technical production potential for liquid biofuels in 2020 result as follows[24]:

- biodiesel up to 10.65 Mio t/a: 63% from woody oil plants and 37% from waste cooking oil and low-grade vegetable oil, which is less than the expected biodiesel demand of 17.1 Mio t according to the alternative ratio of 10%.
- bioethanol up to 8.02 Mio t/a: 75% from energy crops and 25% from food crops, which is close to the estimated bio-ethanol demand of 8.5 Mio t according to the alternative ratio of 10%.

Alternatives[25] and limiting factors for biofuel production, marketing and consumption, such as land and feedstock resources, technologies and technical know-how, biofuel standardization, and supporting policies have been assessed[26]:

- Agricultural crops in China, which can be used to produce biodiesel, include rape, sunflower, soybeans and peanuts, but these plants and their products are used preferably for producing edible oil. Also corn and other potential raw material are mainly planted for human or animal consumption. To produce agricultural food crops, huge amounts of water are required; irrigation efficiency in China is still at 45%, compared with 70% in western countries.[27]
- In forestry there are about 151 plant families with 697 genius and 1553 species of oil–bearing plants, thereof 154 species with oil content higher than 40% and 30 species of arbour and shrubs with a potential of centralized distribution. However, there are less than 10 species of arbour and shrubs that can be used for large-scale production of raw material for biodiesel[28]. In general, accurate data about the production and utilization scale of forestry energy plants are not available yet, because China has just recently started to develop energy forestry for liquid biofuel production. Traditionally forest energy aspects are only related to fuel wood, and woody plant oil is often dedicated to Traditional Chinese Medicine (TCM). China's area of woodlands biomass is about 158,940,000 ha (2003), Liaoning, Gansu, Hubei and Jiangxi are the top four provinces for

[22] Chapter 2
[23] Chapter 3
[24] Summary in Chapter 6.1, 6.2, details in chapter 2 & 4
[25] BTL in Chapter 4
[26] Details in Chapter 5
[27] Prof. Jiang Wenlai, irrigation expert, Chinese Academy of Agricultural Science (Xinhua report, November 7th, 2005)
[28] Wang Tao, 2004

wood fuel forest area. The two largest areas for special purpose forest are in Heilongjiang and Beijing.[29]

- Crops that can be used to produce bioethanol in China mainly include *Sorghum bicolor (L.)*, *Manihot esculenta Crantz*, *Saccharum officenarum L.* and corn; among those *Sorghum bicolor (L.)*, *Manihot esculenta Crantz*, *Saccharum officenarum L.* are already applied in national fuel production. There is little conflict potential between the energy-oriented infields and foodstuff plantations: according to studies on Chinese food supply the potential output per ha can meet most of the increased demand for food[30] - also in future - if farmland management will be optimised.
- For biofuel ethanol production, only *Sorghum bicolor L.* can be used in decentralized or centralized conversion processing units. However, best yield of sorghum is reported within the collection limit of a radius of 25 km. Hence comparison between decentralization and centralization of bioethanol production should be conducted for feasible production. Generally, centralized production of bioethanol from *Saccharum officenarum* L. juice is not feasible, due to rapid decrease of sugar content in the harvested stalks.
- Corn as feedstock is widely popular, as it can be planted all over China; its extended use is limited when the bioethanol production capacity will be increased, because energy corn needs similar land conditions as for food production. Therefore corn will not be considered in this assessment study as future energy crop for bioethanol.[31] However, there is an upcoming discussion whether corn could be imported for biofuel production.

It is universally recognised that a viable liquid biofuel industry requires proactive legislation and initially financial support, but it is equally recognized that there are benefits from an improved environment, higher octane and cetane values leading to more efficient engines and multiple benefits from the encouragement of industry to invest in rural areas. China's rural areas require investment and future oriented production schemes in order to reduce migration and facilitate countrywide balanced economic development.

The three policy levels of government in China are now responding positively and the biofuel industry is now ready to move forward.

[29] Chuan Wang, Survey of CDM Initiatives and Potential Technology Collaboration between China and Sweden The case of biomass energy technology, Stockholm 2003, Master Thesis ISSN 1651-064

[30] Liu Jiang, 2002

[31] see chapter 3.3.4

2 Plant oil & Biodiesel – current situation and technical potential

China's biodiesel industry is still very much in its beginning. Total production nationwide was only 38,000 to 60,000 t/a in 2004[32]. Actually, it is estimated by Chinese experts that Chinese biodiesel may be available in a larger scale for the transportation sector in 3 years. The production capacity will be more than doubled from 2005 to 2006.

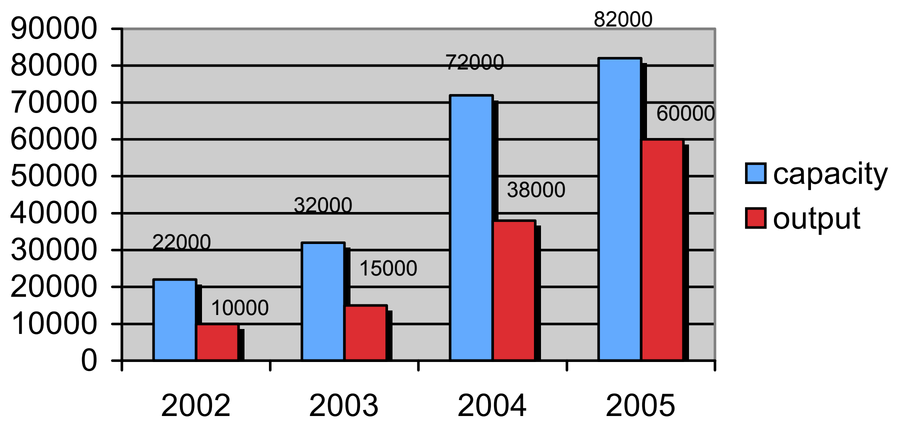
2.1. Main Actors

Chinese biodiesel research took off under the leadership of the government. Many leaders of the Chinese Central Government, such as former Premier Zhu Rongji, Premier Wen Jiabao, and Chairman of the National People's Congress Wu Bangguo, have shown their dedication to the concept and development of a biodiesel industry in China, and emitted policy directions to the National Economy and Trade Committee (NETC, before SETC-State Economy and Trade Commission), the National Development and Reform Commission (NDRC, before SDPC-State Development and Planning Commision), the Chinese Academy of Engineering (CAE).

In the 1980's basic technology research had been supported by the Ministry of Mechanics Industry, China Petroleum & Chemical Cooperation, and the Chinese Academy of Agriculture Engineering. Liaoning Institute of Energy Resources worked on biodiesel in a China-EU research project. The University of Science and Technology of China, Beijing, also carried out relevant initial research.

However, systematic research started in the early 1990's, with the program of "Fuel Plants' Survey and Planting Technology Research" carried out by the Chinese Academy of Sciences (CAS), as one of the National Research Programs during the period of the 8th Five-year Plan[33]. In this program, the fuel plants in the drainage area of Jinsha River, Sichuan province were investigated, the planting technologies of some fuel plants were studied, and 30 ha of *Jatropha curcas L.*[34] were planted for demonstration.

Figure 1: Biodiesel production capacity and output in 2002-2005[35]



From 1991 to 1995, Changsha Institute of New Technology and Hunan Academy of Forestry carried out the program of methyl ester fuel production from *Cornus Wilsoniana* oil and a combustion feature study; from 1996 to 2000, they worked in the program of "Energy-oriented End-use Technologies

[32] estimations from planned capacities and outputs of Table 3, chapter 2.1.2
[33] 1991-1995
[34] for plant description see chapter 2.3.1
[35] Figure according to Wendy Wen, Biodiesel production and consumption in China, Conference proceedings China Biofuels and Ethanol Outlook 2005

with Plant Oil", as one of the National Research Programs during the period of the 9th Five-year Plan[36].

In June 2005, the Chinese Ministry of Science and Technology (MOST) started a program for bio-energy, which aims the development and utilization of standardized industrial biodiesel production units with a designed capacity of 50,000 t/a per unit, to be installed before 2010.

In addition, recently research programs about biodiesel started at the University of Science and Technology of China, Anhui, Jiangsu Polytechnic University, Sichuan University, Chengdu, and Beijing University of Chemical Technology, and Shanghai Tongji University.

Enterprises also show interest in the investment in biodiesel production, which led to many new international joint ventures[37].

2.1.1 R&D

The R&D on biodiesel in China started lately, but advanced rapidly. Research sectors include selection, genetic modification, distribution and cultivation of oily plants, processing technologies and equipments. Research work in each topic has been accelerated. Chinese researchers from various universities (see table 3) have made progress in the field of raw material filtering, production techniques and biodiesel additives.

Table 3: Institutions involved in R&D related to biodiesel & plant oil

Name	Location	Keywords	Webpages
University of Science and Technology Beijing	Beijing	Biodiesel	http://www.ustb.edu.cn
Beijing University of Chemical Technology	Beijing	Biodiesel	http://www.buct.edu.cn/
Tsinghua University	Beijing	Biodiesel and bioethanol	http://www.tsinghua.edu.cn
Jiangsu Polytechnic University	Changzhou, Jiangsu province	Biodiesel	http://www.jpu.edu.cn
Sichuan University	Chengdu, Sichuan	Biodiesel	http://www.scu.edu.cn/
China Agriculture University	Beijing	Biomass energy	http://www.cau.edu.cn/
Chinese Academy of Forestry	Beijing	Energy forestry	http://www.forestry.ac.cn/
Guangzhou Institute of Energy Conversion	Guangzhou	Biodiesel	http://www.giec.ac.cn
China National Center of Biotechnology Development of MOST	Beijing	Biodiesel	http://www.cncbd.org.cn/
Southwest Forest Institute	Sichuan province	Biodiesel	
Northeast Forestry University Harbin	Harbin	Plant oil	http://www.studyhere.net/jianjiee.asp

36 1996-2000
37 see Table 4, chapter 2.1.2

2.1.2 Companies, joint ventures and projects

The following tables list biodiesel companies, international joint ventures and projects for biodiesel research and production.

Table 4: Companies currently engaged in biodiesel production

Name & Location	Year of start-up	Feedstock	Process technology	Designed capacity	Output biodiesel	By-product beside glycerine	Production cost EURO/t	Sale price EURO/t	No. of Staff	Market	Webpage
Fujian Longyan New Energy Zhuoyue Co. Ltd, Longyan, Fujian Province	2003 Ext. 2005	Grease trap waste	1-step sub-acid catalyst process: own technology	10,000 MT/a Ext. to 20,000 MT/a	2004: 6,000 – 8,000 MT/a 2005: 15,000 MT/a	Organic bitumen	80.00 not incl. feedstock purchase	425.00	50 – 60	private fleet owners, biodiesel distributors & fuel stations	http://www.zyxny.com
Wuxi Huahong Biofuel CO. Ltd, Wuxi, Jiangsu Province		Grease trap waste									http://www.entec.com.cn/
Sichuan Gushan Oil & Fat Chemical Ltd, Gushan, Sichuan province	2002 Ext. 2004	Grease trap waste, Rapeseed oil	2-step-acid catalyst process own technology	12,000 MT/a Ext. to 30,000 MT/a	2004: 6,000 – 8,000 MT/a 2005: 30,000 MT/a	Organic bitumen			70	private biodiesel distributors & fuel stations, biodiesel demonstration stations	
Zhenghe Bio-Energy Ltd, Wuan, Hebei province	2002 Ext. 2005	Acidified oil, fatty acid distillates	1-step sub-acid catalyst process own development	10,000 MT/a Ext. to 20,000 MT/a	2003: 6,000 MT/a 2005: 15,000 MT/a	Rubber softening reagent				private fleet owners, biodiesel distributors & fuel stations	

Name & Location	**Year of start-up**	**Feedstock**	**Process technology**	**Designed capacity**	**Output biodiesel**	**By-product beside glycerine**	**Production cost EURO/t**	**Sale price EURO/t**	**No. of Staff**	**Market**	**Webpage**
Handan Gushan Olea Chemical Ltd, Hebei province	2004	Rapeseed oil	Chemical alkaline catalysis Own development	25,000 MT/a	2004: 20,000 MT/a 2005: 25,000 MT/a				70 – 75	Biodiesel distributors & fuel stations	
Zhejiang Haiyan Fine Chemical Ltd.					3,500 MT/a					Mainly sold as fine chemicals	
Wu'an Hengtai Chemical Ltd.					3,000 MT/a					Mainly sold as fine chemicals	
Shanghai Qianwei Olechemical Ltd.					4,000 MT/a					Mainly sold as chemical intermediates	
Shandong Zichuanhuitong Olechemical Ltd.					4,000 MT/a					Mainly for chemical intermediates	
Shaanxi Lantian Science-Tech Chemical Ltd.					3,500 MT/a					Biodiesel	
Wuhai Yuancheng Science-Tech Ltd.					2,500 MT/a					Biodiesel	

Table 5: Joint Ventures in the field of biodiesel

Name & location	Investment	Year of start-up	Designed capacity MT/a	Feedstock	Webpage
D1Energy PLC, UK[38], Sichuan province	Seeds from India, growing medium, technical expertise, purchase of output from plantations.	2005	500,000	*Jatropha curcas L.*	http://www.d1plc.com
Leo ltd, England, & Hunan Tianyuan Clean BioEnergy Ltd., Hunan province	30 Mio Euro	2005	200,000	nd	
Biolux, Austria[39], Weihei City, Shandong province	100 Mio Euro	2005	275,000 – 300,000	nd	www.biolux.com
Lurgi, Germany & Shandong	Technology & turnkey engineering	2005	100,000	rapeseed	
Daimler Chrysler, Germany, & Guizhou Province	Development of large-scale liquid biofuel production	2003	nd	jatropha seeds	

[38] 50-year contract: production from the collection of seeds from existing trees and the establishment of new plantations. D1's business plan is to establish refineries close to crop production sites, which is partly owned. The company's strategy is to control and manage its operations on a regional basis by securing rights to Jatropha plantations and establishing local refineries using its own refinery technology. Any surplus oil will then be exported for refining by D1 Oils or sold to third parties; D1 is a UK based company investing in biodiesel production from jatropha and coconut in India, Egypt, South Africa, Nepal, Philippines, China and Tanzania

[39] www.wirtschaftsblatt.at/cgi-bin/page.pl?id=427705&xslfile=be/energie (September 23rd, 2005) and http://biodiesel.pl/news/read/article/1914/195/

Table 6: Projects planned for biodiesel production

Name & location	Year of start up	Designed Capacity MT/a	Feedstock	Process	Processing costs EURO/t	Market
Henan Xinyang Hongchang Group, Henan province	2006	2006: 30,000 2010: 100,000 2015: 300,000	Local wood plant oil & grease trap waste from different provinces	enzymatic approach developed by Tsinghua University	70-80 (not incl. feedstock purchase)	fuel stations, or directly sold
Hunan Hainabaichuan Biological Engineering Co., Hunan province	2006	10,000	Grease trap waste, rapeseed	enzymatic approach developed by Tsinghua University	70-80 (not incl. feedstock purchase)	fuel stations, buses
Dinuo Chemical ltd [40], Guiyang, Guizhou	2006	2006: 3,000 2010: 30,000	Grease trap waste	own development	nd	nd
Fujian Yuanhua Energy Science Co. Ltd[41], Fujian province	2005	2006: 30,000	Waste grease & oils	nd	nd	nd
Shangqiu Grease Chemical Co. & Shangqiu Administration of Road Management[42], Shangqiu, Henan	Recently passed the feasibility demonstration	110,000	Waste oil	nd	nd	nd
Fuzhou Gushan Oleo Chemical Co. Ltd.[43]	2005	100,000	Waste grease & oils	nd	nd	nd
Yuanhua Energy Technology, Hangzhou Xiaoshan[44]	2006	50,000	Waste grease & oils	nd	nd	nd

40 http://www.gygov.gov.cn/jumpnews/JRGY/05-9-2e.htm
41 http://www.fqtimes.org/Article_Show.asp?ArticleID=4994
42 http://www.lh.e-qy.cn/new_view.asp?id=6525
43 Guanshan's 3rd biodiesel facility
44 agreement signed with county government; Fujian Yuanhua's 2nd planned biodiesel facility: Wendy Wen, Conference Proceedings China Biofuels and Ethanol Outlook 2005

Name & location	Year of start up	Designed Capacity MT/a	Feedstock	Process	Processing costs EURO/t	Market
Shanghai Biodiesel Plant, Jinshan [45]	2005 Ext. 2008	50,000 50,000	Grease trap waste, rapeseed	Japanese technology development According to EU biodiesel standards	nd	Fuel stations & direct sale
Hubei Oil Crops Research Institute Pilot Plant	2006	2,000	Rapeseeds oil & waste grease	nd	nd	nd
SINOPEC Institute of Petroleum Refining Pilot	2006	2,000	Virgin & waste oils	nd	nd	R&D
Changchun Oil & Grease Plant	2006	7,200	nd	nd	nd	Planned for alphatic alcohol
Sichuan University Chemistry Institute	2006	1,000	nd	nd	nd	R&D
Beijing Foodstuff Research Institute & University of Chemistry	2006	320	nd	nd	nd	R&D
Fushun Development Planning Committee	2006	25,000	nd	nd	nd	Planned for MES production
Shaanxi Baotashan Painting Ltd	2006	20,000	nd	nd	nd	Planned for paint production
Shijazhang, Hebei	2006	3,000	Woody plants	SCF	nd	Biodiesel distributors
SINOPEC Commercial Biodiesel Plant	2008	100,000	Virgin & waste oils	nd	nd	Planned to be used for blending with fossil diesel to B20 in SINOPEC petrol stations
Henan Tianguan Group, Nanyang, Henan: SOE	nd	100,000	bioethanol diesel oil as byproduct from bioethanol	nd	nd	nd

[45] www.envir.gov.cn/info/2005/10/1013290.htm

Besides, a lot more investment plans and intentions are emerging from a number of mid and big cities for small sized biodiesel projects at 5,000 - 10,000 MT/a based on local waste grease feedstock. It may be presumed that 20 – 30 of such biodiesel production units can be built up by 2008 with a total capacity of 200,000 to 300,000 MT/a.

2.2. Production and end-use technologies

Biodiesel is defined as a renewable clean energy. As a good alternative of fossil diesel, it can meet the requisites of Europe fuel standard II or III.[46] It is produced potentially from waste oil, waste acidified oil and woody plant oil.

In China, the following methodologies for biodiesel production are developed and applied:

Table 7: Technologies for biodiesel production

Methodology	Characteristics	Observations
Chemical catalysis	Widely used in the international and Chinese biodiesel producing industry; Uses a low cost catalyst and achieves a high efficiency in oil conversion. Ordinary acid catalyst requires H_2SO_4, H_3PO_4, HCL and H_3SO_3, in which H_2SO_4 is most popular because of its low price and abundant occurrence. Ordinary alkaline catalyst requires NaOH, KOH, carbonate and CH_3ONa, in which NaOH and KOH are most popular because of lower prices.	Transesterification with acid catalyst is much lower than with alkaline catalyst, and usually requires higher temperature. When using an alkaline catalyst without strict controlling the free fatty acid and water in oil, the pipeline may be blocked by soap which is created during the process due to too much alkali; The by-product glycerine is hard to recycle; Acid catalyst's erosion to equipment and pipeline is serious; Waste acid/alkaline water affects the environment.
Conventional enzymatic approaches	Excellent production conditions, low restrictions to equipment and no water polluting waste; Are more and more accepted	Industrialization still is not very popularised, due to high costs of lipase and its short service time[47].
New development for enzymatic approach by Tsinghua University Beijing	Uses an inactive organic solvent as reaction medium Shows the negative effects of methanol and glycerine on lipase's catalytic activity and stability. Can effectively convert bean oil, rapeseed oil, cottonseed oil, waste oil, waste acid oil and microbe alga oil to biodiesel.	In Hunan province, a pilot-scale unit with a capacity of 200 kg/day of rapeseed oil has successfully completed the production tests. Lipase's service time is up to 10 times longer than with common technology application. Cost for lipase can be reduced, near the cost of industrialized chemical approaches.

46 www.dieselnet.com/standards/eu/ld.htm

47 because of catalytic activity loss during the chemical reaction

Methodology	Characteristics	Observations
Supercritical fluid system - SCF	Performs a quick chemical reaction rate and a high efficiency of conversion. Needs high temperatures and pressure, so the technical requirements to the equipment are much stricter. Much more research work has to be done before using the technology in large-scale.	At Harbin Forestry University, SCF is applied on laboratory scale. SCF is also applied by different pharmaceutical companies for the production of traditional Chinese medicine for the extraction of plant oil. Before 2006, a SCF biodiesel production equipment with the capability of 3000 t/a, will be put into operation in Shijiazhuang, Hebei province[48].
Co-boiling distillation	No technical information available	Laboratory research has made some important progress at Wuhan Oil Plant Research Institute.
Whole cell catalyst instead of extra cellular lipase	Using whole cell catalyst instead of extra cellular lipase so as to decrease the cost of catalyst.	Laboratory research has made some important progress at Tsinghua University Beijing, and Tianjin University.

Chinese industrialized biodiesel production applies the traditional chemical catalysis method.

2.3. Biomass availability and potential in agriculture and forestry

At present, agricultural crops in China, which can be used to produce biodiesel, include rape, sunflower, soybeans and peanuts, but these plants and their products are used preferably for producing edible oil. Also corn as an other potential raw material for biodiesel production is mainly planted for human or animal consumption.

In energy forestry there are about 151 plant families with 697 genius and 1553 species of oil–bearing plants, thereof 154 species with oil content higher than 40%, and 30 species of arbour and shrubs with a potential of centralized distribution. However, in China there are less than 10 species of arbour and shrubs that can be used for large-scale production of raw material for biodiesel[49]. In general, accurate data about the production and utilization scale of forestry energy plants are not available yet, because China has just recently started to develop energy forestry for liquid biofuel production. Traditionally forest energy aspects are only related to fuel wood, and plant oil is dedicated to Traditional Chinese Medicine (TCM). China's area of woodlands biomass is about 158,940,000 ha (2003), Liaoning, Gansu, Hubei and Jiangxi are the top four provinces for wood fuel forest area. The two largest areas for special purpose forest are in Heilongjiang and Beijing.[50]

China's agriculture and forestry have a broad variety of energy plant resources, among them:

- *Aleuorites*
- *Arachis hypogaea*
- *Brassica campestris var.oleifera*

[48] Information not clear and not proofed
[49] Wang Tao, 2004
[50] Chuan Wang, Survey of CDM Initiatives and Potential Technology Collaboration between China and Sweden The case of biomass energy technology, Stockholm 2003, Master Thesis ISSN 1651-064

- *Cerasus humilis (Bge.) Sok.*
- *Cornus wilsoniana*
- *Elaeis guineensis*
- *Euphorbia timcallitimcalli*
- *Glycine max*
- *Helianthus annuus L.*
- *Hevea brasiliensis.*
- *Idesia polycapa*
- *Jatropha curcas L.*
- *Pistacia chinensis Bunge*
- *Ricinus communis L.*
- *Salix viminalis*
- *Sindora maritima Pierre*

Among the forestry resources, this assessment study concentrates on the most available species[51], however taking in consideration the potential of more varieties for liquid biofuel processing whenever and wherever the required technology will be available.

2.3.1 *Jatropha curcas* L.

Scientific name: *Jatropha curcas* L.

English name: Physic nut, Barbados nut

Family name: *Euphorbiaceae*

Chinese name: Ma Feng Shu

Use of *Jatropha curcas* L oil:

- Locally produced natural insecticide
- Suited for soap manufacturing, dyestuff, and other productions
- Cures diarrhoea
- Residues from oil extraction process serve as fertilizer, because of a high mineral content
- Raw material for liquid biofuel because of its high oil content and fine fluidity
- Can be adulterated with diesel oil, gasoline and ethanol and the mixture will not decompose in long time
- Leaves, cortices and roots can be used as medicine[52].

[51] see following chapter 2.3.1. up to 2.3.5. A detailed plant description including planting requirements can be found in the Annex

[52] Roots: to cure detumescence and haemostats; Leaves: fodder for silkworm

Table 8: Comparison of the characteristics of fossil diesel oil compared to Jatropha curcas L oil

Parameter	**Diesel oil**	**Oil of *Jatropha curcas* seeds**
Density (15/40 °C)	0.84 - 0.85	0.91 - 0.92
Cold solidifying point (°C)	14.0	2.0
Flash point (°C)	80	110 – 240
Cetane number	47.8	51.0
S (%)	1.0 - 1.2	0.13

Regions of actual and potential production:

- Widely distributed from dry subtropical regions to moist tropical rain forests.
- Current production mainly in Guangdong, Guangxi, Yunnan, Sichuan, Guizhou, Taiwan, Fujian, and Hainan.
- Potential production area: tropical and subtropical regions.

Table 9: Current distribution of *Jatropha curcas L*

Variety	**Distribution**	**Current Planting surface**	**Average yield: t/ha/a**	**Possible areas**	**Availability of land**
Jatropha curcas L	Guangdong, Guangxi, Yunnan, Sichuan, Guizhou, Taiwan, Fujian, Hainan	More than 16,000 ha in Sichuan[53] (primary area)	Kernel: 9.75[54]	Mainly in Tropical Very Dry to Moist through Subtropical Thorn to Wet Forest Life Zones	At least 2,000,000 ha[55]

Main actors:

- Scientists from Sichuan University and Southwest Forestry Institute are investigating how to process *Jatropha curcas L* seed oil for conversion into biodiesel.
- Guizhou Province cooperates since 2003 with Daimler Chrysler, Germany, in the development of large-scale liquid biofuel production from jatropha seeds. The cooperation tends to improve the barren area by building up ecological protective screens, and to promote rural economic development through sustainable agricultural production, which shall increase the income of farmers and stop migration.
- Scientific and technical personnel of Guizhou Province assess the resource availability of the whole province, in order to develop large-scale liquid biofuel production.
- The Joint Venture Enterprise D1Oils obtained in 2004 from Sichuan Government the land use right to plant *Jatropha curcas L.;* currently it is projected to cultivate 150,000 immediately and up

[53] NDRC, 2004
[54] NDRC, 2004
[55] NDRC, 2004

to 2 Mio ha, if conditions were favourable[56] with improved seeds imported from India, to process about 200,000 t/a of jatropha nuts[57].

Financial feasibility:

- Seed yields approach 9.75 t/ha with 40% oil, providing the equivalent of up to 3 t biodiesel per ha[58].
- Under very favourable conditions, harvesting of seeds can achieve up to 9 kg per tree per year.
- Under less favourable conditions, harvest can drop to 0.2-2 t/ha.
- Hedges produce roughly 1 kg/m[59].
- Depending on irrigation conditions and the number of shrubs planted per ha, shrubs can deliver 1,600 to 4,000 l/ha of biodiesel
- Depending of the pressing technology 60-80% of the oil content can be extracted[60].
- Economic benefits are further enhanced by a range of side applications as insecticide and dregs as fertilizer. Not quantified are positive side effects like the protection from erosion of poor soils.

Availability of land:

- Very undemanding with regard to soil quality and precipitation, and has therefore a high potential to benefit seriously degraded soils.
- Guizhou karst to Rehe valley area consists of vast barren land, which can not be cultivated, but is suitable for *Jatropha Curcas L.*
- The production areas will remain in the southern provinces.

Assessment of overall production potential, based on findings listed above:

- Currently *Jatropha Curcas L.* seeds are mainly imported from Thailand and India, but China is developing own cultivars, based on local jatropha varieties.
- Highest potential as biodiesel feedstock, because does not interfere with food production.
- In Guizhou and Sichuan provinces, conditions for *Jatropha Curcas L.* plantation are most favourable, with an output of 60% oil content of the pure seeds[61], which make biodiesel production more economical.

2.3.2 *Pistacia chinensis Bunge*

Scientific name： *Pistacia chinensis* Bunge

English Name： Chinese pistachio

Family name： *Anacardiaceae*

Chinese name: Huang Lian Mu

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[56] information confirmed by D1Oils, Nov. 2005
[57] www.d1plc.com/news_show_article.php/126.html
[58] see Table 20, chapter 2.8.2
[59] GTZ, 1995
[60] http://www.jatropha.de/
[61] Chinese Jatrophs varieties generally produce 32 – 40% oil. 60% oil content is only possible, if the black cortex has been already removed – information provided by D1Oils, Nov. 2005

Use:

- Tree species for cities and sceneries.
- Seed oil: edible oil also used to produce soaps and lubricant.
- Seedcake can be used as fodder and manure.
- Leaves, fruits and cortices contain tannin, which can be extracted, distilled and used for black dyestuff.
- Roots, branches and leaves are used as pesticide.
- Leaves are used for aroma oil and tea.
- Wood is used for furniture, sculptures and buildings.

Regions of actual and potential production:

- Distributed in at least 11 provinces:
  - from Hebei and Shandong in the north to Guangdong and Guangxi in the south,
  - from Taiwan in the east to Yunnan and Sichuan in the west, especially in Henan, Hebei and Shanxi.
- Production is fragmentarily, but plant also exists in large areas of pure and mixed forest.
- Largest production area: 28,000 ha in Tai Hang Shan Mountains, covering middle and south of Hebei province, and 22,000 ha in the north of Henan province.
- Total production area in mountain regions is about 66,700 ha, among them about 3000 - 4000 trees older than 100 years[62].

Table 10: Current distribution of *Pistachia chinensis* Bunge

Variety	**Distribution**	**Current Planting surface**	**Average yield: t/ha/a**	**Possible areas**	**Availability of land**
Pistacia chinensis Bunge	Hebei, Henan, Anhui, Shanxi,	About 66,700 ha[63]	Kernel: 7.5[64]	Centralized in Tai Hang Shan Mountains: middle and south of Hebei province and the north of Henan province	At least 300,000 ha[65]

Main actors:

62 Wang Tao, 2004
63 Wang Tao, 2005
64 Wang Tao, 2005
65 Because the availability of land hasn't been investigated yet, the data is a conservative estimation

- Chinese Academy of Forestry, Beijing: research.

Financial feasibility:

- Additional income
  - Timber: furniture construction.
  - Leaves and bark: TCM.

Availability of land:

- According to investigation in 11 provinces, China has more than 66.700 ha of *Pistacia chinensis* Bunge forest resources[66].
- The supply potential mainly is found in Henan, Hebei and Shanxi, and plantation will continue in these provinces.

Assessment of overall production potential, based on findings listed above:

- Pistacia chinensis Bunge oil is yet not been used as feedstock for biodiesel, but offers obviously good potential for this purpose.

2.3.3 *Xanthoceras sorbifolia Bunge*

Scientific name: *Xanthoceras sorbifolia* Bunge.

English name: Yellowhorn

Family name: *Sapindaceae*

Chinese name: Wen Guan Guo

Use:

- Cultivated for biodiesel in large scale.
- Currently mainly used for food oil.
- Various uses:
  - Branches and leaves: medicine to treat arthritis.
  - Leaves: drinks with sterilization function
  - Woods: firm and compact, high-grade timbers.
  - Shuck of seed and fruit: raw material for ethanol.
  - Calyces: sleeping pills
  - Several components of the plant: medicine-treating dementia.

Regions of actual and potential production:

- Naturally largely distributed, but concentrated in the northern and north-western provinces: Shanxi, Shaanxi, Hebei, Inner Mongolia, Ningxia Autonomous Region, Gansu and Henan

66 Wang Tao, 2004

Table 11: Current distribution of *Xanthoceras sorbifolia* Bunge

Variety	Distribution	Planting surface	Average yield: t/ha/a	Possible areas	Availability of land
Xanthoceras sorbifolia Bunge	Shanxi, Shaanxi, Hebei, Neimenggu, Ningxia, Gansu, Henan	nd	Fruit: 45 (but only kernel for biodiesel production)	Mainly in northwest and north China	In mixed natural forest

Availability of Land:

- 99% of the soil in Beijing province is suitable for *Xanthoceras sorbifolia Bunge*.
- Growing the plant in Beijing can not only produce the raw material of biodiesel, but also solve the problem of sand and dust storm in every spring.

Assessment of overall production potential based on findings listed above:

- The plant is expected to be more distributed in the near future, due to its multiple advantages for the environment.

2.3.4 *Cornus wilsoniana*

Scientific name: *Cornus wilsoniana*

English name: Wilson's Dogwood

Family name: *Cornaceae*

Chinese name: Guang pi shu

Use:

- Edible oil: nutrient value superior to rapeseed oil and tea oil, similar to peanut oil
- Woods: furniture and buildings
- Flowers: honey
- Leaves: fodder and manure

Regions of actual and potential production:

- distributed in forests below 1000m in the southern and western provinces:

  Hunan, Hubei, Jiangxi, Guizhou, Sichuan, Guangdong, Guangxi.

Table 12: Current distribution of *Cornus wilsoniana*

Variety	Distribution	Current Planting surface	Average yield: t/ha/a	Possible areas	Availability of land
Cornus wilsoniana	Hunan, Hubei, Jiangxi, Guizhou, Sichuan, Guangdong, Guangxi	nd	Kernel: 4.5-9.0	Mainly in southern provinces	In mixed natural forest

Availability of land:

- *Cornus wilsoniana* is almost distributed in forests below 1000m in the provinces of Hunan, Hubei, Jiangxi, Guizhou, Sichuan, Guangdong, Guangxi.
- The supply potential mainly remains in these southern provinces.

Assessment of overall production potential, based on findings listed above:

- If the oil is improved by biological method, it can become an excellent liquid biofuel with prospering market[67]. Some factories in the mentioned provinces are already working with *Cornus wilsoniana*.
- The plant has a huge potential, which is not yet exploited.

2.3.5 Other crops

The country imports soybean oil and rapeseed in large quantities to meet the demand in food oil production. In 2004, it bought a total of 6.76 Mio t of edible oil, up 24.9 percent over the previous year. Domestic production of oilseed already falls far short of surging demand, and China imported 200 Mio MT of soybeans in May 2005 alone - up 143 % compared to May 2004.

Although Table 13 lists the outputs of edicle oil crops, their use as feedstock in biodiesel production is not feasible due to high purchase cost.

Table 13: Major edible oil plants – outputs in 2003 & 2004

Oil crops	Mio t/a 2003[68]	Mio t/a 2004[69]
Soy bean	15.39	17.20
Peanut	13.42	14.31
Rapeseeds	11.42	13.04
Cotton seeds		10.74
Sunflower		1.97
Sesamin	0.59	0.89
Oil tea seeds		0.83

[67] Dr. Fu, Forestry University Harbin, 2005
[68] CSY 2004
[69] Wendy Wen, Vice President, SinoBright Clean Oil Technologies Co. Ltd, Conference Proceedings China Biofuels and Ethanol Outlook 2005

Oil crops	Mio t/a 2003[68]	Mio t/a 2004[69]
Benne seeds		0.38
Total		**59.37**

The following crops are analyzed according to their actual and future potential for biodiesel production.

Rape, *Brassica napus*

- Widely distributed, especially as winter crop in the area of the Long River including 11 provinces such as Sichuan, Yunnan, Hunan and Jiangsu.
- Belongs to the group of 5 crops whose planting acreage is above 6.67 Mio ha[70].
- Since the price of rapeseed oil is about 40% higher than fossil diesel, biodiesel production using rapeseeds is not financially feasible.
- Chemical constitution similar to diesel oil, therefore technically suitable for biodiesel production.
- Seed contains 38 to 40% of protein, a valuable resource of high protein fodder.
- Planting acreage[71]: 7.2 Mio ha; output: 11.42 Mio t/a.
- Import of rapeseed oil in 2004: 1,1 Mio MT[72]

➢ Meanwhile international biodiesel R&D focus on rapeseed, China is importing rapeseed oil for edible purposes. Currently and in the near future, higher prices for edible rapeseed oil than for energy purposes limit the availability and restrict the use of rapeseed as feedstock for Chinese biodiesel production due to market mechanisms. However, if within the next decade similar price levels for food and non-food rapeseed will be achieved, rapeseed could become a feasible feedstock for Chinese biodiesel production, too.

Soybean, *Glycine max* (L.)

- Widely planted, especially in Songliao Plain in the Northeast and Huanghuaihai Plain.
- Important resource of protein for human beings.
- Fodder value notably superior to other cereals.
- Planting acreage[73]: 9.33 Mio ha; output: 15.39 Mio t/a.
- Import of soybean oil in 2004: 3,1 MT[74].

➢ China is one of the biggest exporters of organic certified soybeans to the world market, especially to Europe and Japan. As these prices will be also in far future significantly higher than energy crop soybeans, there will be no competition at all between soybeans for food/feed and for energy purposes.

➢ China is already the world largest importer of edible soybean oil[75], therefore virgin soybean oil will not be used for biodiesel production in the near future.

70 with rice, corn, wheat and soybean
71 in 2003, CSY 2004
72 http://www.ucap.org.ph/012904.htm
73 data for 2003, CSY 2004
74 http://www.ucap.org.ph/012904.htm

Peanut, *Arachis hypogaea*

- Widely distributed from tropical zone to temperate zone:
  - Shandong province has the largest production area, with planting acreage of 0.99 Mio ha.
  - Also distributed in Henan. Guangdong, Anhui, Liaoning, Sichuan, Guangxi and Jiangsu.
- More than 50% is used to produce edible oil, third edible plant oil in the country.
- Planting acreage[76]: 5.06 Mio ha, output: 13.42 Mio t/a.
- ➢ Virgin peanut oil is used for edible oil. Currently and in the near future, higher prices for edible peanut oil than for energy purposes limit the availability and restrict the use of peanuts as feedstock for Chinese biodiesel production due to market mechanisms. However, if within the next decade similar price levels for energy peanuts will be achieved, peanuts could become a feasible feedstock for Chinese biodiesel production, too.

Algae

- Still in research status.
- Dalian Physics and Chemistry Institute are carrying out laboratory research on oil producing algae for biodiesel production.
- ➢ Actual results reveal that it is not yet economical feasible to apply algae oils for biodiesel production, the competitive price range should reach about 80 EURO per barrel fossil petrol.

Sunflower, *Helianthus annuus L.*

- Original from Southwest of North America.
- Seed contains 50% of protein, a valuable resource of high protein fodder and human nutrition.
- Output: 125 t/a of seed produce in average 32.5 t/a of virgin oil; this is a better yield than from most other oil plants.
- Oil content: above 45%
- ➢ Due to the high market price of edible sunflower oil, it will not be used for biodiesel production in the near future.

Chinese Dwarf Cherry Seed, *Cerasus humilis* (Bge.) Sok

- Seed has nearly 50% grease, 90% of which is unsaturated fatty acid.
- Virgin oil is very suitable to produce biodiesel with ideal diesel fuel properties as shown in the following table analysed with international standard methods.
- Cultivated already for biodiesel production at pilot scale
- Distributed mainly in the provinces of Heilongjiang, Inner Mongolia, Jilin, Liaoning, Hebei

[75] FAPRI, 2005, p 214
[76] data for 2003, CSY 2004

- In Inner Mongolia, research has been carried out on this energy plant to prepare the promotion on small commercial scale.

Table 14: Cerasus humilis (Bge.) Sok seed's fuel properties

Items	Value	GB/T 19147-10
density 20g/cm^3	0.8718	0.82—0.86
viscosity 20mm/s	6.975	
flash point ºC	158	>55
CFPP	-19	<-5
combustion value KJ/Kg (net)	38757.6	
hexadecane number	50.1	>49
anti-oxidant stability	good	

➢ This plant offers a good potential for biodiesel feedstock production on dry land.

Willow, *Salix viminalis*

- Most common species in energy forestry is the basket willow.
- During the establishment year the plantation is susceptible to drought and weeds.
- Rapid growth.
- Resistance to diseases.
- High production is maintained by short rotation periods of about three to five years.
- After each harvest the established root system and the nutrients stored in the roots and stumps guarantee vigorous growth for the shoots.

➢ As this plant grows nearly all over China – except the tropical regions – it could be the ideal feedstock for BTL. Currently the plant is used for handicraft and fuel wood.

Castor-oil plant, *Ricinus communis L.*

- Semi-finished ricinoleic acid can be converted to delicate ricinoleic acid after depickling, washing, dehydrating, decolouring and filtrating.
- TCM and general medical use.
- Important drying agent for organic soybean production.
- Break fluid and motor saw oil:
  - *Ricinus communis* L oil oleic alcohol,
  - Production since the end of the eighties,
  - Oil content of *Ricinus communis* L oil has been enhanced to 75%, by mixing with acetone, KOH and minor chemicals,
  - Used as high speed break,
  - Serviceable range under -40℃, important for working conditions in winter cold areas.
- Regions of actual and potential production:

- Extensive distribution mainly in Northeast China: Jilin, Liaoning, Heilongjiang, Hebei

▫ Expected yields:
  - castor beans: 20.000- 30.000 t/a.
  - plant oil: 8,000- 12,000 t/a.

Table 15: Index of *Ricinus communis* L. oil

Item	Value
proportion g/cm^3	0.945-0.965
boiling point °C	313
cold solidification point (50°C)	5.8-7.0
melting point °C	-10～-18
iodine value mg I/g	83-90
hydroxyl value mg KOH/g	155
autoignition point °C	448
saponification value KOH/g	> 178 mg
flash point °C	229
acid value mg KOH/g	1.11-2.88

➢ good potential for biodiesel, but energy purpose has to compete with the other utilisation possibilities and markets of ricinus oil.

Tung tree, *Aleuorites*

▫ Distributed in the region south of Changjing River,
▫ Grows quickly, lives long,
▫ Comprehensive for industry use,
▫ Oil dries quickly, low specific gravity, adapt of cold and hot, tolerate of alkali and acid;

➢ Potential for biodiesel not yet sufficiently researched and published.

Rubber tree, *Hevea brasiliensis*

▫ Distributed in the region south of Changjing River,
▫ Planted in Yunnan, Taiwan, Hainan, and widely planted in north latitude 18° to 24°,
▫ Oil content: 90%,
▫ Medical industry use.
▫ The byproduct rubber seed oil is food safe, can lower the fat of blood,
▫ Soap, paint and fatty acid for industry use,

➢ Potential for biodiesel not yet sufficiently researched and published.

Oil Palm, *Elaeis guineensis*

▫ Distributed between north and south latitude 40, most distributed in torrid zone and warm semi-tropical zone, planted mainly in Hainan.

- Saturated fatty acid 50%, unsaturated fatty acid 50%, contributes to high oxid stability.
- Oil has high nutrition value, therefore edible use.
- Low cost, high oil content, high production and import: 2,7 MT[77] in 2004.
- ➢ Chinese economic palm oil potential for biodiesel is not yet sufficiently researched and published. Europe imports palm oil methyl ester from Malaysia, but having a CFPP of approx. +11°C this fuel has caused filter blocking and consequently injection pump damages in motors operated in winter cold regions. It has to be emphasized that the damages caused by even small volumes of substandard methyl-ester have a tremendous negative impact on biodiesel's carefully built positive image.[78] However it seems that the latest development of biodiesel processing technologies in Europe has overcome this disadvantage of palm oil.[79] In China, using palm oil for biodiesel production would maintain the country's import dependency in the fuel sector, as the potential oil palm production area is limited to the southern tropical part of the country.

Happy Tree, *Euphorbia timcalli*

- Widely distributed from tropical zone to temperate zone.
- China is importing *Euphorbia timcalli* for decoration purposes.
- Oil can be mixed with fossil crude oil directly.
- Energy content is similar to or higher than petrol.
- Plant has high adaptability to different environments.
- ➢ Potential for biodiesel not yet sufficiently researched and published.

Sepetir, *Sindora maritima Pierre*

- Mainly distributed in subtropical areas in the southeast.
- Has high quality, each plant produces 3-4 kg oil.
- Flammability is similar to fossil diesel.
- Tolerant to drought.
- ➢ Potential for biodiesel not yet sufficiently researched and published.

2.3.6 Other feedstock

Agricultural residues

Apart from the oil crops listed above, there are other agricultural residues, which offer potential feedstock for biodiesel production.

Cotton industry:

Annual production of cotton is 4.86 Mio t[80], main waste generated are stalks and cottonseed husks, which could be used as feedstock for bioethanol production. Cottonseed oil is beside cotton the main

[77] http://www.ucap.org.ph/012904.htm
[78] Austrian Biofuels Institute, 2002
[79] www.lurgi.de
[80] in 2003, CSY 2004

product of this industry. Low-grade oil from this industry can be used for biodiesel feedstock. Detailed data – separated from the overall market for low-grade oil – are not available at present.

Waste grease and low-grade oils

Although edible virgin oil feedstock is not feasible for biodiesel production in China due to high purchase costs, waste grease and low-grade oils are already used as biodiesel feedstock[81]:

- Acidified oil, which is recovered through distillation of the residue oil from vegetable oil refining;
- Slop oil recovered from oily leftover of restaurants;
- Grease recovered from Grease Trap, waste from restaurant kitchen sewage systems from washing oily pots or dishes plates;
- Waste cooking oil from frying oil of restaurants, especially franchised ones and food processing plants;
- Animal fat, oil and grease from meat processing industry.

Based on data from the National Bureau of Statistics, in 2004 China consumed a total of 18 Mio t of edible oil; 4 – 5 Mio t became waste oil, of which 2 Mio t were collectable[82].

Technically the waste oil from cooking could be reused as raw material for liquid biofuel production[83]. But due to the abundant use of spices and soy sauce during typical Chinese food preparation the process becomes more difficult and limits the economy of waste oil feedstock for decentralized small-scale biodiesel processing units.[84]

2.4. By-products

2.4.1 Seedcake

When seeds are crushed to extract oil, the husks and other residues are left over as seedcake. This seedcake is often high in protein and other nutrients, and has a wide variety of applications as organic fertiliser, fodder and nutraceutical. Further processing can convert the seedcake into high protein animal feed.

In the case of *Jatropha curcas L*, the cake is toxic, but can be used as soil conditioner and fertilizer because of its high phosphorous content. *Jatropha curcas L* seedcake also has high-energy content and can be pressed into briquettes and burned as fuel.

Main actors

Seedcakes are sold to local farmers to minimize transportation costs.

Markets and prices

[81] Following information received by Wendy Wen, Vice President, SinoBright Clean Oil Technologies Co. Ltd, Conference Proceedings China Biofuels and Ethanol Outlook 2005

[82] http://www.bjreview.com.cn/En-2005/05-29-e/bus-3.htm

[83] There is a significant informal collection and reuse sector from waste oil from restaurants; its reuse as edible oil after refining is illegal, and therefore official data about the real amount of recollected waste oils are not available.

[84] Interview with Mr. Rick Wen, Owner of Sing Land BioTech International Cooperation from Taipei, Taiwan, on September 20th, 2005 in Beijing; he imported two 5.000 t/a biodiesel units from United Kingdom in 2003, but due to the insufficient quality of Wok waste cooking oil the feasibility of such small scale unit was not given (www.sing-land.com)

There are no standardized prices for seedcake and fertilizers as by-products from biodiesel production available, because they are usually negotiated between local providers and purchasers, as they are only seasonal available and competitive products.

2.4.2 Glycerine

Refining plant oil into biodiesel produces about 10% glycerine, depending on raw oil quality and processing techniques[85]. Glycerine is in demand as raw material for a very wide range of cosmetic, medical and food products.

The national demand for glycerine is about 0.1 Mio t[86]. As the production of biodiesel is still very limited, in 2004 the amount of glycerine produced in China covered only 5% of the national market. If the production of biodiesel could be increased considerably up to the level of 1 Mio t/a, marketing strategies for glycerine will be feasible and may offer a valuable additional income to refiners.

Main actors

In the glycerine market, main actors are identified especially in the cosmetic industry, which buys glycerine in large scale, furthermore trade-companies with export relations and chemical factories producing a range of oil and acid based products.

Markets and prices

The Chinese glycerine industry increases its output with subsequently decreasing prices. While the national price of high purity glycerine is about 800 EUR/t (2005), some chemical products - such as high-valued 1,3-propanodiol, whose price is more than 5,000 EUR/t - may expand the market of glycerine. Thus the biodiesel production can be more feasible.

Chinese companies started recently importing glycerine as supplement to the regional market[87]. Largely traders and distributors drive the buying interest. According to industry sources, deals have been closed at 890 – 900 EUR/MT[88].

Asia as region is the major exporter of glycerine to the global market[89], and therefore of strong interest for international business and trade companies[90]. But the availability of lower-priced biodiesel glycerine in Europe and the USA has added more pressure to the downward price on the refined glycerine offer. In the light of the ample supply of lower-priced biodiesel glycerine, demand from the USA and Europe for high quality vegetable-derived glycerine from China has weakened.

2.5. National Markets - competitiveness, costs and prices of biodiesel

China's total consumption of fossil diesel is constantly rising in the last years to 95.5 Mio t in 2004[91], with about half of the share consumed by road and farm vehicles. The 2004 production of 38,000-60,000 t of biodiesel represents only a minor share.

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85 From the Jinshan Shanghai Biodiesel plant with capacity of 50,000 t/a 6,050 t/a are expected
86 Personal communication, Liu Dehua, September 2005
87 see example of applied US glycerine standard in the annex
88 http://www.icislor.com/il_shared/Samples/SubPage213.asp March 2005
89 some Asian trade companies for glycerin can be found here: http://www.alibaba.com/trade/search/2i1ptyfchms/CN/glycerine.html?RefineCategory=Y
90 http://www.icislor.com/il_shared/Samples/SubPage213.asp March 2005
91 www.bjreview.com.cn/En-2005/05-29-e/bus-3.htm

The price of fossil diesel keeps going up since recent years; therefore the price of biodiesel is now becoming competitive. The market for biodiesel is still limited to local distribution, direct sale and purchase, due to the low output and for not yet having unlimited market access to the main distribution network of the three Chinese leading petrol companies SINOPEC[92], PETROCHINA[93], CNOOC[94].

Table 16: Increase in Chinas diesel consumption

Year	**1996[95]**	**2000[95]**	**2002[96]**	**2004**
Total consumption (Mio t)	51.44	67.38	76.68	95.5
Only for road vehicles	8.21	14.41	nd	nd

Average processing costs for biodiesel production with chemical approaches, according to statements of the involved companies, range about 85 EUR/t, without calculating purchase factory gate costs of raw material.

Table 17: Cost comparison of biodiesel made from different raw material[97] [98]

	Average Consumption t of feedstock / t diesel produced	**Average feedstock purchase cost (EUR/t) incl. feedstock transport**	**Average processing cost (EUR/t)**	**Average biodiesel cost (EUR/t)**
Jatropha curcas L.	2	115	85	315
Pistacia chinensis Bunge	5	60	85	385
Xanthoceras sorbifolia Bunge	4	80	85	205
Cornus wilsoniana	5	65	85	410

Achieving an economical feasible production of biodiesel, factory gate costs for feedstock purchase should not be higher than 350 EUR/t. At present, there are no subsidies from the Chinese government for biodiesel production. In September 2005, biodiesel was sold between 400.00 EUR/t[99] and 425.90 EUR/t[100]. The following table shows that at rising fuel station prices for fossil fuels, biodiesel becomes competitive.

Table 18: Comparison of fossil and biodiesel prices

Fuel type	fuel diesel (Beijing) EUR/l			biodiesel EUR/l
Date	2004-5-18	2005-5-10	2005-9-7	By the end of 2004

[92] http://www.sinopec.com.cn/
[93] http://www.petrochina.com.cn/chinese/index.htm
[94] http://www.cnooc.com.cn/
[95] APERC, 2004, p37
[96] CSY, 2004
[97] http://www.agri.gov.cn/jjps/t20050907_454165.htm
[98] http://www.ycwb.com/gb/content/2005-08/10/content_958991.htm
[99] http://www.bioon.com
[100] CSY, 2004

Sales price	0.343[101]	0.362[102]	0.404	0.374[103]

SINOPEC controls most of the gas stations in the country, and up to date does not accept to share this market with other companies, such as privately owned biodiesel producing enterprises; the company also refuses to share its distribution channels to provide biodiesel to a larger number of clients. Therefore especially biodiesel producers have to look for direct marketing strategies to transportation companies. Sichuan Gushan Grease Chemical has set up such a partnership arrangement with local gas stations in San Tai County, Sichuan Province.

Foreign companies which might have more experience in developing biodiesel distribution networks may help the Chinese transport fuel sector to smoothen the existing monopolization and allow more biodiesel companies to compete in the diesel market. To succeed in the long term China's developing biofuel industry will also have to merge with the existing production and infrastructure of the country's transport fossil fuel industry.

2.6. Analysis: plant oil as stationary fuel or for transport?

Plant oil use for stationary heat or electricity production or industrial processes is much more price dependent than its application for transport fuel. Farmers will always choose the more feasible way to improve their income. So in most cases it will be up to them to decide whether the plant oil increases their income as locally processed biofuel or as sale of seeds to the next biodiesel company.

For biodiesel production there is no governmental subsidy, which may motivate farmers to prefer the one or the other purpose, or which may give incentives to heat- and power plant operators to choose either biodiesel or fossil diesel for running the installation. The only reason for applying biodiesel as stationary fuel is related to the market price and its availability on place; but at present the market price in energy terms for biodiesel is still higher than for fossil diesel, due to the national fixed price policy for fossil fuel.

The following table reveals the priority of natural gas for cooking purposes, although the coal price is still the lowest of all available fuels in China. Due to environmental considerations, cooking and heating with coal is no longer convenient, especially in urban areas.

Table 19: Stationary use of fuels for power generation, cooking and heating[104]

Fuel	Sales price	Energy price
0# fuel diesel	0.40 EUR/l[105]	8.2 EUR/GJ
LPG	0.38 EUR/kg[106]	7.6 EUR/GJ
Coal	0.04 EUR/kg[107]	1.9 EUR/GJ
Natural Gas	0.19 EUR/m³[108]	4.75 EUR/GJ

[101] http://oilpri.w186.leoboard.com/oilprice/www/super/history/20050413.htm
[102] http://news.xinhuanet.com/fortune/2005-05/10/content_2937038.htm
[103] According to chapter 2.1.2, Table 3, the price of biodiesel on the public market by Fujian Company is 425 EUR/t and the density of biodiesel is about 0.88 kg/l. Other prices are not available.
[104] The following conversion factors have been used: energy content of biodiesel: 40.128 GJ/t; energy content of bioethanol: 26.7 GJ/t; density of biodiesel: 0.84 kg/l; density of bioethanol: 0.789 kg/l
[105] http://news.xinhuanet.com/newscenter/2007-07/23/content_3255749.htm
[106] http://www.bjhr.gov.cn/bxsh/yehuaqi.asp
[107] http://www.coal.com.cn/PriceReport/SearchResults.aspx?province=%9%bd%ce%f7&city=&price=&trans= &payType=&tax=1&myClass=1&myType=11&mProvide=
[108] http://www.cas.ac.cn/html/Dir/2001/05/23/5777.htm

Biodiesel (B100)	0.374 EUR/l	10.98 EUR/GJ

From an environmental resource conservation point of view, building small regional plants to produce biodiesel from recycled cooking oil offers a tremendous advantage in energy and resource savings. The ideal scenario for producing an alternative fuel or additive would be to install a local processing unit for locally generated waste oil for use as biofuel in the local market.

2.7. Summary on plant oil & biodiesel

The main challenges for the direct use or the processing of plant oil to biodiesel are related to competing resource use (land/water), true greenhouse gas reduction potential (accounting for emissions in crop collection and fertilizer use) and costs (economies of scale). In the near future, real costs have to be assessed by fiscal support mechanisms for many, if not for all biofuel routes.

Factories producing biodiesel currently sell directly to local transport companies. Gas stations run by Sinopec, CNOOC and PetroChina do not yet offer biodiesel to the transport sector. However, direct sale of biodiesel to transport companies, agricultural machinery and public service cars is done in Sichuan and Fujian provinces, since fossil diesel is already in serious shortage in some areas[109]. Still it is difficult for consumers to identify the biodiesel quality and also to guarantee profit to biodiesel producers. As there is no biodiesel standard established some companies apply the national standard for low-grade light diesel fuel[110]. B100 could not be applied for the new EURO IV norm cars, planned to be adopted for Beijing during 2006, because of technical problems (dust particle filters etc.).[111]

Up to now, plant oils are mostly produced for food purposes; therefore the main actors, markets and prices for edible oil have not been assessed in depth. China's emerging economy imports edible oilseeds already and will do so in future for satisfying food demands[112].

2.8. Medium- and long-term perspectives

2.8.1 Demand for biodiesel in 2020

In 2020, motor vehicles in China will achieve numbers of 130 - 150 Mio. The fossil oil demand by these motor vehicles only will range about 256 Mio t, about 85 Mio t of gasoline and 171 Mio t of fossil diesel.

MOST is planning to achieve a national production of 1.5 to 2 Mio t/a of biodiesel in 2010, and 12 Mio t/a in 2020[113].

The government used to keep the fossil diesel prices at a low level, to support the agricultural sector and guarantee food supply. The controlled diesel prices contributed to regional diesel deficits, and discourage investment in private biodiesel production companies.

Table 20: Diesel consumption for transport purposes[114]

	1996	2000	Change
Diesel fuel consumption	51.44 Mio t	67.38 Mio t	+9.9% per year

[109] http://www.china.org.cn/english/BAT/137372.htm and www.newsgd.com/news/picstories/200508180019.htm
[110] The specification of the light diesel standard is given in the Annex
[111] Honecker, BMVEL, Ref 535, The Biodiesel market in Germany, III German-Brazilian Workshop on Biodiesel: Fortaleza, July 1, 2004 (www.ahk.org.br/inwent/palestras/market_germany.ppt)
[112] Prospects for Agriculture, p.98
[113] www.bioon.com/ (Chinese language)
[114] Table according to APERC 2004

Diesel consumption by road vehicles	8.21 Mio t	14.15 Mio t	+14.6% per year
Diesel consumption by farm vehicles	9.28 Mio t	14.94 Mio t	12.6% per year

Table 21: Growth scenario in demand of diesel as transportation fuel through 2020[115]

	Low case scenario	Mid case scenario	High case scenario
Diesel	171 Mio t	213 Mio t	232 Mio t

2.8.2 Forecast on production potential of biodiesel

The available amount of biodiesel in 2020 depends on the land resources, which can be used for energy-oriented forestry with woody oil plants as raw material resources for biodiesel production.

Table 22: Land resources for raw material plantation for biodiesel production

	Potential woodlands (ha)	**Grain-to-Green[116] land (ha)**	**Barren and uncultivated land suitable for forestland (ha)**
Proportion	57,000,000[117]	14,700,000[118]	53,930,000[119]
Potential utilization ratio for energy-oriented forestry	60%	80%	40%
Potential utilization area	34,200,000	11,760,000	21,570,000
Total	67,530,000		

According to the potential of *Jatropha curcas L.,* with a high average of about 3 t/ha of biodiesel output[120], about 200 Mio t/a biodiesel could be produced from plant production from these lands.

Even if a conflict of interest between the energy forestry and the traditional forestry, which focuses on timber production, could come up due to Chinese long-term forestry formulation[121], most of the available land resources are located where relevant research on biodiesel technology and

115 NDRC 2004, referring to table 59 Scenarios for different oil demands, with stable share of diesel
116 Agricultural land changed to forestry land
117 China Ministry of Forestry, 2002
118 Liu Jiang, 2002
119 China Agricultural Yearbook, 2004
120 which is similar to *Pistacia chinensis Bunge*
121 China Ministry of Forersty, 2002

investigations on land availability for energy forestry have already been carried out. Therefore the figures given for potentially available land are reliable.

Table 23: Minumim Potential for biodiesel from main oil plants in 2020

Variety	Availability of land (ha)	Average yield (t/ha/a)	Feedstock for 1 t biodiesel (t)	Total yield of biodiesel (t)
Jatropha curcas L.,	At least 2 Mio ha[122]	Kernel: 9.75[123]	3.33[124]	5,850,000[125]
Pistacia chinensis Bunge	At least 300,000 ha[126]	Kernel: 7.5[127]	2.5[128]	900,000
Total	At least 2 Mio ha			6,750,000

Table 24: Forestry crops - overview of production potential[129]

Variety	Distribution	Planting surface	Average yield t/ha/a	Possible areas	Availability of land
Jatropha curcas L	Guangdong, Guangxi, Yunnan, Sichuan, Guizhou, Taiwan, Fujian, Hainan	More than 16,000 ha in Sichuan[130] (primary area)	Kernel: 9.75[131]	Mainly in Tropical Very Dry to Moist through Subtropical Thorn to Wet Forest Life Zones	At least 2,000,000 ha[132]
Pistacia chinensis Bunge	Hebei, Henan, Anhui, Shanxi,	About 66,700 ha[133]	Kernel: 7.5[134]	Centralized in Taihangshan Mountains, covering middle and south of Hebei province and the north of Henan province	At least 300,000 ha [135]

[122] NDRC, 2004
[123] NDRC, 2004
[124] NDRC, 2004
[125] NDRC, 2004
[126] Actual planning area is 66,700 ha; availability of land hasn't been investigated but estimated based on official statistics
[127] Wang Tao, 2005
[128] Wang Tao, 2005
[129] based on the findings described in Chapter 2.3
[130] NDRC, 2004.10
[131] NDRC, 2004.10
[132] NDRC, 2004.10
[133] Wang Tao, 2005
[134] Wang Tao, 2005
[135] The availability of land hasn't been investigated, this data (300,000 ha) is just a conservative estimation

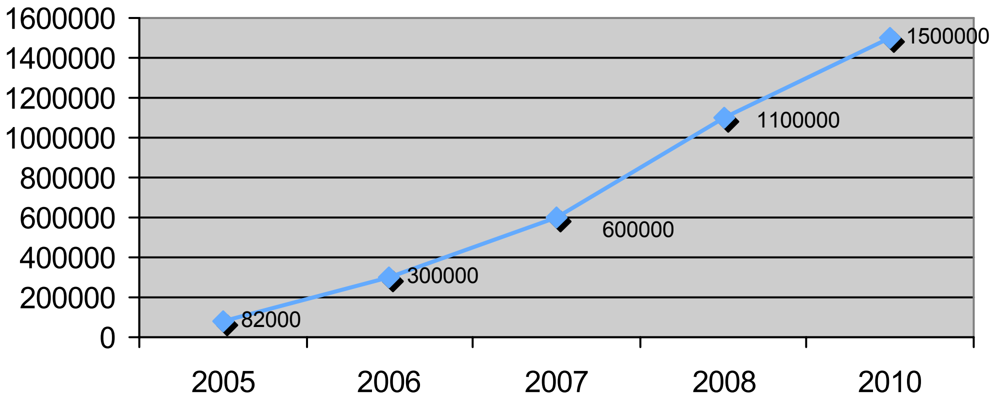
Variety	Distribution	Planting surface	Average yield t/ha/a	Possible areas	Availability of land
Cornus wilsoniana	Hunan, Hubei, Jiangxi, Guizhou, Sichuan, Guangdong, Guangxi	About 10,000 ha	Kernel: 4.5-9.0	Mainly in southern provinces	At least 2,000,000 ha
Xanthoceras sorbifolia Bunge	Shanxi, Shaanxi, Hubei, Neimenggu, Ningxia, Gansu, Henan	About 25,000 ha	Fruit: 45 (but only kernel for biodiesel production)	Mainly in northwest and north China	At least 4,000,000 ha

There are 158,940,000 ha forest in China (2003); forest coverage rate is 16.55%. The forest for firewood production occupies only 3.71% of the total forest area. Liaoning, Gansu, Hubei and Jiangxi are the top four provinces for wood fuel forest area. The two largest areas for special purpose forest are in Heilongjiang and Beijing.[136]

In addition, the annual output of low-grade vegetable oil as “by-product” in the production process of edible plant-oil is about 250 Mio t, which can be used for the production of 1.5 Mio t of biodiesel per year.

The food processing and production industry in China’s cities generates annually 4-5 Mio t of waste oil; (out of the 18 Mio t cooking oil markets) at a certain improved reclaim rate. About 1.5 to 2.4 Mio t of biodiesel can be abstracted from it, so that these two sectors together may contribute with 3.0 to 3.9 Mio t to the annual biodiesel supply.

Figure 2: Biodiesel capacity forecast (2005-2010)[137]



[136] Chuan Wang, Survey of CDM Initiatives and Potential Technology Collaboration between China and Sweden The case of biomass energy technology, Stockholm 2003, Master Thesis ISSN 1651-064

[137] Figure according to Wendy Wen, Biodiesel production and consumption in China, Conference proceedings China Biofuels and Ethanol Outlook 2005

Table 25: Total potential for biodiesel in 2020

	Biodiesel from main oil plants (t)	Biodiesel from cooking waste oil and low-grade vegetable oil (t)
Potential	6.75 Mio	3.9 Mio
Total	10.65 Mio	

2.8.3 Benefit analysis

Energy benefit

The construction investment requested by the biodiesel processing industry with a production capacity of 10.65 Mio t/a is to be calculated with 6 BN EUR. The ratio of annual production value to total investment is about 1:1, higher than in traditional energy industry[138].

Environmental benefit

Independent tests have shown that biodiesel significantly reduces most harmful vehicle emissions, and therefore biodiesel exhaust has a significantly less harmful impact on human health than fossil diesel fuel.

According to the U.S. Department of Energy, biodiesel has the most favourable energy balance of any transportation fuel. For every unit of energy needed to produce one litre of biodiesel, 3.2 units of energy are gained. In comparison, for every unit of energy needed to produce one litre of conventional petroleum diesel, 0.8 units of energy are provided[139].

Biodiesel is biodegradable, making it especially suitable for marine or farm applications. Biodiesel has better lubricity than petroleum diesel, making it suitable for blending into low and ultra-low sulphur diesel, which lacks lubricity. Diesel blends containing 5 % or less (B3) biodiesel are already widely accepted by China's vehicle manufacturers.

The environmental significance of using biodiesel focuses on

- Protection and improvement of China's atmospherically environment, especially in cities. Compared to fossil diesel, biodiesel significantly reduce the amount of atmospheric pollutants such as SO_x.
- Reduction of CO_2 emissions: Based on life-cycle assessment it is proven that CO_2 emission from biodiesel use is significantly lower than from fossil diesel.
- Adding coconut oil to biodiesel mixtures decrease nitrous oxide (NOx) emissions. One argument in the past used by many environmental agencies to hinder the market penetration of biodiesel was that NOx emission could be increased by up to 15% using B100.[140] Also animal fats used to make biodiesel additives can cut NOx in the exhaust gas to about 5 to 10% less than emissions from fossil diesel.[141]

Biodiesel vegetable oil methyl esters contain no volatile organic compounds that would give rise to any poisonous or noxious fumes. The biodiesel does not contain any aromatic hydrocarbons (benzene,

[138] The ratio in thermal power generation is about 0.4:1.
[139] USDE: "Life cycle inventory of biodiesel and petroleum diesel in an urban bus" http://www.nrel.gov/docs/legosti/fy98/24089.pdf
[140] Information from Mark Quinn, D1 Oils Plc.: www.iisd.ca/sd/gfse5/ymbvol93num3e.html
[141] Information from Choi Sau-yim, Chairmann of Better Environment Hong Kong: http://journeytoforever.org/biodiesel_hk_txt.html

toluene, xylene) or chlorinated hydrocarbons. There is no lead or sulphur to react and release harmful or corrosive gases. However, in blends with fossil diesel there will continue to be significant fumes released by the benzene and other aromatics present in the petroleum fraction (80%) of the blend.

Economic and social benefits [142]

Biodiesel could make a reasonable proportion of the transport fuels mix, but higher commodity prices in agriculture highlight an issue about the best value land use.

Because it is made from a locally grown, renewable resource, using biodiesel in vehicles can help boost farm economy and reduce dependence on foreign fossil fuels. Mandating the use of biodiesel in China in the coming years is more related to the support of domestic agriculture than environmental improvement.

It is calculated that the biodiesel processing industry with a yield of 10.65 Mio t/a output can create about 5 BN EUR/a, and can offer employment to more than 200,000 workers. The related energy-oriented forestry can absorb about 6 Mio of labour forces, thus increasing employment in rural areas and developing rural economy[143].

If job creation in rural communities is the goal, then the policies for subsidies should be compared with other government-supported job creation schemes such as public works, or investments in infrastructure, education, and improvement of the business environment.

2.8.4 Potential development barriers

Raw materials for biodiesel and planting technologies

Considering that the processing costs of biodiesel are influenced by the competition between food and energy production, and that the supply amount of feedstock is still restricted by the unavailability of waste cooking oil and low-grade vegetable oil, the developing biodiesel processing industry is more and more relying on energy crops to provide feedstock. At present, breeding of high-quality seeds of main energy crops such as *Jatropha curcas L.* and *Pistacia chinensis* Bunge has advanced. Further research will focus on their applicability to given plantation areas. Especially *Jatropha curcas L.* has a worldwide recognized enormous potential, but is still a relative low profile crop in China. To promote energy crop production on marginalized land, *Jatropha curcas L.* needs to be integrated into governmental programmes.

Genetically modified varieties of oilseeds may produce further productivity increases up to 10%, resulting in cost reductions of a similar order. However these gains may be offset by cuts in producer subsidies.

Collection and transportation of feedstock

Most of forestlands in China are located in mountainous areas; collection and transportation of energy forestry crops is still difficult and access to road infrastructure must be improved.

Processing technology

At present, processing technologies for producing biodiesel from the mainly available energy crops such as *Jatropha curcas L.* and *Pistacia chinensis* Bunge have been considerably researched, but there is still place for technological progress in order to increase the output of biodiesel from seeds. Up to

[142] Agricultural Strategies Research Team, 2003
[143] based on CSY 2004, p 502

now, the investment in technological R&D is still inadequate in relation to the rapid development of biodiesel demand.

Marketing

Biodiesel has serious advantages compared to fossil diesel in performance and price, but still most of the biodiesel sale is oriented to local transport companies. This is not due to intended market monopolization of biodiesel, but to the locally limited availability of biodiesel.

Given a higher economical feasibility and increased production capacity in the future, biodiesel could be bought and sold also by China National Petroleum Corporation and China Petroleum & Chemical Corporation, thus overcoming the general (fossil) diesel shortage in China.

An important aspect of promoting biodiesel is to establish clearly defined and enforced fuel quality standards, as Germany has done.

Grease trap waste management

There is a lack of overview for grease trap waste generation, collection and quality. Currently, illegal collection, unprofessional purification and re-sale of waste oil as raw material for cooking oil, makes it very difficult for biodiesel producers to obtain grease trap waste as feedstock for biodiesel production. Establishing and pursuing strict regulations to manage the collection of grease trap waste and used cooking oil and prohibition of re-sale of purified oil into the food market would provide a big share of feedstock for biodiesel production.

3 Bioethanol - current situation and technical potential

Although China has more than 9000 years of experience in producing alcohol, ethanol for fuel is a new issue.

From 1990 to 1999 the grain production in China increased fast, and the government spent large amounts of money to buy and store surplus grain. This situation was a main reason for the government to launch an ethanol fuel programme in 2000. The program was driven by at least 3 facts: grain surplus, fuel shortage and air pollution[144]. But since then the grain production decreased, making the feedstock purchase and the market for ethanol production for non-food use very unstable.[145]

However, the production of bioethanol is regarded as one of the pathways to large-scale and feasible use of agricultural products.

In 2004, the output of edible ethanol achieved 3 Mio t/a (3.7 BN l/a). According to the promotion plan for bioethanol established by the NDRC[146], fuel ethanol output of the country will reach 1,020,000 t/a by the end of 2005. Additionally new bioethanol factories with production scales of an annual capacity of 50,000 - 200,000 t per unit are planned to start operation soon.

3.1. Main Actors

3.1.1 R&D

Research on bioethanol resources and conversion technologies has been undertaken since the Eighth Five-Year Plan[147]. Producing bioethanol as transportation fuel was announced and implemented by the former State Planning Commission during the Ninth Five-Year Plan[148]. At present, NDRC and MOST set up R&D programs on production technologies of bioethanol from different kinds of plant cellulose, starch, *Saccharum officenarum* L., and other biomass resources like cellulose rich agricultural waste.

Table 26: Institutions involved in R&D related to bioethanol

Name & location	Keywords	Webpages
Tsinghua University, Beijing	Bioethanol, development of enzyme process	http://www.tsinghua.edu.cn
East China University of Science and Technology, Shanghai	Bioethanol by acid hydrolysation of cellulose waste	http://www.ecust.edu.cn/
China Agriculture University, Beijing	Biomass energy	http://www.cau.edu.cn/
Chinese Academy of Agricultural Engineering, Beijing	Bioethanol and energy agriculture, Sweet Sorghum	http://www.caae.com.cn/
Institute of Process Engineering, Chinese Academy of Science	Fuel Ethanol Technology development from cellulose waste by enzyme hydrolysis	
Chengdu Institute of Biology, Chinese Academy of Science	Fuel ethanol technology development by fresh sweet potatoes	

144 LAMNET, 2004
145 LAMNET, 2004
146 Yue Guo Jun, President China Resource Alcohol Heilongjiang Pte Ltd: “Utilization of Etanol in China – an Etanol manufacturer’s perspective” – Conference Proceedings China Biofuels and Ethanol OUTLOOK 2005
147 1991 - 1995
148 1996 - 2000

3.1.2 Companies, joint ventures & projects

The following tables list the companies currently involved in the bioethanol production and national and international projects on bioethanol carried out in China.

Table 27: Companies for bioethanol production

Name & Location	Year of start-up	Feedstock	Process technology	Designed capacity	Output bioethanol	By-product	Production costs EURO/t	Sale price EURO/t	No. of Staff	Market	Webpage
Jilin Fuel Alcohol Company Ltd, Jilin Province[149]: formed by China Petroleum Materials Equipment Corp, China Resources (Holdings) Company Ltd. and Jilin Grain (Group) Co. Ltd.	2003	Corn	Process Design by Vogelbusch Austria	600,000	300,000	DDGs, corn oil	85[150]	about 360[151]			http://www.jfa.com.cn
Anhui Fengyuan Petrochemical Ltd, Bengbu, Anhui: One of the companies hold by Anhui Fengyuan Group	2005	Corn			320,000	DDGs	85,00	360,00			http://www.bbca.com.cn

149 world largest bioethanol fabric: LAMNET, 2004
150 due to lack of information, estimation by Prof. Li Dehua
151 http://news.163car.com/1/2005-8-14/200581456078.shtml

Name & Location	Year of start-up	Feedstock	Process technology	Designed capacity	Output bioethanol	By-product	Production costs EURO/t	Sale price EURO/t	No. of Staff	Market	Webpage
Henan Tianguan[152] Group, Nanyang, Henan: SOE, reorganized by 12 productive enterprises, 6 subsidiary companies, 1 institute with the former Nanyang alcohol factory as its core	2001	Corn, grain, *Manihot esculenta Crantz*	Circular model, with a minimum of waste discharge. Stillage is treated in a biogas system, resulting in energy and organic fertilizer, which is used on the fields.	600,000	200,000	Organic chemistry fine chemistry biochemistry, distilled liquor, food-grade ethanol, distilled spirits	85.00	333.00			http://www.tianguan.com.cn/
Heilongjiang Huarun Jinyu Ltd, Zhaodong, Heilongjiang		Corn			100,000						http://www.hljhrjys.fukesi.com/

[152] 32,000 ha cassava production base has been established by this company in Laos: http://www.worldwatch.org/features/chinawatch/stories/20051006-1

Table 28: Projects planned for industrial scale of bioethanol production

Name, location, structure	**Year of start up**	**Designed Capacity t/a**	**Feedstock**	**Process**	**Process costs EUR/t**
Guangdong Qingyuan Heli Tianyuan bio-engineering technology Co., Ltd, Qingyuan[153]	2006	2006: 20,000 2008: 200,000 t/a	*Manihot esculenta Crantz*	nd	nd
Guangxi Wanjia Sugar Co., Baise[154]	nd	300,000 t/a	*Saccharum officenarum. L* (juice)	nd	nd
Factory Guangxi Nanning	nd	500,000 t/a	Sugar cane molasses and *Manihot esculenta Crantz*	nd	nd
Factory Guangxi Guigang	nd	200,000 t/a	Sugar cane molasses and *Manihot esculenta Crantz*	nd	nd

153 http://www.southcn.com/news/dishi/qingyuan/ttxw/200506260234.htm
154 http://www.bszs.gov.cn/ReadArt.asp?Art_ID=418

Table 29: Chinese national and international programs on bioethanol

Name	Description	Participants	Year
ASIATIC project "Agriculture and small to medium-scale industries in peri-urban areas through ethanol production for transport in China"	EU-China research project to promote, in a sustainable way, the production and use of bioethanol for transportation	**Chinese partners:** MOA, IEEP ERI, State Development Planning Commission Department of Energy and Environment Engineering, Shenyang Agricultural University Center for GIS Industry Development, Chinese Academy of Sciences Institute of Life Quality via Mechanical Engineering, School of Mechanical Engineering, Shanghai Jiao Tong University Institute of Comprehensive Transportation, State Development Planning Commission **European partners:** Institute National de la Recherche Agronomique (INRA), France Laboratory of Energy System (LASEN) Swiss Federal Institute of Technology, Suisse Sorghal, Belgium	2002 - 2004
ECHI-T	Financing large scale bioethanol projects with *Sorghum bicolour (L.)* ion Italy and China；The aim of the project is to elaborate a technical, economic and financial study on an integrated bio-electricity/bioethanol/DDG production from *Sorghum bicolor (L.)* for 3 locations: China (Dongying City area and Huhote, Inner Mongolia) and Italy (Pistachio).	**Chinese Partners:** Dongying City, Hohot, Inner Mongolia CAREI China Association of Rural energy development, Beijing E&E Biomass development ltd Beijing **European Partners:** Basilicata region (Italy), ETA - Renewable Energies - Florence, Italy (co-ordinator) COTEI - Florence, Italy SIEMENS KWU - Erlangen, Germany WIP - Munich, Germany BAFF - Oernskoeldsvik, Sweden DELTA T - USA ISCI - Bologna, Italy SORGHAL - Huy, Belgium ISCI - Bologna, Italy SORGHAL - Huy, Belgium	1999 - 2002

Name	Description	Participants	Year
Producing bioethanol from *Sorghum bicolor (L.)*	National '863' Program in 2001 during 'the tenth five-year plan'. Production and development of sweet sorghum stepped into a new age with the booming of bioethanol.	MOST, CAAE, Beijing Taitiandi energy technology development Co.	2001
Chinese Fuel Ethanol Programme, Phase 1	1. Two existing large-scale alcohol plants retrofitted with dehydration facilities. 2. Experiments on the properties of gasohol (gasoline-ethanol blends) and its corrosion effect on motors. Twelve cars produced in China underwent field tests with gasoline blends[155]. 3. Economics investigated. 4. Five cities chosen for field tests with E10 (10% blend) since June 2001[156]; total number of vehicles: 10.000[157]	Heilongjiang Huarun Jinyu Ltd	2000 – 2003
Chinese Fuel Ethanol Programme, Phase 2	1. Three plants to be constructed in Jilin, Henan and Anhui province. 2. Vehicle numbers using gasohol increase in Henan and Heilongjiang, as drivers and decision makers became aware of the advantages 3. In September 2003, Jilin provincial government decided to totally replace pure gasoline with E10 gasohol.[158] 4. By the end of 2005 the gasohol will totally replace gasoline in 5 provinces (Heilongjiang, Jilin, Liaoning, Henan and Anhui) and partially in 4 provinces.		2003 - 2004

155 7.7%, 10% and 15%
156 Henan province: Nan Yang, Zhangzhou, Luoyang; Heilongjiang province: Harbin, Zhaodong
157 LAMNET, 2004
158 LAMNET, 2004

3.2. Production and end-use technologies

Bioethanol production is a traditional industry in China. The products served for a long time mainly in three areas:

(1) in the liquor industry,

(2) for medicine commerce as a solvent and disinfection product,

(3) and in the production of ethanoic acid.

The Chinese ethanol industry comprises over 200 production facilities in 11 provinces, capable of producing more than 3 Mio t/a edible ethanol.

The Jilin Fuel Ethanol plant is said to be the world largest plant for fuel bioethanol with a designed capacity of 600,000 t/a. Current input material for bioethanol in China is supplied from corn (90%)[159], wheat (9-10%) and rice; *Sorghum bicolor* is not yet applied in a commercial scale but will be in future the most important bioethanol crop.

Bioethanol is commonly produced by the fermentation of sugars. The conversion of starch to sugar, called saccharification, is an alternative process that significantly expands the choice of feedstock to include corn, wheat, barley, sorghum, triticale and cassava, for example. Less expensive starch sources open the way to the commercial manufacture of bioethanol for transport fuel production. The third alternative route to bioethanol involves the enzymatic conversion of cellulose and hemi-cellulose but extensive research over the past 20 years has not been able to arrive at a competitive process, although the potential exists. Completing the picture, ethanol is also commercially synthesised from petrochemical sources but this does not fall into the renewable category, which is the theme of this assessment report.

Bioethanol is universally recognized as clean fuel. In China, as elsewhere, a biological approach is used to produce bioethanol from glucose or saccharomycete ferment through micro-organisms and distillation at different pressure[160].

As high-quality petrol substitute, bioethanol meets the national standards GB18350 and GB18351 according to the USA bioethanol fuel standard. 10% proportion ethanol as transport fuel mixed with gasoline can save petroleum and reduce harmful gas discharge; but as it is still not economical, Chinese fuel ethanol enterprises request national financial subsidy to be sustainable.

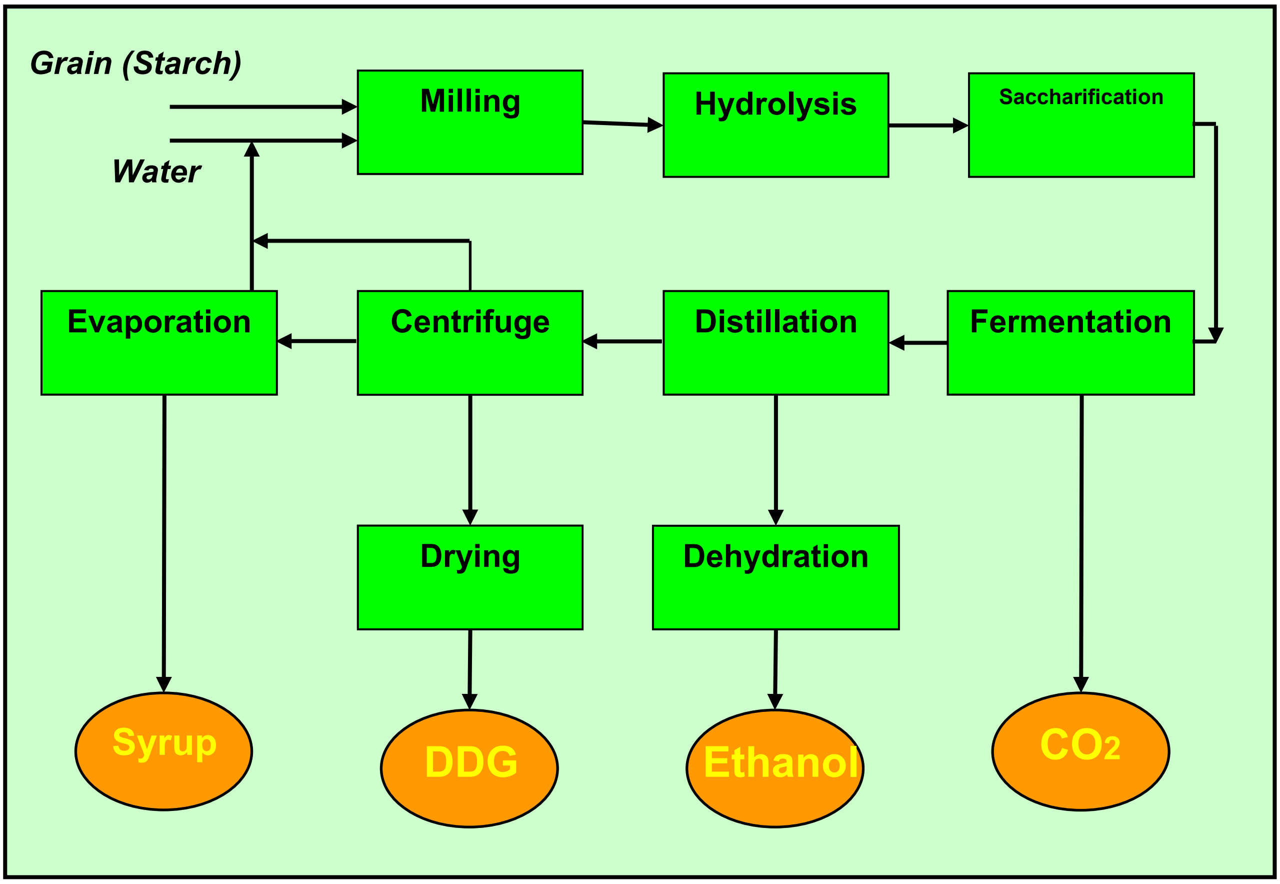
Treatment of wastewater generated by large-scale factories is executed by centrifugal and DDGs technology[161]; medium and small-scale factories adopt anaerobic-aerobic treatment technologies.

[159] LAMNET, 2004

[160] dehydration by molecular sieve

[161] Traditional DDGS is comprised of the residual material that remains after starch in the corn is converted to ethanol in the dry grind process; it is comprised of protein, fat, fibre and unconverted starch. Because traditional DDGS is so high in fibre, its use is mainly limited to ruminant animal feed. With a certain technology it could yield two separate co-products: fibre from which valuable products are made and enhanced DDGS, a product containing less fibre, higher protein and higher fat than the original DDGS.

Figure 3: Configuration for Producing Ethanol from Grain Process



3.3. Biomass availability and potential: agriculture and forestry[162].

At present, energy crops that can be used to produce bioethanol in China mainly include *Sorghum bicolor (L.)*, *Manihot esculenta Crantz*, *Saccharum officenarum L.* and corn; among those *Sorghum bicolor (L.)*, *Manihot esculenta Crantz*, and *Saccharum officenarum L.* are already applied in national fuel production. There is little conflict potential between the energy-oriented infields and foodstuff plantations: according to studies on Chinese food supply the potential output per ha can meet most of the increased demand for food[163].

For biofuel production, only *Sorghum bicolor L.* ethanol can be used in decentralized or centralized conversion processing units. However, best yield of sorghum is reported within the collection limit of a radius of 25 km. Hence comparison between decentralization and centralization of bioethanol production should be conducted for feasible production. Generally, centralized production of bioethanol from *Saccharum officenarum* L. juice is not feasible, due to rapid decrease of sugar content in the harvested stalks.

Corn as potential feedstock is widely popular, as it can be planted all over China; but its extended use is limited when the bioethanol production capacity will be increased, because corn needs similar soil conditions for energy crop production as for food production. Therefore corn will not be considered in this assessment study as future energy crop for bioethanol.[164]

[162] Detailed plant descriptions, including production requirements can be found in the Annex.
[163] Liu Jiang, 2002
[164] see chapter 3.3.4

Table 30: China's main feedstock for bioethanol production (2003)

		Output 10,000 t/a	**Share in national production**	**Remark**
Saccharum officenarum. L Molasses		60	20%	
Corn		132	44%	
Manihot esculenta Crantz	National crop	30	10%	Mainly from Guangxi and Guangdong province
	Imported crop	78	26%	Mainly from Southeast Asia

3.3.1 *Sorghum bicolor (L.) Moench var. saccharafum Kouern*

Scientific name: *Sorghum bicolor (L.) Moench var. saccharafum Kouern*

English name: Sweet sorghum

Family name: *Magnoliophyta : Liliopsida : Cyperales : Poacea*

Chinese name: Tian Gao Liang

Use[165]:

- feed, fuel, food, fibre,
- medicinal properties.

Regions of actual and potential production:

- Temperate zones in Northeast, Northwest and North China, especially in Shanxi, Inner-Mongolia, Liaoning, Jilin and Heilongjiang.
- Grown by families on small plots for family use rather than as a cash or subsistence crop.
- *Sorghum bicolor (L.)* hasn't been planted in large scale so far. Therefore statistical data about the crop usually include also data of grain sorghum and often do not reflect the true plantation area.
- Potential production areas for hybrid varieties tested by National "863" Programme[166] in Hainan, Chongqing, Jiangsu, Henan, Shandong, Inner Mongolia, Xinjiang, Jilin and Heilongjiang.

[165] This versatility has resulted in Prof. Li Dajue (CAS) and Peter Griffee (FAO) coining the name the "Four F's Crop" for sweet sorghum. The "Four Fs" represent the four potential outputs from sweet sorghum, namely: Food, Fuel, Fodder, & Fibre. Wine from Sweet sorghum is distilled and produced in Tuoket county, 70 km from Hohot, Inner Mongolia.

[166] A high technology programme authorized by Deng Xiao Ping in March 1983. The programme is still one of the three major programmes in the actual 10th Five-Year-Plan

Table 31: Current distribution of Sorghum bicolor

Variety	**Distribution**	**Planting surface: ha**	**Average yield: t/ha**	**Possible areas**	**Availability of land in some primary areas**
Sorghum	Shanxi, Hebei, Inner-Mongolia, Liaoning, Jilin Heilongjiang,	722,400	Seeds: 4.0	mainly in Northeast, Northwest and North China temperate zones	
Sorghum bicolor (L.),	Jilin, Liaoning, Heilongjiang, Inner-Mongolia, Sinkiang		Seeds: 4.0 Stalks: 60	mainly in Northeast, Northwest and North China temperate zones	More than 670,000 ha in Jilin, Liaoning, Heilongjiang, Inner-Mongolia, Sinkiang[167]

Main actors:

- Rural households: one of the principal sources of energy, protein, vitamins and minerals for millions of people, it plays a crucial role in the food economy as it contributes to food security[168].
- Beijing Botanical Garden has an advanced breeding programme producing cultivars for high yield, drought tolerance and sugar content, and a wide variation in seed type from germaplasm collection.
- From 2003 to 2004, several institutes jointly made planting tests in Beijing, Liaoning and Henan to select and identify excellent cultivars from 10 popular cultivars suitable to different areas in North China, for the purpose of bioethanol production:
  - National Sorghum Study Center, Shenyang Liaoning Province
  - Shenyang Agriculture University
  - Heilongjiang Academy of Agriculture
  - Jilin Academy of Agriculture
  - China Academy of Agriculture, Beijing
  - Beijing Sustainable Agriculture and Economic Plant Institute
- At present, Chinese Academy of Agriculture Engineering, National Sorghum Breeding Centre, Renewable Energy Laboratory of Henan Agricultural University, and Ecology and Genetic Improvement Laboratory of Shenyang Agricultural University are doing research on *Sorghum bicolor (L.)* species filtrating.
- Production bases that convert *Sorghum bicolor (L.)* into bioethanol have been established in Heilongjiang, Inner Mongolia, Sinkiang, Liaoning and Shandong.
- The Species Resource Institute of the Chinese Academy of Agricultural Science (CAAS) issues authorisation and seed quality certification[169].

[167] Report on renewable energy and new energy high tech industrialization, Energy Research Institute of NDRC, 2004.10
[168] African Journal of Biotechnology Vol. 4 (7), pp. 575-579, July 2005

Financial feasibility:

This report adopts cost-benefit methods to analyze the financial feasibility of *Sorghum bicolor (L.)* planting. The analysis is based on investigation with rural households in Huxin, Liaoning in 2004.

Table 32: Financial feasibility analysis for *Sorghum bicolor* L.

Item	Input EUR/ha	Output EUR/ha	Benefit EUR/ha
Machinery	3		
Fertilizer	11		
Seeds	1	40[170]	
Stalks	0	64[171]	
Pesticide	1		
Manpower	7		
Irrigation and electricity	2		
Total	25	104	**79**

Benefit

- input-output ratio of 4.16:1; benefit from planting corn is about 50 EUR/ha. Compared to corn, the possible benefit from *Sorghum bicolor (L.)* is 25 to 30 EUR/ha higher.
- If 0.1 Mio t bioethanol is produced in one year, 27,000 ha[172] plantation of *Sorghum bicolor (L.)* needs to be expanded. This additional plantation area will create a total agricultural production value of 41,6 Mio EUR and increase the income of rural residents by 31,6 Mio EUR - about 10 Mio EUR more than they could expect from corn production.

Availability of land:

- From Hainan in the south to Heilongjiang in the north, if the adequate variety is chosen.
- The most suitable areas are Northeast, North, and Northwest China, and the drainage areas of the Yellow River and the Huai River, including 18 provinces.
  - In 2003, total sorghum planting area could have been 27,000 ha[173], but only 80% have been exploited.

Barriers to *Sorghum bicolor* (L.) production and its use for bioethanol processing:

- The most important barrier is the volatile sugar content of the plant. Up to now, Chinese researchers have not yet discovered the most adequate method to preserve it.
- Due to the volatile sugar content, feedstock-purchasing radius of ethanol production units is limited within 25 km, so that planting radius is limited around the processing factories.
- Harvest could even be endangered by strong winds, which can easily break the long stalks, thus reducing the sugar content significantly within a short delay.

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[169] For export, the application has to be submitted for ratification to the Seed Division of the department of Planting at the Ministry of Agriculture (MOA). It is then possible to apply for an exporting licence from the Ministry of Foreign Economic & Trade. Certified, licensed seeds are then exported through the PR China Seed Company.

[170] In normal years, 400 kg seeds could be gained per mu. The seed price in Huxin in 2004 is 1 RMB/kg

[171] Stalks are used as feedstock for bioethanol after sweet sorghum is harvested; output of stalks is counted as 4000 kg/mu, and the price as 0.16/kg

[172] 400,000 mu

[173] China Agricultural Yearbook, 2004

Assessment of overall production potential, based on findings listed above:

- *Sorghum bicolor (L.)* as energy crop planted in the current sorghum lands will not influence food supply, because *Sorghum bicolor (L.)* offers both sorghum kernel for food and stalks for bioethanol production.
- Given the characteristics of *Sorghum bicolor (L.)*[174], more than 670,000 ha can be cultivated in Jilin, Liaoning, Heilongjiang, Inner Mongolia and Sinkiang in near future[175], providing feedstock for the production of 2,512,000 t/a bioethanol.

3.3.2 *Manihot esculenta Crantz, M. ultissima Phol, M. aipi Phol*

Scientific name: *Manihot esculenta* Crantz, *M. ultissima* Phol, *M. aipi* Phol

English name: Cassava

Family name: *Euphorbiaceae*

Chinese name: Mu Shu

Use:

- Fresh roots are prepared like potatoes.
- Alcoholic beverages can be made from the roots.
- Young tender leaves can be used like spinach, containing high levels of protein[176].
- Most economical material of bioethanol.
- Mainly used to produce starch and ethanol.

Regions of actual and potential production:

Mainly cultivated in the southern provinces Guangdong, Guangxi, Hainan, Fujian and Yunnan, where industries of starch and ethanol processing based on *Manihot esculenta* Crantz have been developed since long time.

Table 33: Current Distribution of *Manihot Esculenta Crantz*

Variety	Distribution	Planting surface: ha	Average yield: t/ha	Possible areas	Availability of land in some primary areas
Manihot esculenta Crantz	Guangdong, Guangxi, Hainan, Fujian, Yunnan, Guizhou, Sichuan	400,000 (Guangxi) 124,140 (Guangdong)	15	Mainly in southern provinces	At least 320,000 ha in Guangxi, at least 146,700 ha in Guangdong

- Guangxi province[177]:
  - provides with 400,000 ha the largest planting area,
  - produces 70 % of all Chinese *Manihot esculenta* Crantz production.
    - cassava flakes: 250,000 t/a,

[174] see plant description in annex
[175] NDRC, 2004
[176] 8-10% , http://www.hort.purdue.edu/newcrop/Crops/CropFactSheets/cassava.html :.
[177] data from 2004

- starch: 300,000 t/a,
- bioethanol: 80,000 t/a;

- Guangdong province[178]:
  - maintains 124,000 ha cassava planting area;
- Hainan, Guangdong, Fujian, Yunnan, Guizhou, Sichuan contribute 30 % to the national supply, but planting is dispersive and in small scale – therefore no statistical relevant data.

Main actors:

- *Manihot esculenta* Crantz varieties have been introduced by several institutes:
  - Guangxi Subtropical Crops Institute,
  - Plant Research Institute of Chinese Academy of Sciences, Beijing
  - South China Subtropical Crops Institute, Guangdong
- Planting and harvesting is labour intensive, mostly done by hand, and require rural manpower.
- In many areas, cassava is the staple, sometimes the only food, consumed for considerable periods of time. This diet results in chronic protein deficiencies[179]. Planting cassava as energy crop may increase the income of rural households and thus improve their diet through food diversity.

Financial feasibility:

This report adopts the cost-benefit methods to analyze the financial feasibility of *Manihot esculenta* Crantz production. Investigation has been carried out in Fusui, Guangxi province through field survey and interviews with local households.[180]

Table 34: Cost-benefit analysis for *Manihot esculenta Crantz* production

Item	Input EUR/ha	Output EUR/ha	Benefit EUR/ha
Machinery	0		
Fertilizer	90		
Seeds	37.5		
Pesticide	3		
Manpower	144		
Irrigation and electricity	0		
Total	274.50	1125	**850.50**

Benefit:

- Although the unit price per kg *Manihot esculenta* Crantz is the lowest among the main stable food, the input - output ratio of 4.10:1 at farm level indicates that production is relatively competitive.
- The net income of 850.50 EUR/ha is 514.50 EUR/ha higher than for rice production per ha.
- If 0.1 Mio t bioethanol are produced in one year, 60,000 ha with *Manihot esculenta* Crantz need to be planted, which will create an agricultural production value of 68 Mio EUR and enhance the

178 data from 2003
179 http://www.bio.ilstu.edu/armstrong/syllabi/cassava/cassava.htm
180 The primary food crops there are rice, corn, soybean and cassava.

income of rural residents by 51 Mio EUR, an increase of about 31 Mio EUR compared to rice production results.

Availability of land[181]:

- The supply potential mainly is and will remain in Guangxi and Guangdong.
- *Manihot esculenta* Crantz can be widely planted on marginal lands and in low-nutrient soils:
  - Guangxi province:
    - Fallow lands: 210,000 ha. If in future 80% of the fallow land can be used to plant energy *Manihot esculenta* Crantz, the production area will increase by 160,000 ha;
    - Existing planting area: 400,000 ha. If in future 40% of the land can be used to plant energy *Manihot esculenta* Crantz, the production area will increase by 160,000 ha.
  - Guangdong province:
    - Fallow lands: 108,000 ha. If in future 90% of the land can be used to plant energy *Manihot esculenta* Crantz, the production area will increase by 97,000 ha.
    - Planting area: 124,000 ha. If in future 40% of the land can be used to plant energy *Manihot esculenta* Crantz, the production area will increase by 49,656 ha.
- Planting *Manihot esculenta* Crantz on existing production land may influence food production; therefore calculation is done with restrictions.

Barriers to *Manihot esculenta* Crantz production and its use for bioethanol processing:

- Improved cultivars have not yet been introduced in large scale, so that yields per ha still remain low.
- Current planting areas are very scattered and do not perform industrialized plantation scale.
- Traditional planting methods combined with a lack of efficient farm- and crop management skills hinder the potential large-scale implementation of *Manihot esculenta* Crantz even in the provinces where starch and alcohol production are the leading industries.

Assessment of overall production potential based on findings listed above:

- No negative impact on the food market of China, but may occupy parts of the food production fields.
- Positive impact on the rural economy by increasing the income of rural households.
- In Guangxi, there are at least 320,000 ha potential land. The potential for the production of energy *Manihot esculenta* Crantz could be calculated with the yield of up to 4.8 Mio t/a, providing feedstock for the production of 533,000 t/a bioethanol.
- In Guangdong, there are at least 146,700 ha potential land; the potential for the production of energy *Manihot esculenta* Crantz could be calculated with the yield of up to 2.2 Mio t/a, providing feedstock for the production of 240,000 t/a bioethanol.

3.3.3 *Saccharum officenarum. L*

Scientific name: *Saccharum officenarum. L*

English name: Sugarcane / energy sugarcane

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[181] data from 2003

Family name: *Graminiae*

Chinese name: Gan Zhe / Nengyuan Gan Zhe

Table 35: Varieties of Chinese energy sugarcane:

Variety	Yield (t/ha)	Sugar content (t/ha)	Increased Yield(%)[182]	Increased Sugar content (%)[183]
Funong 98-0402	200.4	56.1	73.4	84.4
Funong 93-3406	190.1	53.3	64.4	73.5
Q70	195.15	54.6	68.9	82.2

Use:

- sugar production
- edible sweet
- alcohol production
- bioethanol production (ideal feedstock)

Regions of actual and potential production:

- Actually mainly produced in Guangxi, Yunnan, Guangdong, Fujian, and Hainan
- Can potentially be grown in all southern provinces up to Henan, Jiangsu, and Shaanxi, but there is little additional land suitable for its growth.

Table 36: Distribution of *Saccharum officenarum. L* in China from 1991 to 2003[184]

	1991	1996	1997	1998	1999	2000	2001	2002	2003
Guangxi	40.00	50.60	54.9	61.40	55.30	50.90	57.50		70.60
Guangdong	31.40	22.00	24.1	23.60	19.40	17.80	16.40		15.60
Yunnan	14.10	20.20	24.9	28.30	28.70	26.00	26.90		29.21
Hainan	9.60	7.40	7.7	7.20	8.00	6.20	6.10		6.91
Fujian	5.30	3.80	3.7	3.20	2.20	1.50	1.60		1.83
Jiangxi	4.20	3.70	4.2	3.90	3.40	2.80	2.60		2.44
Sichuan	5.30	3.40	3.1	3.00	2.90	3.10	3.10		3.19
Other provinces	6.50	7.80	8.6	9.50	10.40	10.30	10.60		10.89
Total	**116.40**	**118.90**	**131.20**	**140.10**	**130.30**	**118.50**	**124.80**	**139.30**	**140.90**

Unit: 10,000 ha

182 compared to common *Saccharum officenarum*
183 compared to common *Saccharum officenaru*
184 CSY, 2004

Table 37: Current distribution of *Saccharum officenarum L.*

Variety	Distribution	Planting surface: ha	Average yield: t/ha	Possible areas	Availability of land in some primary areas
Saccharum officenarum. L.	Guangxi, Yunnan, Guangdong	1,409,400	Stalks: 64	Mainly in southern provinces	
Energy *Saccharum officenarum. L.*	Guangxi, Yunnan, Guangdong		Stalks: About 120	Mainly in southern provinces	At least 98,700 ha. in Guangxi, Guangdong, Yunnan

Main actors:

- Research on energy *Saccharum officenarum* L started only in the 1980-ies, but since then it experiences a steady and fast development.
  - Fujian Agriculture and Forestry University developed promising varieties, such as Funong98-0402, Funong93-3406, and Q70 [185] with high biomass yield and high photosynthetic rate for energy production.
  - Guangzhou Sugar Industry Research Institute carries out research on energy *Saccharum officenarum. L* breeding and bioethanol producing

Financial feasibility:

At present, there are two major types of *Saccharum officenarum L* according to different agricultural uses: energy *Saccharum officenarum L,* and sweet *Saccharum officenarum L.* Therefore a cost-benefit comparison among energy *Saccharum officenarum. L*, sweet *Saccharum officenarum. L* and rice - as primary food crop in most *Saccharum officenarum L* production areas – has been established to analyze the financial feasibility of energy *Saccharum officenarum L* planting[186]:

- Average output of energy *Saccharum officenarum. L*: 180 - 240 t/a/ha.
- Considering the increased promotion of high-quality energy *Saccharum officenarum L*, an output of 210 t/a/ha could be used as mean value.
- To produce 0.1 Mio t/a bioethanol, 7,500 ha energy *Saccharum officenarum L* need to be harvested and processed.
- This will create an agricultural production value of 28 Mio EUR, about 14 Mio EUR more than sugar producing *Saccharum officenarum L*, and 20 Mio EUR more than rice, cultivated on the same amount of land[187].

Benefit

This report adopts the cost-benefit method to analyze the financial feasibility of energy *Saccharum officenarum L* production, but due to the production scale of *Saccharum officenarum L* no data from rural household level are available.

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[185] Since 1970s, Brazil had developed excellent cultivars of SP71-6163 and SP76-1143, America had developed US67-22-2 with high biomass yield; India and America had jointly developed IA3132 hybrid with ethanol yield of 12,000 l/ha.

[186] Ecologic and Genetic Improvement Laboratory of Fujian Agriculture and Forestry University

[187] The agricultural economical analysis for sugarcane production refers to the basic data that 1 t bioethanol requires 15 t of sugarcane grown on 1 ha (1t / ha).

Table 38: Economic comparison between crop and crop destination[188]

Crops	Yields t/ha	Price/unit EUR/t	Total price EUR/ha	Price difference to energy sugarcane EUR/ha
Energy *Saccharum officenarum L*	210	18	3780	0
Saccharum officenarum L for sugar production	75	25	1875	-1905
Rice	12	90	1080	-2700

Availability of land

The southern region of Guangxi province, the south-western part of Guizhou province and the western regions of Guangdong province are identified as most suitable areas for *Saccharum officenarum L* production[189].

- Average planting area for all types of *Saccharum officenarum. L* in the past three years was about 1.33 Mio ha, mainly in
  - Guangxi: 0.55 Mio ha,
  - Yunnan: 0.89 Mio ha
  - Guangdong: 0.183 Mio ha[190].
- These three provinces together achieved an output of 59.84 Mio t biomass.
- In 2007, the planting area for *Saccharum officenarum L* will decrease to 1.24 Mio ha; biomass output will reach 83.33 Mio t, and sugar output will reach 9.23 Mio t[191].

Therefore, it is estimated that – when sweet *Saccharum officenarum L* production continues to decrease – 0.1 Mio ha land could be dedicated to energy *Saccharum officenarum L* plantations, and can at least produce 7.4 Mio t/a of biomass for liquid biofuel without the need of any additional land resources.

Barriers to energy *Saccharum officenarum L* production and its use for bioethanol processing:

- *Saccharum officenarum L* is a seasonal crop and not easy to preserve.
- Rising sugar prices may compete with the plantation of energy *Saccharum officenarum L*.

Assessment of overall production potential based on findings listed above:

- Plantation area dedicated to the sugar production will decrease by 98,667 ha. This agricultural land can be used for energy *Saccharum officenarum L* with total yields of 2,072,000 t/a, feedstock for the production of 1,380,000 t/a bioethanol.

188 If the price of energy sugarcane can remain at 180 RMB/t, production value of 1 mu can reach 2520 RMB, 1270 RMB higher than sweet sugarcane (5 t/mu, 250 RMB/t) and 1800 RMB higher than rice (8 t/mu, 900 RMB/ton).
189 According to the National Sugarcane Development Plan, MOA
190 According to MOA statistics
191 According to the Nacional Sugarcane Development Plan, MOA

3.3.4 Other agricultural crops

The following crops are analyzed in regard to their actual and future potential for bioethanol production.

Corn:

- Important food crop and third primary food crop in China, only inferior to wheat and rice.
- Widely distributed in Northeast, North China and Southeast, even in southwest of Sinkiang.
- Has high adaptation and is easy to grow.
- Dry corn contains 65 to 66% of starch, 12% of H_2O, 8 to 9% of protein, and 4 to 4.5% of fat.
- Planting acreage about 20 Mio ha, output about 120 Mio t/a.
- ➢ Already used for high quality food ethanol production, therefore not defined as feedstock for fuel ethanol processing.
- ➢ Also in future corn will mainly be used for food purposes (alcohol), but overtime crop can be applied as raw material for fuel bioethanol.

Sweet potato:

- China is the world biggest producer (90%) of sweet potato.
- Planting area 875 ha, mainly in Sichuan.
- Starch content 13-24%.
- Yield about 15-22.5 t/ha.
- Feedstock costs are lower than for rice and corn.
- Difficult storage in wintertime.
- ➢ Only in pilot stage, has to compete with market prices as fresh product.

Agricultural waste:

Apart from the already mentioned bioethanol feedstock crops, agricultural residues can provide raw material for bioethanol production:

- Fibre crops: the jute and ambary hemp fibres normally represent only 4 % of the total leaf weight. The waste generated annually from this sector in China fluctuated from 1997 from 10.32 Mio t/a to 2.4 Mio t/a in 2003. The main production areas are located in Hubei, Henan, Guangxi and Anhui.
- Coffee: is only produced in Hainan Island; coffee husks represent 20% of the harvested gross weight. National data are not yet available.
- Rice: Husk production per ton of grain rice is estimated at 0,33 t, resulting in an annual waste production of 53 Mio t, mainly in Heilongjiang, Jiangsu, Anhui, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Sichuan.
- Cashew nut: the nut yields a large quantity of shells and husks, which are potential bioethanol feedstock for cellulose rich process technology. In 2003 the national yield ranged at 13.42 Mio t of raw nuts generating about 4.47 Mio t of residues in the provinces of Hebei, Shandong and Henan.

- Cotton: in 2003 the production of cotton in the provinces of Hebei, Jiangsu, Anhui, Shandong, Henan, Hubei, Tianjin and Hunan achieved 4.86 Mio t; main wastes generated are stalks and cottonseed husks.

3.4. By-products

Different methods can be used to derive bioethanol from plants. Depending on the process, different by-products will occur. By- and sub-products from bioethanol production receive attention, if their market value is high, such as the conversion of ethanol into ethylene. National research is supported by the NDRC and MOST to improve the production technology. The production range is being shifted from traditional food and medical market to transportation fuel and by-products gradually, already obtaining wide market prospects.

Figure 4: Simplified scheme for by-products from Sorghum bicolor (L.) cultivation for bioethanol[192]

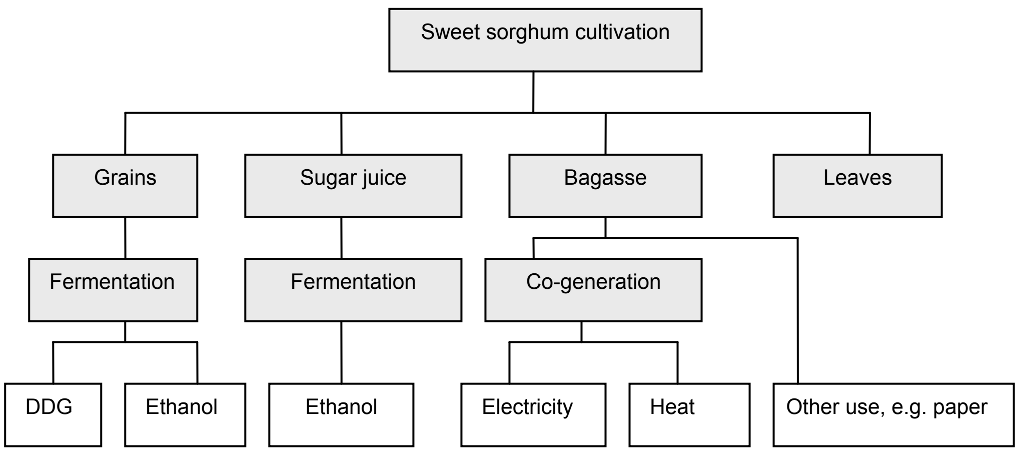


Table 39: Examples of by-products from bioethanol production

Feedstock	**By-product**	**Observations**
Sorghum bicolor L., *Saccharum officenarum* L.	sugar juice, bagasse, charcoal, activated coal, hydrogen, methanol, compost, paper production	The output balance can be roughly calculated with 33% ethanol, 33% DDG and remaining CO_2. Dry bagasse is used to produce pellets, which can be utilised in different purposes, such as pulp for paper, for composting, or as heating material in cogeneration and steam engines.
	CO_2	By processing the sugar juice, CO_2 is captured during the fermentation process. Calculated with 100% input, CO_2 outcome is about 40-50% of input mass (t/a), which can either be directly or controlled converted into methane.

192 Designed according to ETA 2002

Feedstock	By-product	Observations
	Animal feed: • DDG • Fermentative sludge • Low compacted pellets are produced from a mix with chopped corns stalk.	Non-fermentable residues, so called stillage, and dry bagasse can be processed into DDG, a high-value protein rich, vegetable animal feed, esp. for cattle breeding.

Main actors:

When delivering DDG as fodder material, the relevant feed industry sector requires the approval by the National Feed Engineering Technology Research Center, Feed safety and Bio-availability Evaluation Center, both under the responsibility of the MOA.[193]

Markets and prices:

DDG from bioethanol production is sold within local contracts to livestock farmers. But in most cases DDG is post processed to make it more digestible for animals and is than used as basic for feed industry. Therefore no price statement could be obtained. As DDGs do not yet have an own developed market its prices are linked to feed corn prices.

Compared with ethanol by-products, ethanol derivatives are even more preferred. Ethylene and its derivatives ethylene epoxy, ethyl benzene, ethylene oxide, as well as acetaldehyde and acetate acid produced from ethanol are competitive with petroleum-based products.

3.5. National Markets - competitiveness, costs and prices

In 2005, the market price for bioethanol is about 360 EUR/t, supported by governmental subsidies. Although resource restriction of "overtime grain" and high price of fresh corn increase the cost of bioethanol, the current (subsidized) market price of bioethanol is less than fossil gasoline, which ranges between 480 and 510 EUR/t.

At present, governmental subsidy to 1t of fuel ethanol is about 137 EUR. Even if production will be running at full scale, about 137 Mio EUR/a will be requested as subsidies. But the ethanol subsidy has been already reduced from 183 EUR/t to 137 EUR/t, and will further gradually decrease to 0 in 2010.

The processing costs of 100% bioethanol are about 101 EUR/t, including the different positions as stated in the following table, not considering the purchase costs for feedstock.

Table 40: Processing costs of 100% bioethanol per ton, without feedstock purchase

Process step	EUR /t
Power/energy	27
Removing excess water (from 95% to 99.8%)	42
Salary	10

193 www.mafis.com.cn

Process step	EUR /t
Permanent assets depreciation	10
Equipment maintenance	2
Equipment manufacture	2
Sale fee	2
Management/financial fee	6
Total	**101**

Currently, the total production cost of bioethanol ranges from 287.5 to 481 EUR/t, including 70% for raw material purchase[194]. Existing raw materials, especially corn and wheat, cost over 400 EUR/t bioethanol, but by-products such as DDGS can be sold to compensate high feedstock costs. *Manihot esculenta Crantz* is purchased at about 250 EUR/t ethanol, but the value of by-products from this feedstock is relatively low. Hence, the cost-benefit analysis results almost equal.

The question how to reduce bioethanol production cost in order to compete with fossil fuel remains to be a central research focus. Some factories reduce costs by replacing the raw materials. For example, Henan Tianguan Group produces bioethanol with *Manihot esculenta* Crantz instead of wheat and cut production cost down for 30 EUR/t. The Group has also purchased 180,000 ha lands in Laos as planting ground for *Manihot esculenta* Crantz.

Experiments for producing bioethanol by fermenting dried *Sorghum bicolor (L.)* has been concluded at laboratory scale. *Sorghum bicolor (L.)* as feedstock lowers the costs by 40-50 EUR/t compared to corn.

Table 41: Cost comparison of 95% alc. vol. ethanol made from different raw materials

		Consumption amount t	**Feedstock purchase cost (EUR/t)**	**Production cost (EUR/t)**	**Fuel ethanol cost (EUR/t)**
Corn		3.3	120	85	481.0
Manihot esculenta Crantz	Fresh	7.5	30	85	310.0
	dry	3.0	100	85	385.0
Sugar cane		14.0	20	85	365.0
Sorghum bicolor (L.)		13.5	15	85	287.5

In 2000, provincial governments have initiated trial scenarios for automotive fuel ethanol with support from the national government for 1 year in 5 cities, namely Zhengzhou, Luoyang, Nanyang (all Henan province), Harbin and Zhaodong (both Heilongjiang province). Until June 18th 2002, Zhengzhou and Luoyang have build up 97 service stations, and Nanyang finished 45 stations and an allocation center. In Heilongjiang, which presents the main corn producing area in China, the aim was to produce fuel ethanol from surplus and overtime corn and to test the performance of bioethanol as fuel in cold winter days. Financial and policy support is given to Tiangguang group, Henan and The Huarun Alcohol group Corp. in Heilongjiang province through tax exemption and the payback of the value added tax.

Heilongjiang, Jilin, Liaoning and Henan and Anhui have been identified subsequently as pilot provinces[195] to test E10 ethanol mixed gasoline. During the one-year-test, bioethanol achieved the

[194] including costs for transport farm to factory
[195] Yue Guo Jun, Utilization of Etanol in China, Conference Proceedings CHINA Biofuels and Etanol OUTLOOK 2005

acceptance of users in cold and temperate regions. No bigger technical problems have been reported, but budgets to spend for grain storage or elimination of overtime crops could be reduced; emissions of CO in the pilot areas have been reduced by 30%. Encouraged by these results, Shandong, Jiangsu, Hebei, Shanxi will be the next provinces to use gasohol (E10)[196] in a large scale.

3.6. Analysis: bioethanol as stationary fuel or for transport?

Bioethanol is not very suitable for stationary usage in China. Using natural gas, LPG, (or biogas) is cheaper than using liquid fuels, and therefore the prime choice to meet household fuel demand, and energy for stationary power production, as already proven in the discussion about biodiesel for stationary energy generation[197]. Furthermore, in China few household fitments are designed to use liquid fuels.

Most of the stationary motors (about 1000 village electrification grids in Western China are supplied by hydropower and diesel generators) are using fossil diesel so to be more powerful than using gasoline engines. Stationary engines have to be adjusted due to the higher risk of corrosion when applying bioethanol E95 or E100. Because of the low flame point at 21°C the tank must be well secured.

Ethanol is a good fuel for spark ignition engines but when using ethanol in a diesel engine, various problems may occur. This is due to the low cetane number and a low lubricate level in the ethanol. An ignition improver (polyetylenglycol) or a sparkling plug has to be added. Blending ethanol with gasoline increases the ignition capacity whenever the water content is lower than 1-2 %, otherwise there is a risk for phase separation[198].

In the future, bioethanol will be mainly used for transport, as it is technically possible to blend and/or replace fossil fuel in the transport sector by industrialized bioethanol fuel. If the cost of bioethanol is competitive, technological, economical and environmental advantages will create a new demand for sustainable energy production and consumption. In China, E10 (10% of bioethanol and 90% of gasoline) is compatible with the existing infrastructure and potential; no adjustment has to be done to vehicle engines neither to the gas station equipment.

Table 42: Cost comparison for stationary use of bioethanol for power generation, cooking and heating[199]

Fuel	Sales price	Energy price
93# gasoline	0.43 EUR/l[200]	7.40 EUR/GJ
Bioethanol (E100)	0.45 EUR/l	13.48 EUR/GJ

3.7. Medium- and long -term perspectives

3.7.1 Demand for bioethanol in 2020

In 2020, the number of motor vehicles in China will reach 130 - 150 Mio. At that time, only the oil consumed by motor vehicles will count up to 256 Mio t/a: 85 Mio t/a of gasoline and 171 Mio t/a of

196 Personal Communication Li Shizhing, September 2005
197 see Table 18, chapter 2.6
198 On farm production, it is not considered technically feasible to remove the final 5 % of water so gasoline can not be added as it is done in industrial production.
199 The following conversion factors have been used: energy content of biodiesel: 40.128 GJ/t; energy content of bioethanol: 26.7 GJ/t; density of biodiesel: 0.84 kg/l; density of bioethanol: 0.789 kg/l
200 http://news.xinhuanet.com/newscenter/2005-07/23/content_3255749.htm

diesel. If 10% of bioethanol is added to gasoline (E10), the demand for bioethanol in 2020 will reach 8.5 Mio t; therefore it is predictable that E10 gasohol will be already widely used in 2010. E85 (formulated for flexible fuel cars (FFVs)), and E10 (formulated for conventional gasoline cars will be the most offered forms of bioethanol in future. A higher blending rate will depend on experimental results of the pilot usage of E20, E35, E95 or pure bioethanol E100.

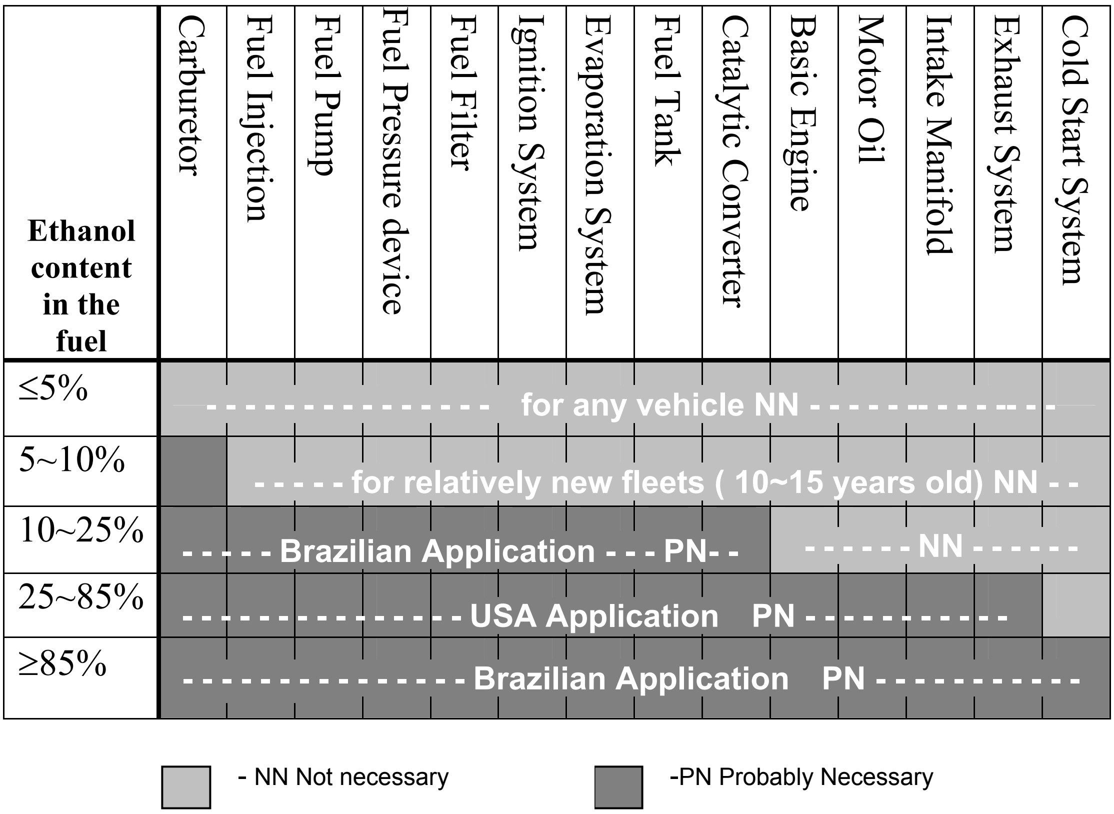
Table 43: Growth scenarios in demand of gasoline as transportation fuel through 2020[201]

	Low case scenario	**Mid case scenario**	**High case scenario**
Gasoline	85 Mio t	106 Mio t	115 Mio t

Chinese carmakers are already investigating in flexible fuel vehicles (FFV)[202]; but it is expected, that they will not achieve before 2020 an important place in China, as there is still a long way to go to promote first E10 and B10 for fuel blending. At present the production ratio of gasoline to diesel cars and trucks is about 1:1.8, while the consumption ratio of gasoline to diesel is about 1:2, over 1:2.5 in some area. Therefore as in the future an increasing number of cars will use diesel instead of gasoline - just like in most European countries - the demand for diesel will increase significantly[203].

As demonstrated in the following graphic, the countywide introduction of E10 will not create technical problems with existing car manufacturing standards. However, the promotion of higher blend ratios requires more cooperation between biofuel producers and the car manufacturing sector.

Figure 5: Compatibility of existing vehicles with bioethanol-gasoline blend[204]



201 NDRC 2004

202 Driving an FFV and ethanol is available, it can fuel with ethanol and help reduce petroleum consumption while supporting Chinese farmers and protecting the environment.

203 http://www.bloomberg.com/apps/news?pid=10000080&sid=ast5RhlMDMCo&refer=asia

204 Oswaldo Lucon, Bioethanol: Lessons from the Brazilian Experience, India 2005

Motorcycles and automobiles including cars, mini-buses and light-duty trucks consume today more than 90% of the gasoline in China[205].

3.7.2 Forecast on production potential

Potential from food crops

At present, the production capacity of the 4 existing fuel ethanol factories is 820,000 t/a. When the product line of Anhui Fengyuan Bio-chemical Ltd will take up production in 2005, the capacity will achieve 1 Mio t/a. Considering the safety of food supply and limitations of land resources, the yield of fuel ethanol from food crops will not exceed 2 Mio t/a[206] in 2020; the food crop use for bioethanol production will not exceed 6 Mio t/a, and therefore will not have a negative impact on the internal food market.

Potential from energy crops

The available amount of bioethanol in China depends on the land resources, which can be used for energy-oriented agriculture and plantations for feedstock for bioethanol production.

Table 44: Land resources of energy crops for bioethanol production (2020)

	Potential infields/ha	**Salina lands (recently reclaimable) ha**	***Sorghum* planting lands[207] ha**
Proportion	9,470,000[208]	1,670,000[209]	722,400[210]
Possible utilization ratio for energy-oriented agriculture	60%	80%	80%
Possible utilization area	5,682,000	1,336,000	578,000
Total	**7,596,000**		

Table 45: Potential for bioethanol from main energy crops in 2020[211]

Variety	**Additional availability of land in primary areas**	**Average yield t/ha**	**Feed- stock for 1 t bio-ethanol (t)**	**Total yield of bioethanol (t)**
Sorghum bicolor (L.)	More than 670,000 ha in Jilin, Liaoning, Heilongjiang, Inner-Mongolia, Sinkiang[212]; 361,000 ha of existing sorghum planting acreage[213]	Stalks: 60 (kernel for food)	13.5	2,512,000 3,866,000
Manihot esculenta Crantz	At least 320,000 ha in Guangxi, at least 146,700 ha in Guangdong	Cassava: 15	7.5	533,000: Guangxi, 240,000: Guangdong

205 see Table 19 and Figure 1 in chapter 2.8
206 Wang Tao, 2005
207 (in 2003)
208 Resources: Liu Jiang(2002). Chinese Resources Usage Strategies Researches. Chinese Agriculture Press, Beijing
209 Resources: Xue Ping(2004), Resources Demonstration. Geology Press, Beijing
210 Resources: China Agricultural Yearbook in 2004
211 related to data from Chapter 3.3 "energy crops"
212 Report on renewable energy and new energy high tech industrialization. Energy Research Institute of NDRC. 2004.10
213 According to chapter 3.1.1, the existing sorghum planting acreage (2003) is 722,400, it's estimated that 50% of these acreage will be used for sweet sorghum in 2020.

Variety	Additional availability of land in primary areas	Average yield t/ha	Feed- stock for 1 t bio-ethanol (t)	Total yield of bioethanol (t)
Energy *Saccharum officenarum. L*	About 98,600 ha in Guangxi, Guangdong, Yunnan	Biomass yield: about 210	14	1,380,000
Total	**1,596,300**			**6,019,000**

Table 46: Agricultural energy crops – overview[214]

Variety	Distribution	Planting surface at present: ha	Average yield t/ha	Possible areas	Availability of land in some primary areas
Sorghum & *Sorghum bicolor L.*	Shanxi, Hebei, Inner-Mongolia, Liaoning, Jilin, Heilongjiang, Sinkiang	722,400	Seeds: 4.0 Stalks: 60	mainly in Northeast, Northwest and North China temperate zones	More than 670,000 ha in Jilin, Liaoning, Heilongjiang, Inner-Mongolia, Sinkiang[215]
Manihot esculenta Crantz	Guangdong, Guangxi, Hainan, Fujian, Yunnan, Guizhou, Sichuan	400,000 (in Guangxi) 124,140 (in Guangdong)	Tubercle: 15	Mainly in southern provinces	At least 320,000 ha in Guangxi, at least 146,700 ha in Guangdong
Saccharum officenarum. L. & energy cane	Guangxi, Yunnan, Guangdong	1,409,400	Stalks: 64 Stalks: 120	Mainly in southern provinces	At least 98,700 ha. in Guangxi, Guangdong, Yunnan
TOTAL		**2,655,940**			

Table 47: Production potential for bioethanol in 2020

Variety	Yield of fuel ethanol / Mio t/a	
	2004	In 2020
Food crops	0.82	2
Energy crops	nd[216]	6.019
Total	**0.82**	**8.019**

3.7.3 Benefit analysis

Energy benefit

According to the price of raw material, technological approaches and constructions, the investment of bioethanol production capacity is about 450 EUR/t[217]. As costs for barren land recovery and construction investment in the liquid biofuel processing industry are relatively low, the overall

214 Based on data from CSY 2004

215 Report on renewable energy and new energy high tech industrialization, Energy Research Institute of NDRC, 2004.10

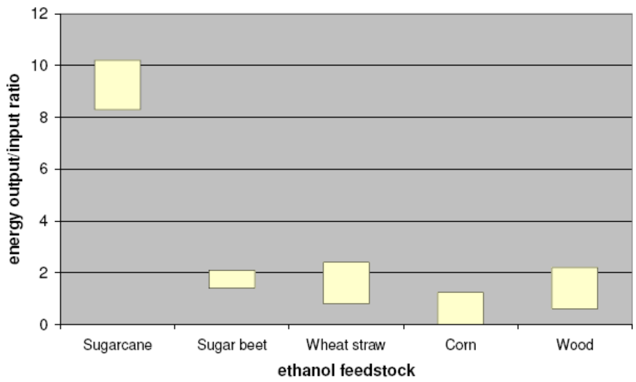
216 At present, there is no available factories producing bioethanol from energy crops (sweet sorghum, energy cane and cassava) in large scale.

217 Personal communication Wang Mengjie, former Deputy Director of Chinese Academy of Agriculture Engineering, August 2005

investment for bioethanol processing industry with a production capacity of 8.02 Mio t/a is calculated to range at 3.6 BN EUR. The ratio of annual production value to total investment is about 1:1, higher than in traditional energy generating industry[218].

With regard to the importance of process energy need in China, a significant operating cost part for bioethanol production is the consumption of processing energy. Several integrated energy balances – particularly the multiple effect relationship between distillation, dehydration and evaporation, and the utilisation of dryer waste heat for steam generation, support the whole process.

Figure 6: Energy balance of bioethanol production from different feedstock[219]



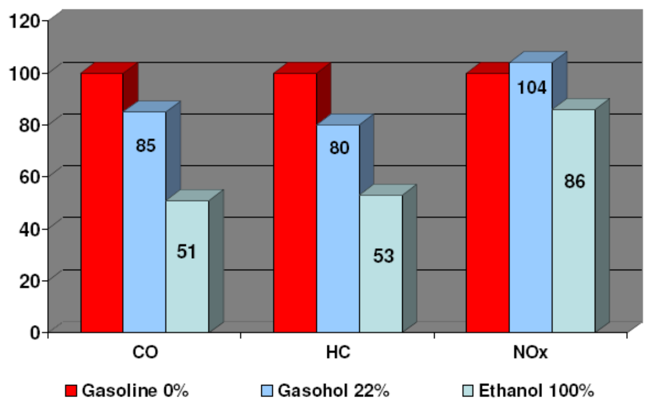
Sources: (Macedo et alii, 2004; UK DTI, 2003 and USDA, 1995)

Environmental & Health benefits

Bioethanol has a high octane number, and is also used as a replacement for lead. Blending gasoline with bioethanol reduces emissions of CO and hydrocarbons from old engines running "rich" with a low air-to-fuel ratio.

The following figure illustrates the results of a Brazilian Study with a direct injection car, model 1998: NO_x emissions are slightly higher when gasoline is blended with ethanol, but all other emissions are reduced.

Figure 7: Comparative raw exhaust emission[220]



Source: ANFAVEA (2005)

The "dilution" effect of bioethanol is also beneficial to the environment and human health: denatured bioethanol contains little or no sulphur, aromatics, and olefins; adding bioethanol to gasoline lowers

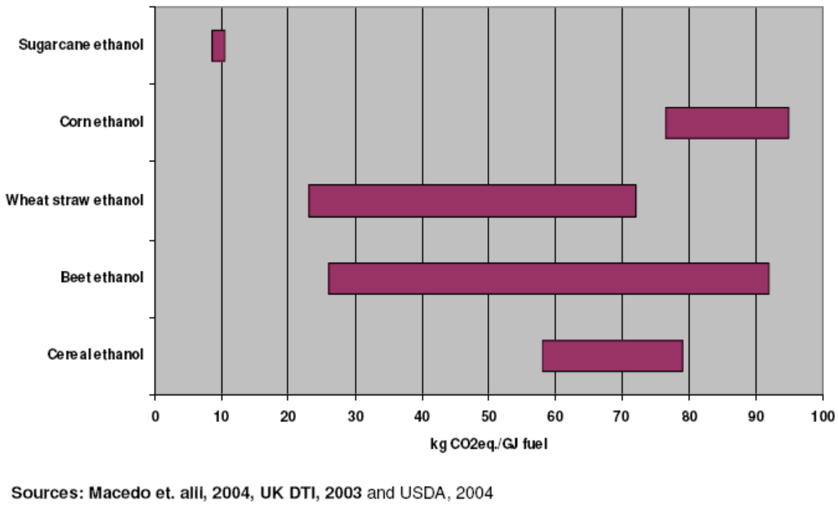
[218], the ratio in thermal power generation is about 0.4:1
[219] Oswaldo Lucon: Bioethanol – lessons fromthe Brazilian experience, India 2005
[220] Oswaldo Lucon: Bioethanol – lessons fromthe Brazilian experience, India 2005

the concentrations of these components which are recognized to have direct and indirect harmful effects on health.

The environmental significance of using bioethanol focuses on

- Protection and improvement of China's atmospherically environment. Compared to fossil fuel, biofuel produce a significantly reduced amount of atmospheric pollutants such as NO_x and SO_x.
- Reduction of CO_2 emissions: Based on life-cycle assessment, CO_2 emission from biofuel use is significantly lower than from fossil fuels.

Figure 8: Lifecycle assessment of greenhouse gas emissions related to different types of ethanol feedstock[221]



Concerning the use of water resources, agricultural energy crops are selected varieties which require little water, resist draught and flooding and are specifically well appropriated to areas, where food crops give no longer satisfying yields.[222]

Bioethanol manufacture involves a variety of chemical engineering processes wherein water plays a major role. Depending on the applied technology reasonable amounts of process water is needed, which in technically advanced designs are reused through fertirrigation.

Economic and social benefit[223]

It is calculated that the bioethanol processing industry with a yield of 8.02 Mio t/a can create about 3.6 BN EUR/a, and will absorb more than 160,000 of labour forces. Relevant energy-oriented agriculture can offer working places to about 2.9 Mio of labour forces, thus increasing employment in rural areas and developing rural economy[224].

[221] Oslwaldo Lucon: Bioethanol – lessons from a brazilian experience, India 2005
[222] ECHI-T, 2002
[223] Agricultural strategies research team, 2003
[224] calculation according to CSY 2004

3.7.4 Potential development barriers

Raw material and planting technology

Considering that the process cost of fuel bioethanol is influenced by the competition between food and energy purpose of the crop and the product, the developing fuel ethanol industry relies more on energy crops to purchase feedstock than on food market oriented crops.

To date, breeding of high-quality seeds of main energy crops such as *Sorghum bicolor (L.)*, *Manihot esculenta Crantz, Saccharum officenarum L.* has made progress. Further research will focus on their applicability to potential planting areas and large-scale field tests.

No energy plant in this assessment study is protected by law, and no information could be obtained, if they are under research as GMO. The Chinese law on agricultural GMO was published in May 2001 with the purpose to protect human life and health, and the biological environment.

Planting technology should be improved in order to cultivate energy crops in industrial scale and to achieve cost reduction.

Land and manpower

Food demand relies on present crop fields, therefore there is little competition or potential conflict between energy-oriented and food-oriented cropland; land considered in the forecast of 'potential fuel ethanol producing capacity in 2020'[225] refers mainly to barren and agricultural low-grade land.

Furthermore, land included in the forecast of potential fuel ethanol producing capacity is mainly located in areas where rural manpower is available and economic development is needed.

Processing technology

At present, processing technologies for bioethanol from the main energy-oriented crops such as *Sorghum bicolor (L.)*, *Manihot esculenta Crantz, Saccharum officenarum L.* has been considerably researched, but there is still need for know-how and technological progress.

If processing technologies producing bioethanol from fibrous material will achieve the industrialization scale, the output of bioethanol from *Sorghum bicolor (L.)* and/or *Saccharum officenarum L.* per ha will increase significantly. Research on this technology has been carried out in China with support from Denmark. In addition, the adequate storage of raw material for bioethanol processing requires still more research work.

Although it is possible to convert most starch containing feed grains to bioethanol, their use for fuel bioethanol is not yet researched in depth. However, all the non-starch material, such as protein and fibre in the feed grain reports to the by-product DDG, and the economics of bioethanol production depend on the achievement of adequate quality and good market prices for this solid material. Protein content, palatability, shelf life, transport logistics take all part in the price equation.

Infrastructure

Most of the land referred to as suitable for energy agriculture is located in areas where access is convenient, so that investment for road construction could be kept in considerable scale. As mechanised cultivation generally is implemented at long terms, the investment in agro-machinery is less than in bioethanol production equipment and factory construction.

[225] See Tables 43 - 46

Where salina alkali land will be used as cultivation area recovering costs have to be considered; however, the environmental benefits from regaining these lands for productive purposes will balance these investments at medium- and long-term.

Marketing

At present, the government provides subsidies for bioethanol within the promotion programme “Trial Scenario for Automotive Fuel Ethanol Application”.

The marketing of bioethanol is easier with rising petroleum prices and increasing bioethanol output. When bioethanol will become more profitable, and governmental regulations still provide an enabling environment, it can be expected in the near future that - even under the monopolization of the petrol and oil market in China - the China National Petroleum Corporation and China Petroleum & Chemical Corporation will take up the sale of bioethanol or E10 gasohol to share profit.

Cost and competence

Despite the environmental advantages of bioethanol, it is still difficult for the fuel ethanol factories to generate benefits. If there would be no subsidy from the government, the existing four plants would all work at a loss. The main reason is that most feedstock of bioethanol production is also traded on the food market, which keeps the production cost very high.

The current subsidy standard in 2005 of 137 EUR/t is provided within the promotion programme to only four plants[226]. Including the governmental subsidies the benefit of the Henan Tianguan Group is about 5%. Data from Jilin Fuel Ethanol Company reveals that the plant is loosing 140 EUR/t[227] of fuel bioethanol.

Producing bioethanol from energy-oriented agricultural crops is in the start-up phase in China, and there is still considerable space and demand for technology development. With increased experience and advanced technology, cost reduction could be achieved in the future - for example, the cost of producing bioethanol from *Sorghum bicolor (L.)* is expected to be less than 280 EUR/t. [228].

Ethanol blends of up to 35% have been tested already, modifying cars’ fuel/ignition systems. If the domestic biofuel market could be satisfied only with E10 in the year 2010, China will not become an importer of bioethanol, but will maintain its dependency from imported liquid fuel for transportation.

Economics of scale favour larger capacities, but as the biofuel industry is still in a developing stage, the marketing of large volumes of bioethanol and DDGs as feasible by-product without firm contracts is a matter of risk.

With small-decentralized plants it may also be possible to market WDG, which would obviate the need for a dryer and reduce high operating costs in this aspect. Proximity to animal feed lots prepared to purchase WDG is particularly important for such plants. Sufficient water must be available and also sufficient economically priced energy.

In summary, each bioethanol project has its own set of economically independent parameters. The most significant costs for bioethanol production will always be feedstock, capital cost and energy. However, financial and political support from government will be the ultimate determining factor[229].

[226] Personal Communication Prof. Li Dehua, September 2005
[227] http://www.fstv.com.cn/news/show.asp?id=35686
[228] personal communication Prof. Fu Yujie, September 2005
[229] personal communication Prof. Fu Yujie, September 2005

4 Biomass to Liquid (BTL) – current situation and technical potential

BTL stands for Biomass-to-Liquid and like GTL (Gas-to-Liquid) and CTL (Coal-to-Liquid) it belongs to the group of synthetic fuels. Synthetic fuels made from biomass are a relatively new research field and up to now unavailable on the market. Its components are designed for the requirements of modern motor concepts. Biomass is first converted into Biogas and later liquefied to a synthetic Diesel fuel.

4.1. Main Actors

4.1.1 R&D

On April 2004, Guangdong Institute of Energy Conservation (GIEC) and Japanese Toyama University signed a cooperation protocol on a Sino-Japan-cooperated biomass synthesis fluid fuel.[230]

At present, several Chinese research institutes develop different processes for the production of BTL-fuels on a pilot scale. It is necessary to bundle the knowledge and the experiences of these projects, from the supply of the biomass over the optimisation of single sub-processes to the production of BTL-fuels on a pilot scale. Within the scope of the first pilot plant in China it may be expected to detect more detailed statements on efficiency, economy and environmental performance evaluation.

Table 48: Institutions involved in BTL research

Institution	R&D topic
Shandong University of Science and Technology, Shandong	Biomass liquefaction through pyrolysis process
Guangdong Institute of Energy Conservation (GIEC) and Japanese Toyama University	Biomass synthesis fluid fuel
Northeast Forestry University,	Development of equipment for biomass flash pyrolysis liquefaction
Guangzhou Institute of Energy Conversion, Chinese Academy of Science,	Studies on FT process

4.1.2 Industries, joint ventures & projects

Currently, a BTL pilot plant is planned to be set up in Zibo, Shandong province. The Sino-German company, Zibo Treichel Industry & Trade Co. Ltd, will organise the planning of a 3,000 t/a BTL pilot plant: CHOREN (composed by Volkswagen, Daimler Chrysler and Royal Dutch Shell) and the German KfW Bankengruppe are co-investor and credit institution. Meanwhile, another German company, Lurgi, also show interest to sell BTL technology in China.

May 2003: first delegation of the Chinese Ministry of Agriculture (MOA) and the Chinese Academy of Agricultural Engineering (CAAE) visited the Choren Company in Freiberg, Germany, the leading company in clean transport fuel research and development.

July 2005: Chinese delegation of high ranking officials, including the director of the renewable energy division of the National Development and Reform Commission (NDRC), the State Planning

[230] CA 2004

Commission (SPC) and from different Ministries visited the German company Choren Industries[231] to be informed about the state of art in biomass-to-liquid 'sunfuel' technologies.

4.2. Biomass availability and potential

The overall advantage of BTL-fuels is that many resources can be used for their production: residues like straw, organic or cellulose rich agricultural waste, and bio-refuse, remainders of waste wood, and energy-crops that are only grown for the production of biofuel[232]. Whereas only parts of a crop (mostly the seed) can be used for the production of customary biofuel, the complete crop can be used for the production of BTL-fuels. It is expected that over 4.000 l BTL-fuels can be produced on 1 ha agricultural land.[233] No potential analyses have yet been published about BTL in China.

4.3. By-products

BTL-fuels are produced synthetically and are also called designer fuels. Their properties can be influenced selectively and adapted to the requirements of an optimized combustion sequence. Fuel design can react on further developments of engine technology. The noxious emissions, especially NO_x and the particle output, could clearly be reduced. It is emission-free of sulphur and odour. Future emission standards, which are not achievable in this amount by current biofuel without technical adaptations, are of no problem for the BTL-fuels. And the increased cetane number ensures an optimal combustion in the engine.

Table 49: Summarized facts on BTL[234]

Resources	**Energy Crops and Wood**
Annual Output per Hectare	about 4.050 l/ha
Fuel-Equivalent	1l BTL-fuel replaces ca. 0.93l Diesel fuel
Cash Value	0,50 – 0,70 €/l
CO_2-Reduction	> 90 % towards Diesel fuel

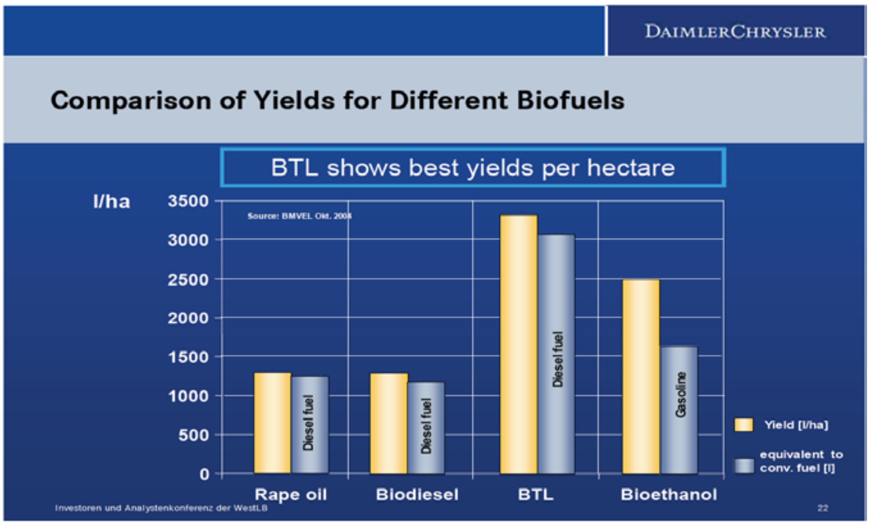
During the combustion of BTL-fuels, CO_2 is released only at the amount, which has been bound by the plants during their growth period. Thus the CO_2-balance is nearly closed. Although an energy-input is required for the production of BTL-fuels, a large amount of CO_2 can be saved compared to the combustion of fossil fuels: BTL-fuels contribute to the climate protection.

4.4. National markets, competitiveness, costs and prices

No market study for BTL-fuel was published up today, but according to estimations of DaimlerChrysler[235] BTL shows best yields per ha; if the technology will be available and approved under Chinese conditions, BTL will have a great future in the country.

231 http://213.174.34.155/de/choren_industries/aktuelles/?nid=50
232 see chapter 2.3.5 and 3.3.4
233 http://www.nachwachsende-rohstoffe.de/
234 http://www.btl-plattform.de/
235 http://www.btl-platform.de/

Figure 9: Comparison of yields of different biofuel[236]



4.5. Perspectives of BTL

Great parts of forest biomass are currently not exploited. Wood does not require huge inputs of fossil fuel fertilizers; it consists almost entirely of carbon, hydrogen and oxygen - the greenhouse gas CO_2 and water. Growing and harvesting trees do not necessarily consume fossil fuels - energy input can be provided by surplus wood or biofuel.

Wood can easily be converted to BTL-fuel or methanol. Currently, there are no defensible arguments besides forestry technologies – and therefore economical feasibility - that hinder the large-scale exploitation of wood grown at hillsides. Continuous reforestation programmes should be consequently followed up to maintain wood as a sustainable and renewable energy resource, and to prevent erosion.

Future will show if BTL-technology can be made available in China.

236 Koehler, 2005

5 Biofuel in relation to …

5.1. China's national energy policy

The substitution of petroleum imports, fuel diversification for the increasing public and private transport sector, the safety of fuel supply, and environmental considerations are important aspects for China's activities in the biofuel sector. The country is the world's second largest source of greenhouse gases; Beijing, Shanghai and Guangzhou are among the 16 Chinese cities, which are listed by the World Bank in the group of the top 20 polluted cities in the world. Acid rain and thick smog are common place, attributable not only to the 1.6 BN t of coal burnt every year and the amount of sulphur dioxide emitted as a consequence, but also to the daily increasing vehicle traffic.

The policy shift towards renewable energy and biofuel promotion is not only based in environmental reasons, but also in social and economical facts: according to the Chinese government, coal mining accounted for more than 6,000 deaths in 2004 alone, while critics put this figure closer to 20,000[237]. In addition, farmers are economically marginalized due to the low prices paid for crops; creating an additional market for agricultural and forestry products by using them as raw material for biofuel production would have a considerable impact on Chinese citizens' living standard in rural areas.

China has introduced laws to assess the environmental impact of power generation projects, and the RE-Promotion law requests power companies to buy electricity generated by green energy sources. The government has also set a target for the use of cleaner natural gas in power generation of 6 % by 2030 – almost a 5 % increase on current levels.

The transport sector will likely experience the strongest demand for oil over the mid- to long-term. Currently there are roughly 28 Mio vehicles in China, with projections anticipating 130 – 150 Mio by 2020. This will push transport fuel demand from 33% to 57%.

In October 2001, the State Economic and Trade Commission (SETC, now re-named in NETC) proposed its Tenth Five-Year Plan for Sustainable Development, including the Tenth Five-Year Plan for New and Renewable Energy Commercialization Development.

Past experience has shown that the government is powerful enough to impose the relevant legislation and realise such commitments as to cut its countrywide emissions during Kyoto's second phase:

⇒ The Ministry of Science and Technology of China, the China National Reform and Development Committee, and the China Engineering Academy rank biodiesel research and production as the leading priority of the Chinese energy industry.

⇒ Liquid biofuel are cited in the 10th Five-Years Development Policy and Regulation as a major future direction for new Chinese industrial development.

⇒ Chinese researchers have made significant advances in the fields of raw material filtering, production techniques, and biodiesel additives.

Policies on the development of renewable energies are categorized in three classes in terms of their scope and characteristics.[238]

[237] Green Budget News, 2005
[238] www.nrel.gov/docs/fy04osti/35786.pdf

Table 50: Policies on the development of renewable energies

First level	**Task**	**Activities / results**
Central Government (National People's Congress (NPC), State Council (SC))	providing general direction and guidance	Provides general direction and guidance; speeches of state leaders about development of renewable energy and the Chinese government's standpoint on the global environment; Provides the enabling environment to facilitate the implementation of the other two levels by issuing regulations.
Second level	**Task**	**Activities / results**
Relevant departments of the Central Government (National Development and Reform Committee - NDRC), National Economic and Trade Committee (NETC), Ministry of Science and Technology (MOST), Ministry of Water Resources (MWR), Ministry of Agriculture (MOA) and Ministry of Commerce (MOC))	specifying goals / objectives and development plans	Specifies goals/objectives and development plans focusing on rural electrification, renewable energy-based technologies and fuel wood. Aims to standardize trends, focal points, and objectives of renewable energy development from different points of view. Some departments propose specific policies and regulations. Second-level policies have played a key-role in promoting technologies for renewable energies.
Third level	**Task**	**Activity / result**
Local governments: provincial and municipal governments, county governments	practice oriented, specific incentives and managerial guidelines	Outlines specific supporting measures for developing and using renewable energy, applying practical and specific incentives and managerial guidelines; Provides crucial support to develop renewable energy in its early introductory stage; Executes what the previous two levels require. Since the mid-1990s, many provinces and autonomous regions have adopted policies including subsidies and tax reduction to develop and implement renewable energy.

Table 51: Major policies on the first level

Year	Policy Instrument
1983	Suggestions to Reinforce the Development of Rural Energy
1992	China Agenda 21
1992	Ten Strategies on China’s Environment and Development
1995	SSTC Blue Paper No. 4: China Energy Technology Policy
1995	Outline on New and Renewable Energy Development in China: SPC, SSTC, SETC
1995	Electric Power Law
1996	Guidelines for the Ninth Five-Year Plan and 2010: Long-Term Objectives on Economic and Social Development of China
1996	State Energy Technology Policy
1997	Electric Power Law
1997	Energy Saving Law
2001	Standards for bioethanol-fuel
2003	Renewable Energy Promotion Law (draft)
2005	Renewable Energy Promotion Law

The recently edited Renewable Energy Promotion Law and since Feb. 2005 the CO_2-emissions trading system, are thought to stimulate the introduction of liquid biofuel in the transport sector[239].

Table 52: Major policies on the second level

Year	Policy Instrument
1994	Brightness Program and Ride the Wind Program, formulated by SPC
1995	New and Renewable Energy Development Projects in Priority (1996-2010) China, by SSTC, SPC, SETC
1996	Ninth Five-Year Plan and 2010 Plan of Energy Conservation and New Energy Development by the State Power Corporation
1996	Ninth Five-Year Plan of Industrialization of New and Renewable Energy by SETC
1998	Incentive Policies for Renewable Energy Technology Localization by SDPC and MOST
2001	Tenth Five-Year Plan for New and Renewable Energy Commercialization Development by SETC
2003	Rural Energy Development Plan to 2020 for Western Areas

[239] Article 16 and 31 (in act on January 1st, 2006)

Table 53: Major policies on the third level

Year	Policy Instrument
1997	Circular of the Communication and Energy Department of SPC on Issuing the Provisional Regulations on the Management of New Energy Capital Construction Project
1999	Circular of MOST and SDPC (now NDRC) on Further Supporting the Development of Renewable Energy
2001	Adjustment of Value-Added Tax for Some Resource Comprehensive Utilization Products by MOF and State Tax Administration
2001	Electricity Facility Construction in Non-Electrification Townships in Western Provinces of China or Township Electrification Program by SDPC (now NDRC) and MOF

The Third Level specifies and executes supporting measures for the development and utilization of biofuel. As biofuel technologies still are in their initial stages of dissemination, they are characterized by high capital cost, low productivity and low profit margin. Given still a socialist market view, it would be impossible for the biofuel industry to grow without – even only initial - governmental support. Therefore, the policies of the third level are crucial to achieve the objective of biofuel production and market development.

Table 54: Characteristics of environmental policies and regulations

Background:	meet short-term energy needs;
Objectives:	strengthen a long-term sustainable development by utilization of biofuel;
	reduce air pollution, safeguard human health and the environment;
	provide power to off-grid rural areas;
	contribute to mitigating climate change in all energy sectors;
Content:	synthesize basic principles of the market economy and the political objectives of energy security;
Structure:	incentives to encourage the development of renewable technologies;
	provide market opportunities for renewable energy companies
Stakeholders	Local governments, energy enterprises and the public.

Some provinces and autonomous regions have already adopted regional policies for the broader dissemination of biofuel, such as offering subsidies and reducing or remitting taxes.

Provincial governments set up so called “gasohol offices” to promote gasohol. In a first step, local governments, state owned enterprises and other governmental organizations are asked to use gasohol as transport fuel; further steps of the strategy phase out pure gasoline, until only E10 can be supplied. Higher blend ratios (E15, E20 and so on) are currently not available due to limited bioethanol production capacities and existing engine technologies.

5.2. China’s policy framework on liquid biofuel

5.2.1 Policy instruments for the utilisation of liquid biofuel

Chinese policy instruments for the promotion of liquid biofuel include research, subsidies, tax, price limits, quotations, limits and changes established by law.

Restrictions for transport fuel consumption:

In order to share less fossil fuel among more vehicles, the Chinese automobile efficiency standard in force since January 1st, 2005, defines that all new cars must adhere to limitations on their fuel consumption ranging from a maximum of 6.2 l/100 km for small vehicles to 15.5 l/100 km for small trucks[240].

Subsidies:

Retail prices for petroleum products are regulated, with variations based on location and the type of consumer. Recently, there has been substantial pressure to raise domestic prices in the context of high world oil prices. A series of increases in the state-mandated prices, however, has still not been sufficient to keep pace with the world market. This led, in the first half of 2005, to increases in exports of some petroleum products, particularly diesel, as the gap between domestic prices and world prices widened. The eventual goal for 2010 is to eliminate subsidized prices, but given the dependency of vulnerable segments of the Chinese population on cheap fuels, particularly in agriculture, it will likely take at least several years to accomplish this goal[241].

At present, the Chinese government subsidies fuel bioethanol with 137 EUR/t, (starting at 2000 with 180 EUR/t) but will gradually decrease the subsidy until the years following 2010. By this date, liquid biofuel is thought to have gained sufficient market to be competitive to fossil fuel.

Limitation for fossil fuel importation:

The Chinese government has undertaken several steps to limit the country's dependence on oil imports; however these measures need time to show impact:

- In 2002, China had to import about one third of its crude oil demand; according to official estimates[242] this figure will increase by more than half by 2007.
- Following 2008, the Chinese government will tighten its upper limits on fossil fuel consumption for transport.
- To guarantee the country's economic stability the amount of imported fuel is forecasted to be limited from 2010 onwards.
- Based on economic assessments, proposals on tax incentives for fuel ethanol have been considered, which include exemption of sales tax and fuel tax as well as reduction of value added tax[243].
- China plans to implement a fuel tax policy by the end of 2005, which could prompt vehicle owners to reduce fuel consumption or buy energy-efficient cars.[244]

5.2.2 Promotion of bioethanol

For bioethanol the former SPC, authorized by the State Department, promoted that fuel bioethanol can be mixed with gasoline for use in vehicles. As a result of the China fuel ethanol programme, and in order to regulate the field tests conducted during this period, 2 national standards were issued in April 2001 about "denaturalization fuel ethanol" and "ethanol gasoline for motor vehicles", established by the General Administration of Quality Supervision, Inspection and Guarantee of PRC[245]. The

240 www.efchina.org/documents/CSEP_Update_Jan_05.pdf
241 http://www.eia.doe.gov/emeu/cabs/china.html
242 State Council, 2003
243 LAMNET, 2004
244 9 August, 2005 http://www.energybulletin.net/7912.html
245 2001

government invested 500 Mio EUR[246] to establish 4 bioethanol enterprises for the processing of overtime crops, which all together and totally produced 1 Mio t of bioethanol[247].

During the 10th Five-Year-Plan[248], the Ministry of Science and Technology continued with the promotion of bioethanol. The focus was set on technology demonstration and application[249]:

- Ethanol production from cellulose waste, including the demonstration of production of 600 t/a.
- Ethanol production from *Sorghum bicolor (L.)* including the demonstration of production of 5,000 t/a.

Table 55: Chinese Standards for fuel ethanol and ethanol gasoline[250]

Name	Keywords	Publishing Date	Publishing Agency
GB 18351-2001 Denatured fuel ethanol	Standard: definition, request, experimentation method, inspection rule and sign, package, transport ion and store request of denatured fuel ethanol	Apr 2nd, 2001	General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China
GB 18350-2001 Ethanol gasoline for motor vehicles	Standard: technical qualification for vehicle ethanol gasoline, which is composed of liquid hydrocarbon without oxygen-compound, mixed with denatured fuel ethanol and additive to improve using quality. Applicable for fuels in ignition internal-combustion engine.	Apr 2nd, 2001	General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China

The guidelines are only issued for the production of liquid biofuel, not considering further environmental or social standards. The quality standard for bioethanol refers to US standard and is different from European standard.

Table 56: Comparison of bioethanol quality standards[251]

Parameter	Unit	China (based on US standard)	Europe
Ethanol	% v/v	min. 97.1	min. 99.75
Water	% w/w	max. 0.8	max. 0.05
Methanol	% v/v	max. 0.5	max. 0.01
Non-volatile matter	mg/100ml	max. 5	max. 5
Sulphur	ppm	max. 10	max. 1
Chlorides	ppm	max. 32	max. 0.5
Copper	ppm	max. 0.08	max. 1

246 5000 Mio RMB
247 see chapter 3.1.2
248 2000 - 2004
249 Wang Mengjie, June 2003 www.bioenergy-lamnet.org
250 Detailed requirements of the standards are given in the Annex
251 Vogelbusch, "Incorporating the ethanol plants in Europe and China" Conference Proceedings, CHINA Biofuels and Ethanol OUTLOOK 2005

Parameter	Unit	China (based on US standard)	Europe
Acid (as CH3COOH)	ppm	max. 70	max. 10
Colour	Pt-Co	max. 50	max. 5
Ester	ppm		max. 100
Aldehydes	ppm		max. 20
Higher saturated alcohols	% v/v		max. 0.005
Permanganate time	minutes		60 minutes

By the end of 2005, bioethanol mixed gasoline – gasohol (E10) - will substitute entirely fossil gasoline for vehicles in the 5 provinces of Heilongjiang, Jilin, Liaoning, Henan and Anhui; in some regions of Hubei, Shandong, Hebei and Jiangsu provinces, the same will happen[252].

Ethanol blends higher than 10% in gasoline may cause problems in the motor fuel system or need flexible fuel cars (FFVs), but before 2010 China will not exceed the 10% (E10) quality. Thus the limitation to E10 blends avoids any technical problems. By comparison with LPG, which requires modification of the motorcar plus a separate LPG market distribution network, both bioethanol and biodiesel are “drop in” fuels – they can be integrated into the existing market infrastructure without technical modifications or extension of the liquid fuel distribution network.

5.2.3 Promotion of biodiesel

There are no specific Chinese national policy instruments for promoting research and utilization of biodiesel. Assessing the promotion of liquid biofuel, the strategy applied in Hainan province may give an example of what can be possible in the Chinese context. Up to date, no similar promotion strategy has been reported from other provinces.

Example Hainan[253].

Hainan province government together with the “Hainan Biological Energy Company” has adopted in 2004 "the government - enterprise - farmer household - bank – technology system", which serves as a countrywide pilot model to promote biodiesel.

⇒ The government encourages the farmer to plant the oil-energy-crop through agricultural advisory services.

⇒ Between the enterprise and the farmer household a raw material purchase contract is signed.

⇒ The bank provides an oil-energy-crop loan directly to the farmer household.

⇒ The enterprise and the farmer household provide a mutual guarantee for the bank.

⇒ The government (agro-service) and the company take over the technical support to the farmer household.

⇒ A governmental scientific research unit provides technical support to the company.

At an intermediate stage 25% of the company and bank profits are used to promote the dissemination and planting of energy crops on farms and in forests

[252] Personal communication Li Shizhing, September 2005

[253] http://www.biotech.org.cn/news/news/show.php?id=27462; http://www.cae.cn/expadvs/content.jsp?id=1010

At present no official Chinese biodiesel standard and no industrialization strategies exist. But a standard has already been drafted by the Institute of Petroleum Science & Technology in cooperation with SINOPEC and is likely to be issued by the end of 2005. This standard will be based on US-American specifications for biodiesel - D6751 -, which were issued, by the American Society of Testing and Materials (ASTM) in 2002.

When the government were to issue a biodiesel standard, biodiesel industrialization would develop faster.

5.3. China's sustainability targets

Energy is a crosscutting issue because of the crucial roles of fuel in the social and economic development of the country. The implementation of almost all development targets – in relation to the internationally accepted Millennium Development Goals (MDGs) - requires energy services. Some direct and indirect energy linkages with each one of the eight MDGs are listed below. A clear crosscutting focus on energy and specifically on liquid biofuel issues is combined with initiatives that strengthen its linkages of social infrastructure with farming and agriculture, road construction, as well as associated institutional and financial aspects[254].

Table 57: Energy and the Millennium Development Goals[255]

Goal	Direct and Indirect Contributions (selection)
1) Extreme poverty and hunger • To halve, between 1990 and 2015, the proportion of the worlds people whose income is less than one dollar per day. • To halve, between 1990 and 2015, the proportion of people who suffer from hunger.	• Access to affordable energy services from gaseous and liquid (bio-)fuel and electricity enables enterprise development.[256] • Local energy supplies can often be provided by small scale, locally owned businesses creating employment in local energy service provision and maintenance, fuel crops. • Privatisation of energy services can help free up government funds for social welfare investment. • Clean, efficient fuels reduce the large share of household income spent on cooking, lighting, and keeping warm (equity issue - poor people pay proportionately more for basic services). • Energy for irrigation helps increase food production and access to nutrition.
2) Universal primary education • To ensure that, by 2015, children everywhere will be able to complete a full course of primary schooling.	• School buses or motor bikes powered by liquid biofuel[257]

[254] Johansson et al., 2005
[255] UNDP, 2004
[256] Lighting permits income generation beyond daylight hours, Machinery increases productivity; The majority (95 percent) of staple foods need cooking before they can be eaten and need water for cooking. Post-harvest losses are reduced through better preservation (for example, drying and smoking) and chilling/freezing
[257] Energy can help create a more child friendly environment (access to clean water, sanitation, lighting, and space heating/cooling), thus improving attendance at school and reducing drop out rates; Lighting in schools helps retain teachers,

Goal	Direct and Indirect Contributions (selection)
3) Gender equality and women's empowerment • Ensuring that girls and boys have equal access to primary and secondary education, preferably by 2005, and to all levels of education no later than 2015.	• Affordable and reliable energy services and liquid biofuel offer scope for women's enterprises.[258] • Availability of modern energy services- including environmental sound liquid biofuel frees girls' and young women's time from survival activities (gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farming work).
4) Child mortality • To reduce by two thirds, between 1990 and 2015, the death rate for children under the age of five years.	• Indoor air pollution contributes to respiratory infections that account for up to 20 percent of the 11 million deaths in children each year[259]. • Gathering and preparing traditional fuels exposes young children to health risks and reduces time spent on childcare. • Provision of nutritious cooked food, space heating, and boiled water contributes towards better health. • Electricity enables pumped clean water and purification.
5) Maternal health • To reduce by three quarters, between 1990 and 2015, the rate of maternal mortality.	• Energy services are needed to provide access to better medical facilities for maternal care, including medicine refrigeration, equipment sterilisation, and operating theatres. • Excessive workload and heavy manual labour (carrying heavy loads of fuel wood and water) may affect a pregnant woman's general health and well-being.
6) HIV/AIDS, malaria and other major diseases. By 2015, to have halted and begun to reverse: • the spread of HIV/AIDS • the scourge of malaria • the scourge of other major diseases that afflict humanity.	• Electricity in health centres enables night availability, helps retain qualified staff, and allows equipment use (for example, sterilisation, and medicine refrigeration). • Energy for refrigeration allows vaccination and medicine storage for the prevention and treatment of diseases and infections. • Safe disposal of used hypodermic syringes by incineration prevents re-use and the potential further spread of HIV/AIDS. • Energy is needed to develop, manufacture, and distribute drugs, medicines, and vaccinations. • Electricity enables access to health education media through information and communications technologies (ICT).

especially if their accommodation has electricity; Electricity enables access to educational media and communications in schools and at home that increase education opportunities and allow distce learning; Access to energy provides the opportunity to use equipment for teaching (overhead projector, computer, printer, photocopier, science equipment); Modern energy systems and efficient building design reduces heating/cooling costs and thus school fees, enabling poorer families greater access to education.

258 Clean cooking fuels and equipment reduces exposure to indoor air pollution and improves health; Good quality lighting permits home study and allows evening classes; Street lighting improves women's safety.

259 WHO 2000 (based on 1999 data), www.who.int/indoorair/health_impacts/burden_global/en/index.html

Goal	Direct and Indirect Contributions (selection)
7) Environmental sustainability • To stop the unsustainable exploitation of natural resources; and • To halve, between 1990 and 2015, the proportion of people who are unable to reach or to afford safe drinking water.	• Increased agricultural productivity is enabled through the use of machinery and irrigation – powered by liquid biofuel, which in turn reduces the need to expand quantity of land under cultivation, reducing pressure on ecosystem conversion. • Traditional fuel use contributes to erosion, reduced soil fertility, and desertification. Fuel substitution, improved efficiency, and energy crops for liquid biofuel production can make exploitation of natural resources more sustainable. • Using cleaner, more efficient fuels will reduce greenhouse gas emissions, which are a major contributor to climate change. • Clean energy production can encourage better natural resource management, including improved water quality. • Energy can be used to purify water or pump clean ground water locally; reducing time spent collecting it and reducing drudgery. • Plantation of energy-oriented crops and forests recover fallow land and provide CO2 sinks.
8) Develop a global partnership for development	• Energy for poverty alleviation and sustainable development; • Know-how transfer in advanced technologies for liquid biofuel production and promotion

5.3.1 Food security

China is the world's most populous country, with 1.3 BN people living on 9.6 Mio km^2 of land. Feeding such a huge population places a great burden on the state, a problem that has been made worse by desertification. According to official figures, 27% of China's territory is desert; as a result of excessive grazing and cultivation, desertification is increasing by 2,460 km^2 each year[260].

Over the past 25 years, China has made great strides in improving agricultural productivity and reducing hunger and poverty levels. As a sign of the progress made, the UN World Food Programme has decided to phase out its aid programmes to China in 2005, saying the country no longer needs its help. Grain harvest has achieved 460 Mio t for 2004 compared with 431 Mio t in 2003. Demand however, was estimated at 458 Mio t for 2005, and the perennial debate about national food security[261] is still ongoing.

Stiff competition will always exist for both the biomass for liquid biofuel production and the requisite land resource to grow it. This is often capsulated in the five "f" of biomass usage: food, feed, fibre, forage, and fuel. Even if it is possible to grow biomass extensively and solely as energy crops for fuel, it is more convenient in the Chinese context to promote energy-oriented agriculture with at least some valued dual use or co-product derived from the crop.

In the case of the selected forestry plants, their destination to liquid biofuel production does not shorten their life cycle but supports the recovery of deforested mountainous areas.

There is little conflict between the energy-oriented infields and foodstuff plantations according to a study on Chinese food provision, partly because the potential output per ha can meet most of the increased food demand[262]. Especially, using *Sorghum bicolor (L.)* as energy crop planted in the current sorghum lands will not influence food provision, because *Sorghum bicolor (L.)* offers both sorghum

[260] CBH, 2005
[261] CBH, 2005
[262] Liu Jiang(2002). Chinese Resources Usage Strategies Researches. Chinese Agriculture Press, Beijing

kernel for food and stalks for bioethanol production. Considering the potential of energy crops in a near future, most available land resources are those areas where similar crops are already planted and relevant technological research on crops and investigation on land availability have been already carried out.

Agricultural raw material production on low-grade land

China has about 123 Mio ha of farmland, but the country lost around 2.5 Mio ha of farmland in 2003, more than the 1.7 Mio ha that had disappeared already in 2002. [263]. In April 2004 as restriction in order to curb the problem of shrinking farmland a nationwide moratorium on the conversion of agricultural land into non-agricultural land for a concentrated period of around half a year have been set. It will be continued beyond that period in all areas that fail a land market assessment until specified land regulation and rectification requirements are met. The government demands better protection for arable land and a halt to illegal encroachment by industry and housing developers[264].

Significant parts of low-grade lands can be used to implement energy-oriented agriculture while studies on resources usage strategies reveal that energy-oriented agriculture even on farmland will have no negative impact on covering an increased food demand[265]. Anyhow, there is an ongoing discussion about the most suitable biofuel feedstock, as still many engineers in international jointly implemented research projects prefer sunflower, soybean or rapeseed oil for biodiesel production[266].

Following Chinese statistics[267], 7,596,000 ha of land can be used for energy-oriented agriculture, without threatening Chinese food supply:

- 9,470,000 ha of fallow land; 60% of which are potential infields;
- 10,200,000 ha of salina lands; 80% of which are potential infields[268]; 1,670,000 ha can be reclaimed by already existing Chinese agricultural technology;
- 722,400 ha are used as grain sorghum planting area[269], 80% of which could be used for double purpose *Sorghum bicolor (L.)*.

FAO: China will determine the future feed grain markets[270]

China may decisively influence the world market as this country accounts for 40% of the total meat consumption of developing countries. Currently, the feed use of cereals is roughly 75 Mio t or about 18% of total supply. With a grain deficit of 2%, China teeters on self-sufficiency. Although the data base on China is particular weak and sometimes contradictory, its opportunities to increase domestic crop production appear to be limited in view of already high yield levels and land claims of some of the best cropland by industrial development. Should meat consumption, and subsequently feed grain consumption, continue to grow at current rates of 6 to 8%, China could develop a grain deficit of about 50 Mio t by the year 2010. This corresponds to about 25% of the current world trade in cereals, and would require a substantial crop area increase. On top of this comes a move from household production systems, using left over, to grain based industrial production. The implications on world market prices and global food security would therefore be enormous. This scenario, however, may not develop if the potential for improving feed conversion in its industrial pig production systems is efficiently tapped. Assuming that half the production comes from industrial production, and that the productivity gap between China and OECD countries could be closed, more than 30 Mio t of grain could be saved.

263 CBH, 2005
264 CHB 2005
265 Liu Jiang, 2002.
266 http://www.fh-amberg-weiden.de/redaktion/kommentar/vollansicht.php?ansicht=230
267 Liu Jiang, 2002ing
268 Xue Ping, 2004
269 RChina Agricultural Yearbook, 2004
270 www.fao.org/WAICENT/FAOINFO/AGRICULT/aga/lspa/LXEHTML/tech/ch5a.htm

5.3.2 Energy supply

China is on the way to be the most important energy market in the world. Approximately 1.3 BN people use 10.4 BN Mwh energy annually. In the last two decades, the primary energy production was more than doubled. Moreover, China has relatively limited resources of petroleum and natural gas.

Thus sustainable energy supply and consumption is one of the challenges for the country, while utilization of renewable energy and liquid biofuel are two of the solutions[271]. Biomass generated biodiesel and bioethanol, wind, hydropower and solar energy are at hand and the technologies to make use of them are developed in different scale. The total amount of biomass resources[272] is counted at 650 Mio TCE[273]/a, which corresponds to nearly the half of the country's total energy consumption in 1995. Main part of the biomass is to be found in agricultural residuals, which most current are just burned for heating and cooking with very low efficiency, high pollution and negative health impact. Thus, development of new technologies for appropriate utilization of biomass as liquid fuel is a challenge[274].

For the transport sector, biodiesel and bioethanol have been identified as important renewable fuels, because the need to partly replace fossil fuels is seen as urgent and big[275]. However speed of extending the utilization of biodiesel is still slow, due to a lack of demonstration and promotion. Some China-based car manufactures as CITROEN, PEUGEOT, VOLKSWAGEN and AUDI already offering biofuel-adapted vehicles for the Chinese market[276].

Liquid biofuel are already on the way to achieve regional importance and contribute thereby to China's energy security before gaining a countrywide importance and impact on energy provision[277].

China's energy scenarios

The fast growing economy in China has resulted in a rapid growth of energy consumption and demand. The national energy consumption in 2004 reached a total of 1.386 BN TOE, which increased 15.1% from the previous year[278]. Energy sources were mainly coal and oil.

Table 58: China's energy consumption and production in 2004[279]

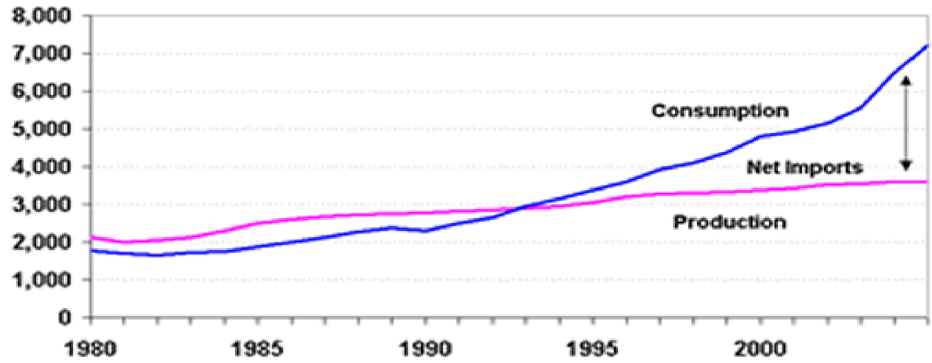
	Consumption	Increase since 2003	Production	Increase since 2003
Total	1.386 BN TOE,	15.1 %		
Coal	956.9 Mio TOE	14.6 %	989.9 Mio TOE	13.3 %
Oil	308.6 Mio TOE	15.8 %	174.5 Mio TOE	2.9 %

271 Weigang , Barz, 2003
272 together with municipal solid waste
273 Mio TCE
274 Lin/Barz, 2003
275 Changzhu Li et al., Forestry Academy of Hunan, Changsha, Hunan: New Feedstock for Biodiesel Production …Sino-German Workshop on Energetic Utilization of Biomass, 2003.10, Beijing
276 situation in oct. 2004
277 However, if 1,4 Bn EUR would be invested in liquid biofuel research, factory construction and promotion, it seems easy to predict that the impact on energy security of renewable and clean energies would increase rapidly
278 BP, 2005
279 BP, 2004

Chinas oil consumption reached 308.6 Mio TOE in 2004, or 6,684,000 barrels/d[280]. The country is now the second largest oil consumer behind the USA. The oil consumption per capita is 0.21 TOE, which is still a low figure compared to USA, Japan and other western countries, and lower than the world average of 0.58 TOE/capita[281].

But as figures clearly show, Chinas own oil production is lower than its own consumption[282]: meanwhile 122.7 Mio t has been imported in 2004, still 5.7 Mio t[283] has been exported.

Figure 10: Comparison of Chinas Oil Consumption and Production (barrels/day)[284]



Reasons for the country's own low fossil fuel production can be identified as follows:

- Chinese fossil oil resources are limited: by the end of 2000, available exploitation has been 2.46 BN t representing 1.7 % of entire world exploitation;
- Small-scale oil fields, bad quality of fossil oil resources, low ratio of resources and exploitation capacity

This gap between consumption and production is resulting in an increasing dependence from oil imports, with worldwide increasing fossil fuel prices and limited markets. If the energy forecast for China up to 2020 in Scenario A would become reality, which represents a 'business as usual' Scenario, the dependence on oil imports will rise to figures, which are highly above the alert limit on import dependence of 1/4 (see Table 60). Therefore China is forced to implement energy policies that have positive implications as shown in Scenario B and Scenario C.

280 BP, 2004
281 Gao Shixian, chief of the Center of Energy Economy and Development Strategy Research, NDRC
282 In contrast to the rapid increase of consumption, production rate only increased 1.5% during the period of 1990-2000.
283 BP 2005; based on international contracts with Russia, North Korea and other Asian states.
284 www.eia.doe.gov/emeu/cabs/china.html

Table 59: Chinas oil consumption development and forecast

	1991[285]	2004[286]	2010[280]	2020 (forecast[287])		
				Scenario A	Scenario B	Scenario C
Oil consumption (100 Mio t)	1.24	3.09	3.2 - 3.8	6.1	5.6	4.5
proportion of total energy consumption (%)	17.1	22.2	25.3	26.7	27.5	26.0
Annual increase rate %)			3.4 - 5	5.1	4.6	3.4

Table 60: Forecast of China's dependence on oil import[288]

	2004	2010	2020
Crude oil import forecast Mio Barrel/day	122.7 (Mio t/a)	4.6	8.5
Dependence on import	40%	61 %	76.9 %

In 2010, fuel requirement will be 138 Mio t, and 256 Mio t in 2020[289]. In addition, fuel efficiency of Chinese vehicles is lower then vehicles sold in other esp. western countries.

Chinas demand for transportation fuel will undoubtly continue to rise, but will be influenced by factors such as GDP growth and economy development, oil availability and prices, energy demand compared to transport demand, changes in the transportation sector, and implementation of policies which support more energy efficient vehicles.

In the transportation sector the road transport (cars, trucks, buses, etc) consumes the highest amount of energy, as shown in the following table. And the share rises from 48% in 1990 to 68% in 2000; most of energy is in form of oil. The share of civil aviation is likely to rise in the recent years due to market opening for private airline companies.

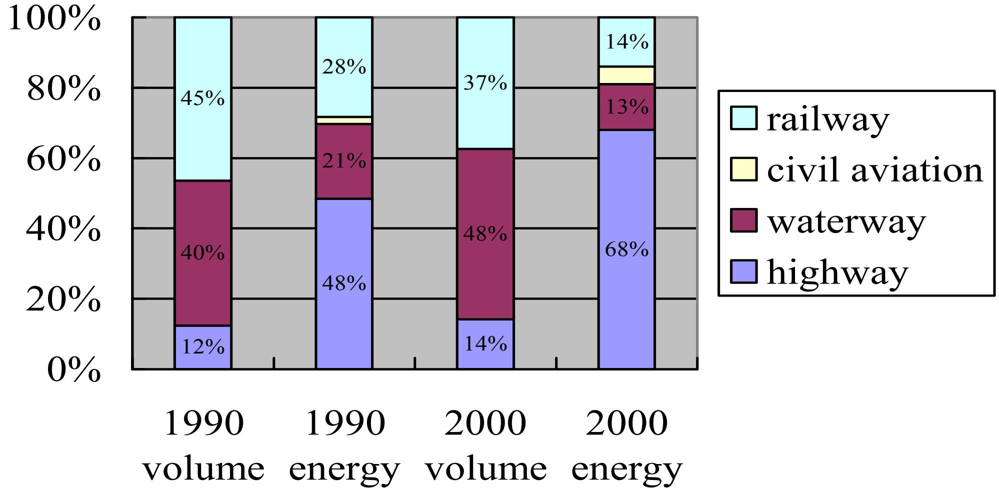
Table 61: Energy Consumption for Transportation in China by transport mode, 1990-2000[290]

Transport mode	Transport volume		Energy consumption (kTOE)		Consumption share		
	1990	2000	1990	2000	1990	2000	change
Railways	45.2 %	36.6%	14,851	13,017	27.8 %	13.5 %	-14.2 %

285 CSY, 2004
286 BP, 2005
287 NDRC, 2005 Scenario A: Business as usual, no special policy measurements Scenario B: related energy policies are adjusted, Scenario C: advanced policy scenario in energy, economics and environment
288 Conservative estimations, NDRC, 2004
289 State Council, Center of Development Research,2004
290 APERC, 2004, page 25, with data compiled from the Institute of Comprehensive Transportation of the NDRC, China Transportation Association

Transport mode	**Transport volume**		**Energy consumption (kTOE)**		**Consumption share**		
	1990	2000	1990	2000	1990	2000	change
Highways	12.4 %	13.7 %	25,495	65,516	47.6 %	68.1 %	+20.5 %
Waterways	40.2 %	48.1 %	11,407	11,988	21.3 %	12.5 %	- 8.8 %
Civil Aviation	0.1 %	0.3%	1,222	5,090	2.3 %	5.3 %	+3.0 %
Pipelines	2.1 %	1.3%	550	605	1.0 %	0.6 %	- 0.4%
TOTAL	2,9265 BN t km	4.950 BN t km	53,524	96,214	100 %	100%	100%

Figure 11: Distribution of volume and energy consumption in the transport sector[291]



Passenger traffic is dominated by cars for short trips and planes for long trips, going in line with an extensive program of infrastructure development. The government strongly supports this development which helps to maintain economic growth, by first building the necessary infrastructure and secondly to encourage production and sale of automobiles. If only domestic transport is considered, railways play still an important mode, but the share is gradually declining due to increase in private cars. Roughly road and farm vehicles consume half of the diesel fuel.

The growing wealth of the population within the last 20 years is also reflected in the transportation sector and in an increased number of vehicles; furthermore forecasts indicates that the vehicle tenure will continuously increase by 15% each year. In 2004, Chinese vehicle tenure has been at 28 Mio, and the petroleum consumption by vehicles has been registered with 81.2 Mio t[292], equal to 594 Mio barrels, nearly 1/3 of the whole petroleum consumption in China[293].

[291] Figure according to APERC 2004
[292] 2003: 70 Mio t
[293] www.sohu.auto.com

Table 62: Vehicle tenure forecast [294]

	2000	2004	2010	2020
Vehicle tenure (Mio)	16	28	60-100	110-150
Fuel consumption (Mio t)	65.5	81.2	138	256
Proportion of total petroleum requirement		26 %	43 %	57 %

In summer 2005, China's most prosperous city of Guangzhou started rationing gasoline and fossil diesel to cope with a fuel shortage. Guangzhou experienced a monthly shortfall of approximately 50,000 t of oil products[295].

With increased amount of automobile vehicles, the fraction of imported oil will increase dramatically, which will have great impact on the world oil market as well as the energy security in China. It is estimated that the Chinese petroleum deficit will reach about 8.5 Mio b/d in 2010-2020[296].

5.3.3 Environment

The environmental impact of liquid biofuel is analysed through a life cycle assessment, evaluating all relevant processes including feedstock production and transport, conversion into liquid biofuel, and distribution until the final supply to the transport sector.

The environmental impact depends very much on the specific characteristics of the different liquid biofuel, e.g. regional context, resource, vehicle, propulsion system, state of technology. Reliable information is available in China for bioethanol; fewer studies are currently available for biodiesel.

This Assessment Study refers to a case study carried out in Guangxi province concerning bioethanol production based on *Saccharum officenarum L.*

Life cycle assessment and energy balance analysis[297]

Life cycle assessment of the environmental aspects of biofuel means that aspects from the different processes through the whole life cycle of biofuel are analyzed. Its purpose is to present clear data and information to outline the environmental benefits and impacts of different biofuels, to provide reliable information on biofuels for further decisions for the implementing of biofuel projects and to identify areas where information is still lacking to stimulate further research and development.

Energy balance means that the energy input for the production of biofuel must be less than the energy output; the ratio between energy input and energy output is described as Energy Efficiency. Within this analysis allocation appears most relevant in the two generic process steps “production of biomass” and “conversion to biofuel”.

[294] Feng Fei, et NDRC, www.sdpc.gov.cn and forecast according to Scenario C in Table 59
[295] in August 2005 http://www.china.org.cn/english/BAT/137372.htm
[296] LAMNET, 2004
[297] Approach: a spreadsheet based on Microsoft Excel was developed, allowing the cultivation data for each crop to be easily introduced. The output of this spreadsheet is a conversion of data on cultivation and technical means data into energetic equivalents (MJ*ha-1). The spreadsheet then calculates the energy balance of the cultivation using a method based on the work of Bullard and modified by Bona. The model also calculates the CO2 balance on the same cultivation data. For the two crops considered, the model, using only sowing dates and yields, estimates CO2 fluxes- using a period of one year as a time base. Energy and carbon balance were determined from a survey based on data from questionnaires which should be presented to farmers by survey manager who ask details of techniques and products used for cultivation.

Table 63: Energy balance from a case study in Guangxi: Production of sugarcane biomass[298]

Consumption GJ/ha ）		**Output GJ/ha ）**	
Fertilizer	15.4	Juice	50t, 125.47
Field work	3.6		
Harvesting	3.2	branchs	35.82
Stock age	2		
Seed	13.78	Residue of straw	102.98
Sowing	4.5		
Irrigation	30.99		
Sum total	73.47		264.27
Net output 264.27-73.74=190.8		**Energy ratio: ER=264.27/73.47=3.6**	

Table 64: Energy balance of conversion[299]

Consumption (GJ/ha)		**Output GJ/ha ）**	
Production	73.74	Branch unused	35.82
Transportation	0.62	Residue of straw	102.98
Calcareousness (0.1t)	4.16	Juice	125.47
Sum total	**78.52**		**264.27**
		Ethanol (3.8t)	96.64
		Residue	31.58
			128.22
Energy ratio: ER=(128.22+35.82)/78.52=2.09			

Carrying out the LCA analysis with maize (corn) and cassava, the results of Energy Efficiency of biomass-based ethanol is respectively 1,1 and 0.70[300].

298 Working packages in the ASIATIC programme "Life Cycle Assessment on Biomass-based Ethanol Fuel in China". not yet published

299 Working packages in the ASIATIC programme "Life Cycle Assessment on Biomass-based Ethanol Fuel in China". not yet published

300 Working packages in the ASIATIC programme "Life Cycle Assessment on Biomass-based Ethanol Fuel in China". not yet published

Emission analysis

China's CO_2 emissions are assumed to grow by 3.3% per year[301]. Concerning the CO_2 balance, the quantity of carbon stored in the plant is considered in all its forms and in all transformations; the duration of storage of CO_2 in different forms was computed. To achieve GHG and SO_X reduction emission balances for liquid biofuel the same approach has been applied.

Up to date no overall study on carbon balance and CO_2 reduction emission by liquid biofuel has been carried out in China, therefore data from similar natural conditions are quoted[302]:

- The use of bioethanol-blended fuels as E85 (85% ethanol and 15% unleaded gasoline) can reduce the net emissions of CO_2 by as much as 25%. The reduction is attributable to carbon sequestration during corn farming, which more than offsets CO_2 emissions during corn farming and ethanol production.
- Bioethanol-blended fuel as E10 (10% ethanol and 90% gasoline) can reduce CO_2 up to 3.9%.
- Particulate emissions of biodiesel are measured as 20% to 39% lower than low sulphur fossil diesel and 10-29% lower than Ultra Low Sulphur Diesel (ULSD).
- SO_X emissions: from biodiesel are at least 80% lower than from low sulphur fossil diesel and are comparable or lower than ULSD due to the negligible sulphur content of liquid biofuel.
- Hydrocarbons are reduced by 90%, saturated hydrocarbons are reduced by 50%, carbon monoxide is reduced by 43%, and carbon dioxide is reduced 78% by the use of biodiesel.
- The ozone-forming potential of biodiesel emissions is nearly 50% less than from fossil diesel.
- Nitrous oxide (NO_x) emissions may increase or decrease but can be reduced below fossil diesel levels by adjusting engine timing.
- Biodiesel exhaust is not offensive and doesn't cause eye irritation.
- In the Chinese biofuel trial areas tests have proven a 30% decrease of CO in car emission compared with using fossil gasoline of the same index[303].

The rapid increase in the number of motor vehicles and of the transport sector in general due to the booming economy - combined with the fact, that much of China's power and heat is still produced by burning local coal, which has high sulphur content - has exacerbated air pollution in major cities. The level of pollution in industrial cities such as Shenyang and Wuhan can reach three to four times the maximum level advised by WHO. As a result, acid rain is a serious problem.

The decision to hold the Olympic Games in Beijing in 2008 has stimulated a major drive to clean up air quality in the capital, particularly by enforced switch from coal to natural gas and reforestation, and already the cities air has improved[304], even if liquid biofuel is not yet introduced into the Beijing transport fuel market.

Impact on biodiversity, water, soil, forestry and nature conservation

Environmental improvements are intended by the promotion of liquid biofuel in the transport sector; also in order to avoid negative impacts from leakages from decaying infrastructure of underground pipelines carrying gasoline and diesel to the far corners of China, which are seeping into ground and

[301] IEA, 2004
[302] N.Burcu Parlak, University of Ankara, Faculty of Agriculture, Department of Soil Science 06110 Diskapi-ANKARA
[303] Yue Guo Jun, Utilization of Etanol in China – an Ethanol manufacturer's perspective, Conference Proceedings CHINA Biofuels and Ethanol OUTLOOK 2005
[304] CBH, 2005

water supplies. Chinese water tables and water bodies are polluted with this seepage, contaminating precious drinking water. Installation of these pipelines dates back to 1920 to 1940; they are rotting out having heavily negative impact on the bio-diversity, and neighbouring water and soil resources. In addition to this, the spillage from vehicles washes via drains into the rivers[305].

Liquid biofuels are generated from organic matter and are biodegradable. After several years or even shorter time, biofuels will be degraded and will not pollute natural environment, unlike petroleum based fuels.

Moreover, the development of biofuel feedstock as non-food crop could act as positive drives of change in the countryside, and contribute to the distinctiveness of the landscape. There is potential for increased use of biofuel and non-food crops to support activities towards increasing and maintaining biodiversity.

Concerning water protection, well-managed biofuel feedstock and non-food crop plantations are intended to regulate the water flows and mitigate the risk of floods and drought, especially woody crops that are harvested on long rotation.

Table 65: Relative contribution of different crops to environmental impacts on soil and water[306]

Crop	Erosion (risk and contribution)	Nutrient loss (leaching and run-off)	Water use (soil moisture fertility status)	Nutrient demand (impact on soil)	Pesticide use (impacts on biodiversity and pollution)
Maize	**	***	***	**	***
Wheat	*	***	***	**	***
Sorghum Bicolor	**	*	*	*	**
Soybean *Glycine max* (L.)	**	*	**	*	**
Manihot esculenta Crantz	*	**	**	***	*
Sweet potato	*	**	**	***	*
* low, ** -moderate , *** high potential impact.					

5.3.4 Socio-economic impact

UNDP stated in the 2005 Human Development Report[307], that China's economic advance has outpaced social progress, though it has made rapid progress in offering basic education, medical and social security for its population. The nation is facing the challenge of ensuring that remarkable income growth is converted into sustained progress in non-income dimensions of human development. However, the report asserted "crippling low incomes, lack of access to health care and low education prospects all plague the Chinese countryside"[308]. Millions of migrant workers from rural areas earn

305 CBH, 2005
306 composed with data from http://www.fao.org/WAICENT/FAOINFO/AGRICULT/aga/lspa/LXEHTML/tech/ch5a.htm
307 UNDP Human Development Report 2005, China Daily, Vol 25, 2005/09/10
308 Statement of Malik, K., UNDP Resident Representative in China, *China Daily*, Vol 25, 2005/09/10

their living in towns and cities; China's urban population is expected to grow to 750 Mio by 2020[309] with consequences for all energy related sectors, and especially transportation.

The production of raw materials for liquid biofuels, their processing and conversion into affordable modern forms of energy and fuels for transport will address the situation of people living in poverty in rural contexts; priority should be given to technology options that are technical proven, cost-competitive and can demonstrate a track record of performance in developing and emerging countries [310].

According to official announcements of the Minister of Agriculture, China has embarked on a strategy of revitalizing agriculture through science and technology, and has made "headway" in areas such as biotechnology[311].

Rural economic development

About 62% [312] of China's population lives in the countryside. Policies designed to improve rural living conditions paid dividends in 2004. Strengthening food grain prices – in January-June 2004 they raised 27% year-on-year - helped lift rural incomes and the incentive for people to farm. Prime Minister Wen Jiabao promised to raise investment in agriculture and in rural areas in 2004 by at least 20%, or 3 BN EUR, and to direct financing raised from treasury bonds towards rural infrastructure. The declining output of the previous few years was inversed[313]. The government switched in 2004 from an indirect grain subsidy system, operated through state trading company procurement, to the direct subsidy to farmers. Grain farmers were to get 1.2 BN EUR in direct subsidies over the course of the year.

Incomes and wealth levels have risen since 2003. Consumption in the countryside expanded but with sales growth of 9.1%, the rural economy still lagged behind urban areas, where retail growth for January-June 2004 was 14.7%[314]. The ratio of per-capita net income between urban and rural residents has expanded to 3.2 to 1 in 2004 from 1.8 to 1 two decades ago, urging the government to invest in agricultural development, promoting innovations in agricultural technology and facilitating the translation of research results into productivity[315].

With the earnings of migrant labourers making an important contribution to rural revenues, the government ordered prompter payment of wages and arrears by SOEs[316].

Implementing a promotion programme of liquid biofuels is expected to have significant impact on the rural economic development, due to locally available income generation opportunities through processing units and improved land use for raw material production.

[309] CBH, 2005, according to Asian Pacific Economic Cooperation Forum
[310] Johansson et al., 2005
[311] statement of Du Qinglin, Minister of Agriculture, *China Daily* September 10, 2005:
[312] 800 Mio people
[313] CBH, 2005
[314] CBH, 2005
[315] Justin Lin – China Centre for Economic Research, Beijing University. *China Daily* September 10, 2005:
[316] CBH 2005

Land tenure

There are two types of land ownership in China: state ownership and collective ownership.

Table 66: Land ownership[317]

State Owned Land	**Collectively Owned Land**
Urban areas	Agricultural land
Uncultivated land in remote areas	Homesteads in suburban and rural areas

Individuals / corporative entities are not permitted to own land, but they may own the property above land; in a commercial economical aspect, land-use rights are of greater significance than land ownership.

Table 67: Land use rights

Right	Grant giver	Grant taker
Land grant system introduced in 1990	Land grant contract with the local land bureau Government may take back the land before it expires only in cases of public interest, but has to give compensation	Enjoys a fixed land-grant term and must use the land for the purpose specified in the contract. Maximum land grant: 40 years for commercial use to 70 years for residential us Rights are transferable in accordance with the law and the land grant contract Substantial payment & annual land-use fee
Land lease	Land grant contract with the local land bureau	Higher annual rent, no large down-payment
Allocated land-use rights	Administrative approval by government	No payment of a land-grant fee
Collective land-use rights	Contracts with rural collectives	
Non granted land-use right		Lack marketability and security of tenure

This legal framework facilitates the large-scale plantation of energy crops, as far as community decisions are respected and information on cultivation, harvest and technology are shared.

Employment in agriculture and forestry

800 Mio people live in China's rural areas, up to 200 Mio of them have no opportunity to generate an income, which permit them to survive under given conditions. The Chinese government defines it as a pressing task to solve the employment problems of these surplus labourers. During the process of China's urbanization, millions of rural residents have moved to urban areas and gradually have become a major work force in shaping the modern cities. Actual figures are given with 150 Mio migrants,

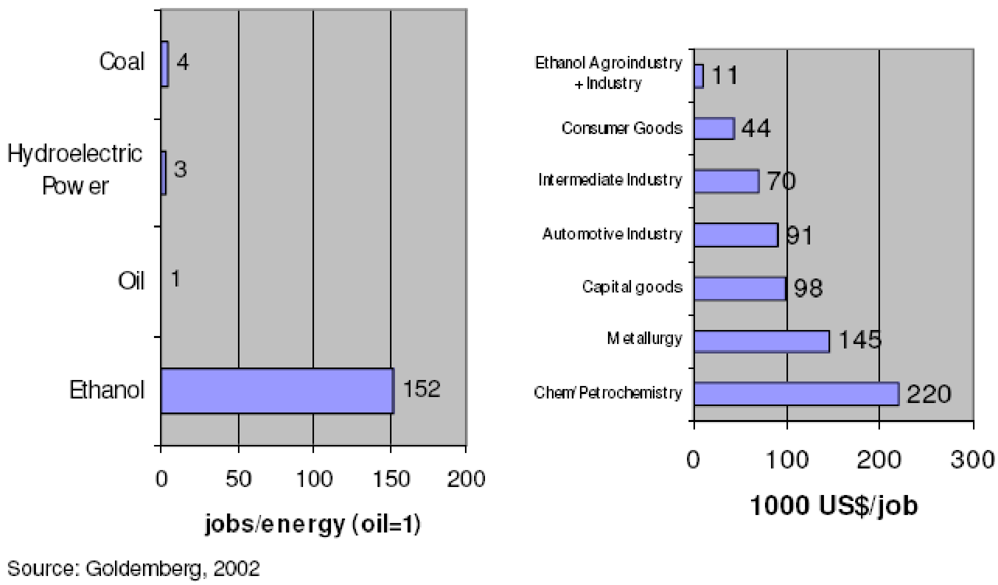
[317] CBH, 2005

representing rural labour force without labour in the countryside, thus making up the backbone of China's labour construction force. While there are certainly some farmer-turned-workers who have merged themselves quite well into urban life, most of them are still walking the perilous edge of poverty[318].

The concerted development of rural and urban areas requires income increases for rural residents, the free flow of rural labour to non-agricultural industries and urban areas, and the industrialization and urbanization of rural regions. That offers a way to promote unity in different social strata [319]. The production of raw material for liquid biofuel production and the investments in production units offer an opportunity for a new cycle of rural development, generating a fair amount of employment and self-employment[320]. It is calculated that in total up to 9.2 Mio work places can be created in agriculture, forestry and the related industry through the large-scale production of liquid biofuels.

Up to date, detailed studies on this topic have not yet been carried out in China; therefore a Brazilian analysis is given as example in the following figure.

Figure 12: Comparison of jobs in the Brazilian Ethanol industry with other energy generating and industrial sectors[321]



Agriculture

The promotion of liquid biofuels offers an opportunity for both employment in agriculture and non-agricultural industries located in rural areas: in the plantation of energy crops, their harvest, transport and conversion to liquid biofuel. This will help to avoid or at least to pamper negative impacts of labour shortage in the urban areas on the rural economy[322]. Prospects and working

318 Guo Zi: Migrant workers deserve equality, *China Daily*, 25 August 2005
319 Wang Jingrong, vice-secretary of the political and legislation committee under the Central Committee of the Communist Party of China, Qi Jingfa, vice-minister of agriculture, *China Daily* 2004-08-25
320 Sachs, 2005
321 Oswaldo Lucon: Bioethanol: lessons from a brazilian experience, India 2005
322 In 2004, an unanticipated knock-on effect of the achievements in the countryside was a serious labour shortage in core industrial areas such as Pearl River Delta region. Real wages for low-paid migrant workers had hardly moved for years and, with inflation on the rise, in effect declined in 2004.

conditions are now often better in the countryside than in urban factory hotspots, meaning that many labour forces will stay in the rural area[323].

These labour forces could be used in building up a modern, environmental sound agriculture, providing feedstock for liquid biofuel production. As well as increasing the level and application of agricultural technology, speeding up the transfer of farmers to non-agricultural jobs is a key to China's problem of sluggish rural income growth[324], and will turn many food producers into consumers.

Even if agricultural energy crop production is seasonal, many workers can be contracted for annual employments for the maintenance of agricultural and industrial equipment during off-season.

The production of biofuel (plant oils) on village level seems technically and commercially possible, as agricultural companies are interested to experiment small-scale production systems. Mechanized farms can be self-sufficient in fuel if using 10-20 % of the arable land for energy crop cultivation. At the same time the price of fossil fuels is expected to increase steadily. In this scenario, the difference between the non-subsidized market price of biodiesel and the fixed price of fossil diesel will decrease.

High-quality biodiesel production requires high-quality plant oil feedstock for gaining good benefits. In order to formulate a sustainable development frame for biofuel industries, various institutes carry out decentralized research work on available feedstock, even if they are based in the same region[325].

Forestry

To date, forest coverage in China has reached 16.55 %. In the course of building a moderately well-off society in an all-round way and pressing ahead with socialist modernization at an accelerated pace, Chinese government emphasizes and strengthens forestry work and makes forestry the centrepiece of ecological development, especially for the development of the western regions[326].

Sustainable economic and social development urgently calls also for a major transformation of Chinese forestry. The Chinese government has released a decision on speeding the development of forestry.[327] The plan includes measures for tackling environmental degradation, desertification and illegal logging. The plan also covers ways of mobilizing the society to become more involved in forestry, for instance by tree planting and environmental awareness raising campaigns.

It is estimated that by 2010, the coverage rate of forests in China will reach more than 19%, while soil erosion in major river reaches and the expansion of desert land in major sand areas will slow down, due to improved know-how and technologies to make use of barren and desert lands. Ecological needs have become society's No. 1 demand in forestry. Forestry in China is in an important phase of transformation and transition. It is in the midst of an historic shift from being oriented towards timber production to being oriented towards ecological construction[328] among these issues also liquid biofuel production could find a place.

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[323] CBH, 2005

[324] Lin, China Centre for Economic Research at Beijing University. *China Daily* September 10, 2005

[325] Forestry Academy of Hunan and Tiandi Biomass Institut of Changsha, Hunan; But a detailed overview has still to be seen as incomplete, due to time restrictions for the present assessment study.

[326] Decision of the Chinese Communist Party [CCP] Central Committee and State Council on Accelerating the Development of Forestry in China, Chinese news agency *Xinhua* Beijing, 2003.09:

[327] The development blueprint calls for building up a forestry industry based on government guidance and supervision, market competition and regulation. The forestry industry will also be further opened up to foreign and private sector investment and participation, and forestry enterprises will be encouraged to export forestry products overseas and seek new markets. The plan also covered the establishment of a legal and supervisory framework for the forestry industry, land transfers and land use rights, as well as environmental protection.

[328]: Decision of the Chinese Communist Party [CCP] Central Committee and State Council on Accelerating the Development of Forestry in China, Chinese news agency *Xinhua,* Beijing 2003.09

The Chinese Forestry Law intends to speed up forestry development for a sustainable economic and social development, including new aspects of productivity, as it could be the production of raw material for liquid biofuels. The CCP-Central Committee and the State Council have attached a good deal of importance to forestry work and taken a series of policy measures, thus greatly promoting forestry development[329]. Key projects launched in recent years, such as the protection of natural forests, the reforestation of former farmland, and anti-erosion works, have been making good progress.

Forestry is playing an increasingly important role in the development of agriculture and the rural economy, expanding urban and rural employment and boosting rural habitant incomes[330]. The production of raw material for liquid biofuels can be developed as one of the most interesting output of forestry, providing long-term impact on the rural economy.

Converting barren or salina land and mountain areas in energy-oriented forest in order to provide biomass for liquid biofuel production will not threaten food security. There is still a lot of potential forestland in China, which could be reforested with *Jatropha curcas L., Pistalia chinengsis Bunge ,* *Cornus wilsoniana ,* and other tree varieties; existing forestland can be enriched with energy woods, thus rendering higher economic value.

5.4. Macro-economic impacts and international markets

5.4.1 Macro-economics

Redesigning of habitat, urban and rural infrastructure and transportation systems will have a decisive impact on the future demand for liquid biofuels.

On the other hand, much more is at stake than the mere substitution of petrol by liquid biofuel. The three major challenges for China are**:**

(1) provision of decent work for all,

(2) reduction of oil import dependency, and

(3) stopping the global warming**.**

The biofuel option lies at the intersection of these challenges and contributes to their solution.

The structure of the Chinese energy market is highly fragmented. While national policy is set in Beijing, actions by each province and municipality reflect local needs and interests. End-use of energy, particularly gas and electricity, and also liquid biofuel, is subject to local price control. This is partly to prevent exploitation of local monopoles in delivery, but also represents a residual of habits created during central planning days in the energy and fuel sector, which is seen as critical to many industrial and transport activities.

China's petroleum industry has undergone major changes over the last decade. In 1998, the Chinese government reorganized most state owned oil and gas assets into two vertically integrated firms - the China National Petroleum Corporation (CNPC) and the China Petrochemical Corporation (SINOPEC). Before the restructuring, CNPC had been engaged mainly in oil and gas exploration and production, while SINOPEC had been engaged in refining and distribution. This reorganization created two regionally focused firms - CNPC in the north and west - and SINOPEC in the south, though CNPC is

[329] Forestry Law, Passed by the Seventh Session of the Standing Committee of the Sixth National People's Congress on September 20, 1984 and Revised in Line with the Decision on the Revision of the Forest Law of the People's Republic of China of the Second Session of the Ninth National People's Congress on April 29, 1998; Beijing 10 September 2003: Decision of the Chinese Communist Party [CCP] Central Committee and State Council on Accelerating the Development of Forestry in China

[330] http://www.rednovacom/news/science/8307/chinese_government_plan_on_speeding_up_forestry_development/

still tilted toward crude oil production and SINOPEC toward refining. The other major state sector firm in China is the China National Offshore Oil Corporation (CNOOC), which handles offshore exploration and production and accounts for more than 10% of China's domestic crude oil production. Regulatory oversight of the industry now is the responsibility of the State Energy Administration (SEA), which was created in early 2003[331].

China is having difficulty placing SOEs under tight budget constraints; they have historically had ready access to bank credit, and nowadays banks are under instruction to make loans only on a commercial basis.

The development of the liquid biofuel sector fits in the centralized-decentralized pattern, as the availability of feedstock is limited to regions and the actual consumption of liquid biofuel is already organized by some of the producing enterprises and local transport business. However, promotion from the Chinese government and the design of the political and economical framework for liquid biofuel application are requested, in order to amplify the availability of liquid biofuel in the countrywide market`.

Today's understanding is that sustainable energy and transport policies should maximise the long-term welfare of citizens by keeping a reasonable balance between the traditional policy objectives of secure/safe, competitive and environment-friendly energy and transport services[332]

5.4.2 International Markets

International liquid biofuel trade

Although bioethanol as alternative fuel is known since some time — Henry Ford initially considered powering the famous Model T with alcohol — its trade on the international market recently started in May 2004[333]. Today, the New York Board of Trade (NYBOT) believes the time is right to launch a futures contract and judges ethanol as a consumable commodity especially for USA and Latin America, with an increasing economic presence in both the agricultural and energy sectors. China does not appear in the list of the nine countries of origin currently listed, but is internationally expected to become an importer of bioethanol for fuel. For November 2005, the bid at the Chicago Board of Trade for ethanol future is about 611 EUR/t bioethanol E100[334].

The international market for liquid biofuel is moving. Global bioethanol output is estimated to more than double by 2010, and NYBOT's ethanol contract underscores the increasing role this liquid biofuel has in the world. Since there is no clear international reference price for ethanol, NYBOT seeks to establish such a benchmark with its contract. Biomass-derived, undenatured, anhydrous ethanol meeting specific quality criteria is on the way to be a product with a large trade flow, as many countries will be in need of cleaner fuels (E5 or E10) in order to fulfil the Kyoto requirements.

Globally, the prospects for international trade in bioethanol are looking quite bright[335]. Although in China bioethanol is still mainly a corn-based product, over 60 percent of the world's ethanol production is actually distilled from sugar. At the moment, the fact that bioethanol is being subsidized almost anywhere in the world provides a powerful justification for high import tariffs in order to

331 http://www.eia.doe.gov/emeu/cabs/china.html
332 European Commission: Commission Staff Working Paper – Integrating environment and sustainable fdevelopment into Energy and transport policies, 2001
333 http://www.cbot.com/cbot/pub/page/0,3181,1754,00.html
334 http://www.cbot.com/cbot/pub/page/0,3181,1754,00.html
335 http://www.futuresindustry.org/fimagazi-1929.asp?iss=143&a=922

neutralize these subsidies[336]. If *Sorghum bicolor L.* will be applied, Chinese bioethanol production will be competitive to Brazil prices, which are actually at 300 EUR/t.

Some EU-countries as Sweden includes import of liquid biofuel from non-European countries as efficient instrument to fulfil their national policy and to provide sustainable markets for new farm products in developing countries. UK sees international trade of liquid biofuel as „undesirable" for national fuel replacements; meanwhile Brazil is seeking international markets for its liquid biofuel as the national market could be already satisfied by the existing bioethanol production.

China has not yet any trade position, but certainly will follow the "best market value" of agricultural products and of biofuel, when national development goals could be integrated and combined within a market strategy and supply security could be guaranteed. As international delivery of bioethanol must take place at ports that have the capacity to export bioethanol, Chinese ports must still be prepared for.

Impact on China's international trade

The impact of Chinese liquid biofuel production on the Chinese macro-economic situation, esp. in the framework of China's position in international markets, depends not only from national conditions, but also even more from global policies and market trends.

Goods, which are subject to Chinese state trading, include[337]:

- For import: grain, vegetable oil, processed oil, crude oil, chemical fertilizer
- For export: tea, rice, corn, soybeans, coal, crude oil, processed oil

The liquid biofuel market is an example of an "environmentally preferable products" market (EPP[338]) that is expected to grow. Particularly with implementation of the Kyoto Protocol, rising oil prices and growing world energy demand leads to estimations that liquid biofuel will supply half or more of global transport fuel needs in 2050[339].

The exploitation of renewable energies or raw materials in international commercial markets is still low, being constrained by costs and uncompensated benefits (externalities) as well as intermittent supply and other technical and institutional constraints. UNCTAD Experts at a Meeting on Definitions and Dimensions of Environmental Goods and Services in Trade and Development[340] emphasized that trade liberalization in renewable energy products could result in clear environmental benefits as well as increased exports for certain developing and emerging countries, thus improving their international position and national economy.

The International Energy Agency predicts that, over the next 20 years, markets for economically viable renewable resources – such as biomass for liquid biofuel production - will increase as a result of cost reductions from technological improvements and expanding markets. New market-based instruments to address climate change will also create markets for renewable. In addition, environmental concerns have increased the attractiveness of renewable energy sources to policymakers.

UNCTAD secretariat calculations[341] indicate that within the renewable energy product group China can easily enter into production of raw material for liquid biofuels using abundant agricultural and forestry resources and organic wastes from food processing.

336 http:www.ethanolrfa.org/industry/market
337 CHB, 2005, p. 60
338 EPPs include organic, non-wood forest, traditional knowledge based and renewable energy products.
339 According to surveys cited in International Energy Agency, " Biofuels for transport, an international perspective", 2004.
340 (Geneva, 9-11 July 2003),
341 http://www.unctad.org/en/docs/c1em26d2_en.pdf

The promotion of liquid biofuel will also bring developmental benefits: reduction of fuel imports, security in energy supply, and diversification of agricultural production, new export markets and social benefits through job creation and rural economic development.

The conditions for liquid biofuel trade between developed, developing and emerging countries exist already: the cost of production of crops for biofuels is lower in developing and emerging countries, and demand for biofuel in developed and emerging countries will increase mainly due to implementation of the Kyoto Protocol. China – although it has to meet increasing energy and food demand - could turn this trade into a win-win solution if trade barriers are removed and national conditions – also in remote areas – adequately designed to promote renewable liquid biofuels.

International trade in renewable energy services and equipment has become a relatively important issue in the context of the multilateral trade negotiations at the WTO on environmental goods and services (EGS) and in UNCTAD's work. China's need for recovering barren lands and deforested mountains at one hand, the abundant availability of manpower and research skills at the other hand offer the tools for implementing an environmental friendly, social and economic development by using liquid biofuels at large scale. The country has the potential to enter the international markets for liquid biofuel, or – at least – by improving its own capacity reducing significantly the dependency from fossil oil imports.

Overcoming trade barriers in energy goods and services and in agriculture, in particular, is critical to effectively strengthening and entering in the market for renewable energy products, including liquid biofuels; accompanied by effective technology transfer and adaptation, this could provide significant economic and environmental benefits for China as for other developed and developing countries[342].

[342] There has been strong interest in enhanced cooperation between India and Brazil on the production, use and export of ethanol. In April 2002, India and Brazil signed a Memorandum of Understanding (MoU) for technology sharing in blending petroleum and diesel fuels with biofuel ethanol.

6 Synthesis & Recommendations

This chapter summarizes the potential of liquid biofuels in China and derives some recommendations to Chinese decision makers.

6.1. Summarized potential for liquid biofuel production

Biodiesel

As seen in table 68 the demand for mineral diesel is suspected to rise dramatically during the next years, biodiesel can only cover a small part (about 6 %) of the Chinese diesel market. The total demand for diesel in the transportation sector will reach at least 171 Mio t in 2020.

Table 68 and 69 show the conservative and optimistic scenario for biodiesel production in China.

Table 68: Conservative scenario for biodiesel, 2020

Demand	Production Potential	Available land
17.1 Mio t, if blending ratio biodiesel/fossil diesel of 10% is considered.	10.65 Mio t/a: 63% from woody oil plants and 37% from cooking waste oil and low-grade vegetable oil. Based on 2,0 Mio ha only for *Jatropha,* the potential biodiesel output from *Jatropha* is 5.85 Mio t/a.	8.3 Mio ha[343], in addition forest area could be enriched with biodiesel feedstock plants.

To accomplish the demand, biodiesel would have to be imported.

Table 69: Optimistic scenario for biodiesel, 2020

Demand	Production Potential	Available land
17.1 Mio t, if blending ratio biodiesel/fossil diesel of 10% is considered.	200 Mio t/a: *Jatropha curcas* L., with about 3 t/ha of biodiesel output in a good year and 70 Mio t/a, with about 1.0 t/ha in a bad year.	67.53 Mio ha which includes potential woodlands, barren and uncultivated land suitable for forestland and Grain-to-Green [344] land.

Relevant energy-oriented agriculture and industry for biodiesel can offer about 6 Mio of jobs.

Table 71 shows that even if the Chinese biodiesel production can potentially only cover a small share of the Chinese diesel demand, in 2010 it will be already similar than the German production level.

343 (Jatropha = 2, Pistacia = 0.3, Cornus = 2, Xanthoceras = 4 Mio ha)
344 Agricultural land changed to forestry land

Table 70: Summary on biodiesel use in China

Parameter	*China (now)*	*China (2020)*
Acreage for oil seed plants (edible & biofuel) (Mio ha)	**40**	**up to 67**
Cooking oil (Mio t/a)	**18**	**70**
Biodiesel production (t/a)	**38,000-60,000 (2004)**	**1.5 – 2.0 Mio (2010)** **10.6–200 Mio (2020)**
Bio diesel plant capacity (t/a)	**82,000 (2004)** **241,500 (2006)**	**1,5 to 2,3 Mio (2010)**
Bio diesel production costs (Euro/l)	**0.17 – 0.35** **depending on various feedstock**	
Biodiesel energy GJ/ha	**120**	**130**

Table 71: Summarized potential for biodiesel production in China compared with Germany

Parameter	**China (2005)**	**China (2020)**	**Germany (2005)**	**Quotable source (G – Germany, C-China)**
Acreage for oil seed plants (ha)	40 Mio (edible and for fuel)	67 Mio (mainly for biofuel)	1,04 Mio (2004) = 9% of German acreage	G: FNR
Biodiesel production (t)	38,000-60,000 (2004)	1.5 – 2.0 Mio (2010) 10.6 – 200 Mio (2020)	1.05 Mio (2004) 1.50 Mio (2005) 2.00 Mio (2010)	G: UFOP BMVEL, 2004
Cooking oil market (t/a)	18 Mio	70 Mio	-	
Biodiesel plant capacity (t/a)	82,000 (2004) 241,500 (2006)	2,342,020 (2010)	1,197,000 (2004) 2.20 Mio (2010)	G: Campa Biodiesel BMVEL, 2004
Biodiesel production costs (EUR/l)	0.17 – 0.35 Depending on feedstock		RME100 = 0.76 RME05 = 0.71	G: Bundestags Drucksache 15/5816
Biodiesel production efficiency (net energy balance)	1:3.2	1:3.2	1:3,4	C: USDOE
Biodiesel energy GJ/ha	120	130	123.7	G: Campa Biodiesel,

Bioethanol

The total demand for gasoline for the transportation sector will reach at least 85 Mio t in 2020. As seen in table 72 the demand for gasoline is suspected to rise dramatically during the next years, whereof bioethanol can cover about 10 % of the Chinese gasoline demand for transport.

Table 72: Conservative scenario, 2020

Demand	Production Potential	Available land
8.5 Mio t/a according to the blending ratio of 10%.	8.02 Mio t/a in 2020 (75% from energy crops and 25% from food crops); including bioethanol output from Sorghum: 3.9 Mio t/a	1.59 Mio ha

Table 73: Optimistic scenario, 2020

Demand	Production Potential	Available land
8.5 Mio t/a according to the blending ratio of 10%	28.5 Mio t/a Sorghum bicolor (L.) with about 3.75 t/ha of bioethanol output[345]	7.59 Mio ha

If more fuel bioethanol is produced or imported the blending ratio could be higher.

Relevant energy-oriented agriculture and industry for bioethanol can offer about 2.9 Mio jobs.

Table 74: Summary on bioethanol use in China

Parameter	*China (now)*	*China (2020)*
Fuel bioethanol output (Mio litres)	**1.27**	**8 – 28**
Total bioethanol (Mio l)	**3,797,000**	
Fuel bioethanol area (Mio ha)	**2.7**	**4.3 (2010)** **at least 7.6 (2020)**
Subsidies for bioethanol (Euro/t)	**137**	**0**
Mandatory blending (%)	**10% in 5 provinces**	**10%**
Production costs for bioethanol (Euro/l)	**0.23-0.38**	
- of which feedstock price	**0.16-0.32**	
Bioethanol net energy balance (I/O)	**1:1.1 (corn)** **1:2.1 (cane)** **1:0.7 (cassava)**	

345 which is similar to that of *Saccharum Officenarum* or *Manihot Esculenta Crantz*

Table 75: Summarized potential for bioethanol production in China compared with Germany

Parameter	China (2005)	China (2020)	Germany (2005)	Quotable source
Fuel ethanol output (t)	1.27 Mio	8 - 28.5 Mio	1.14 Mio t (2006)	Meo, 2005
Fuel ethanol – area (ha)	2.7 Mio	4.3 Mio (2010) 7.6 Mio (2020)		
Fuel ethanol cars (FFV)	10,000			B: 1.5 Mio new/a since 95
Subsidies for bioethanol processing (EUR/t)	137	0	Tax deduction (mineral oil tax)	G: Mineral oil tax Law 27.11.03
Subsidies for biofuel feedstock production (EUR/ha)	0	0	45	G: EU Luxemburg consensus
Production costs for bioethanol (EUR/t)	287.5 - 481		0.45-0.50 Euro/l	G: Meo, 2005
- of which feedstock price	202.5 - 360			
Bioethanol net energy balance	1:1.1 (corn) 1:2.1 (cane) 1:0.7 (cassava)		1: 2,81 (wheat) 1: 4,25 (wheat with energetic use of straw)	Senn/Lucà, 2003 G: Meo, 2005
Potential energy from biomass		9.0 EJ/a (of 48 EJ) (Exajoule = 10^{18} J)	500 (PJ/a) 2030: 103* to 153** PJ/a (GER) 2030: 170* to 380** PJ/a (GER) * harvested biomass ** harvested biomass and residues	G: Fritsche, 2005 = Öko-Institut 2004, Fritsche = IFEU 2004

Expected socio-economic and environmental benefits

The environmental significance of using biofuels focuses on

- Protection and improvement of China's atmospherically environment. Compared to fossil fuels, biofuels significantly reduce the amount of atmospheric pollutants such as NO_x and SO_x.
- Reduction of CO_2 emissions: Based on life-cycle assessment it is proven that CO_2 emission from biofuel use can be significantly lower than from fossil fuels, if the correct crops are selected as feedstock and the transport radius of feedstock is optimised.

Moreover, the development of biofuel from non-food crop could act as positive drives of change in the environmental conditions in the countryside, and contribute to the distinctiveness of the landscape. There is potential for increased plantation of biofuel feedstock and non-food crops to support agricultural and forestry activities towards maintaining and broadening biodiversity. Concerning water protection, well-managed biofuel feedstock plantations and non-food crops are intended to regulate the water flows and mitigate the risk of floods and drought, especially woody crops that are harvested on long rotation.

The production of raw material for liquid biofuel production and investment in processing units offer an opportunity for a new cycle of rural socio-economic development, generating a fair amount of employment and self-employment[346]. It is calculated that in total up to 9.2 Mio work places can be created in energy oriented agriculture, forestry and related industry through large-scale production, marketing and use of liquid biofuels.

6.2. Limiting factors for biofuel production and marketing

6.2.1 Agricultural and forestry land

Land resources for energy crops for bioethanol production are estimated to be limited to 7.59 Mio ha; for biodiesel feedstock plantation 67.53 Mio ha land resources are available (optimistic case).

It is obvious, that these resources need to be assessed for a feasible use as energy oriented agricultural or forestry land, including an analysis of their accessibility and further required technological improvement and investment. Furthermore, farmers and communities generally rely on governmental and/or market-led incentives to start with energy oriented agriculture and forestry, an aspect which is not yet sufficiently addressed.

6.2.2 Technology, biofuel quality standards

Chinese know-how on conversion techniques for liquid biofuel is not yet updated about (smaller scale) decentralised biofuel production in locations where biomass or appropriated wastes are available, thus avoiding energy expenditure and costs for transport. Similar need for know-how updating is nessesary for promoting stationary use of liquid biofuels as direct plant oil. Recently, in June 2005, MOST started a program for bio-energy promotion, which aims the development and utilization of standardized industrial biodiesel production units with a designed capacity of 50,000 t/a, to be installed before 2010. There is still a lack of national standards for biodiesel, instead low-grade light diesel standard is applied[347]. If the government were to issue standards for production quality, techniques, distribution networks, and biodiesel industrialization, the market for biofuel would develop faster.

For bioethanol, the Chinese regulations follow the US-American standard, which differs from the European standard.[348]

Regarding BTL, there is a remarkable interest from Chinese decision makers in the development of this technology, as China's landscape and rural areas can provide uncountable amounts of agricultural wastes and woody leftovers. Although the first Chinese conference on BTL-fuel was already carried out in 2001, up to date there is no BTL pilot plant operating in the country.

6.2.3 Marketing

The current distribution monopolization of the fossil oil industry makes it difficult for biofuel companies to compete in the transport fuel market, limiting the distribution of biofuel to local customers. International know-how and marketing strategies are not yet applied in the Chinese biofuel

346 Sachs, 2005
347 http://www.oilgas.com.cn/News/NewsItem.aspx?id=27031
348 see annex and chapter 3

market, addressing for example customer's decision-making for an improved environment when using biofuel for his car.

6.2.4 International liquid biofuel trade

Although the prospects for international trade in bioethanol are looking good[349], and Chinese production costs are lower than the "world market prices", China is not considered as provider: Reasons are limited production capacity combined with a high national demand, and that delivery must take place at ports that have the capacity to import and export bioethanol and biodiesel. At least for bioethanol this is still not possible in Chinese ports.

6.2.5 Grease Trap Waste and waste cooking oil management

There is currently a lack of overview on waste cooking oil production, collection and quality; this potential feedstock for biodiesel production is only partly accessible due to informal market structure for waste cooking oil.

6.3. Recommendations for China

6.3.1 Perform research and investigation on agricultural and forestry resource potential in species and land

Energy-oriented agriculture and forestry are primary material providers for biofuel processing. Related sectors yet do not pay enough attention to their potential, and significant data for efficient work in this field is lacking. The relevant stakeholders (Ministry of Agriculture, State Forestry Bureau, Ministry of Land and Resource, State Environmental Protection Agency) should be involved as follows:

a) Perform research and investigation on land availability, including the species, acreage and distribution of available land resource.

b) Establish maps at Province level of identified land resources for biofuel feedstock plantation.

c) Investigate the applicability, potential and distribution of possible energy plants.

d) Integrate energy-oriented agriculture and forestry into the research category of agriculture and forestry development strategy.

e) Regulate the collection and use of waste cooking oil in order to open this feedstock sector for biodiesel production

6.3.2 Strengthen technology R&D

In order to achieve the development goal of the biofuel sector[350], China needs to strengthen technology R&D, in the following topics:

a) Selection and cultivation of new species of energy crops with optimized yield and high

349 http://www.futuresindustry.org/fimagazi-1929.asp?iss=143&a=922

350 "Agriculture and forestry could become leading sources of bioenergy, a key element in achieving two of the UN MDG: eradicating extreme poverty and hunger and ensuring environmental sustainability." http://www.fao.org/newsroom/en/news/2005/101397

adaptability.

b) Technology and equipment of labour intensive energy crop harvest, storage and transportation.

c) High efficient processing and conversion techniques and equipment for different resource species.

d) Install a pilot plant for BTL technology

e) Promote by-products with higher economical value[351].

6.3.3 Extend industrial demonstration

China has achieved the bioethanol production using food crop as material on certain scales. Future biofuel production should focus on non-food energy and forestry crops as main feedstock. Therefore, industrial demonstration should be extended towards the entire process chain from the cultivation of various energy plants to the production of biofuel, in order to develop biofuel production on a large scale:

a) Investigate suitable level for biofuel production using different local raw material in different regions.

b) Investigate sustainable management mechanism of agricultural and forestry feedstock production, harvest, transportation, storage and fuel production, involving different stakeholders.

c) Establish as soon as possible biodiesel and bioethanol production demonstration bases using different raw materials in different regions, including planting, harvest, transportation, and storage facilities.

6.3.4 Expand support policy scope

The energy-oriented agriculture and forestry and the liquid biofuel processing industry offer remarkable social and environmental benefits, which require support by governmental decision makers. Current subsidies for bioethanol production are related to time limited projects or programmes. In order to give involved parties medium- and long-term investment guarantees, the following suggestions have been formulated:

a) Promote and support policies that encourage the farmers to start planting energy crops by the provision of high quality seed, technical assistance, fair trade principles and market security.

b) Issue a preferential tax revenue policy for biodiesel and bioethanol production and use, as well as for related R&D and demonstration projects.

c) Motivate consumers to use liquid biofuel by implementing a carbon emission based fuel tax.

d) Speed up the number of areas obliged to use E10 gasoline, covering the whole country within 5 years.

e) Focus on the country's social, economical and environmental sustainable development by pushing the growing transport sector's demand towards the use of biofuel, produced in

[351] http://journeyforever.org/biodiesel_glycerin.html

China.

f) Include policies on technology standards and urban planning in the policy scope for biofuel promotion, thus encouraging industrial development and innovation, which in turn can accelerate biofuel technology development.[352].

g) Involve all related national and provincial Ministries and Departments, as well as the County and Municipality level in the biofuel mainstreaming promotion: agriculture, forestry, transport, economic development, poverty alleviation, education, urban and land use planning, and infrastructure development

6.3.5 Enable fair and open market environment

Chinese fuel market structure restricts the market access for the liquid biofuel industry. Recommendations are as follows:

a) Establish product standard for biodiesel;

b) Elaborate marketing strategies for biofuel application;

c) Encourage investment into the biofuel industry and distriburion network;

d) Participate in the international biofuel trade.

e) “Downstream” firms in the refinery and retail business of transport fuels should begin blending their products with biofuels (E10, B10, B5, B3).

f) Joint Ventures with experienced foreign companies could bring in know-how for developing biofuel marketing strategies and national distribution network.

6.3.6 Cooperate in the international know-how exchange

Economic development is the right for all countries; however China does not need to repeat the pollution practices of other industrializing countries.

a) Facilitate knowledge transfer on biofuels at all administrative levels who decide on investments into the sector

b) Establish close cooperation with biofuel experienced countries and companies to speed up the development of the liquid biofuel sector in China;

c) Attract investments and joint ventures for the liquid biofuel sector in Chinas.

d) Introduce advanced technologies in liquid biofuel production especially in BTL and optimized DGG storage and use through technological cooperation with China

e) Make use and benefit from technological cooperation in the sectors of energy and transport as targeted in the recently agreed EU-China Climate Change Partnership.[353]

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[352] International Conference for Renewable Energies, Bonn 2004: Policy Recommendations for renewable energies

[353] European Parlament, Committee on the Environment, Public Health and Food Safety, Report on Winning the Battle Against Global Climate Change (2005/2049 (INI)), 20.10.2005

6.4. International Recommendations

1. China must take the path of sustainable development because of the pressures of scarce energy resources and the environment. Sustainable development is one of the most important purposes of Clean Development Mechanisms (CDM); therefore this instrument is consistent with the development strategies of China. Investments in CDM can be an opportunity for the country to increase its international trade and introduce foreign investment in the biofuel sector.

2. Investments into the future market of biofuel production and distribution could become highly profitable, if technology export were successfully organised to China. The scope of products ranges from efficient decentralised to centralised biofuel production plants, distribution network devices and know-how for the booming automobile market in the emerging economy[354], and for potential stationary use. The promotion of liquid biofuel provides the opportunity for Germany and the EU to develop a competitive edge in technology transfer.

3. Including biofuel projects in international development cooperation programmes will address at a large scale poverty alleviation and rural sustainable development through energy-oriented agriculture and forestry without neglecting the national food security.

[354] Deutsche Bank Research, August 15, 2005, Current Issues, Energy Special

7 SWOT-Analysis on biofuel in China

For a quick overview, strengths, weaknesses, opportunities and threats to bioethanol and biodiesel in China are shown in the following table. The reader should keep in mind that biofuels are not really in competition to each other, as they require different engine types.

Table 76: SWOT-analysis biofuels

Bioethanol	Biodiesel
Strengths	
Has been commercially blended since 2001	Has been commercially produced since 2002
For subsidy reasons, at present commercially viable, as its market price matches the import parity price for petroleum	Mostly based on utilization of waste oil
	Successful trials on its use in both road and farm vehicles
Better environmental performance through reduction in vehicular pollution and Green House Gas (GHG) emissions	Lower market price than fossil diesel
	Help reduce vehicular pollution and GHG emissions
Policy and institutional environment for promoting use of bioethanol is in place	Jatropha, Chinese Pistacia and Cornus Wilsonania can be grown successfully under rain fed condition
	De-oiled cake is a good organic fertilizer locally used in agriculture
Weaknesses	
Dependence on a single source – corn – for bioethanol production	A relatively new fuel in the Chinese context
Corn production as fuel feedstock in competition to food purpose	There are still concerns on engine performance and maintenance requirements – in EU-4-Norm cars B100 can not be applied
	No subsidies for biodiesel production
Production costs still too high due to high feedstock costs	Seed yields show enormous variations because of difference in germ-plasm, plantation practices and climatic conditions
	Economic viability depends a lot on seed yields and income from by-products
Up to now only 5 from 31 provinces promote the use of bioethanol (E10) as fuel blending	Lack of appropriate legal set up to promote their use; not much policy improvement and still no national standards for biodiesel
Opportunities	
Utilization of sweet sorghum, cassava and energy sugarcane as feedstock	Opportunity for utilizing non edible oils and waste oil
Research is being carried out to develop technology to produce ethanol from other feedstock at more economical level	Many potential land for plantation of oil fruit bearing trees and bushes
Research is being carried out for improvement of agricultural technologies,	Opportunity for greening of wastelands and prevention of further land degradation

Bioethanol	Biodiesel
Research is being carried out how to conserve the sugar content in sweet sorghum and energy sugarcane	Generation of enormous number of jobs in feedstock planting, raising, reaping and processing of biodiesel
Threats	
Use of food grains for production of ethanol is not viable because of the issues related to food security	Little plant improvement work has been carried out till date. The existing low yield levels per ha further constrain the production potential
The limited water and land resources constrain the expansion of area under energy crop cultivation	Quality of biodiesel is still not reliable enough for large scale application
26% of total bioethanol feedstock is imported from other South Asian countries	Trans-esterification requires certain scale of production for the sake of economy
Subsidy policy could be finished before economical feasible production is in place	Trans-esterification with aced catalyst: by-products are hard to recycle; serious erosion of equipment and pipelines; acid waste water affects the environment.

Bibliographies

Publications:

Agricultural Strategies Research Team (2003): Strategy Research on National Science and Technology Development Program- Research on Agricultural Waste Materialization and Strategies of Rural Biomass Energy, Beijing

Asia Pacific Energy Research Centre - APERC (2004): Energy in China, Transportation, Electric Power and Fuel Markets http://www.ieej.or.jp/aperc/pdf/CHINA_COMBINED_DRAFT.pdf

Austrian Biofuel Institute (2002): Biodiesel – a Success Store, The Development of Biodiesel in Germany, Report for the International Energy Agency, Bioenergy Task 27 Liquid Biofuel, Vienna, www.biodiesel.at

Biodiesel Industries (nd): Material Safety Data Sheets. Biodiesel, Glycerine www.biodiesel.org

British Petroleum – BP (2005): BP Statistical Review of World Energy http://www.bp.com/genericsection.do?categoryId=92&contentId=7005893

Bundesministerium fuer Wirtschaftliche Zusammenarbeit; Bundesministerium fuer Umwelt, Naturschutz und Reaktorsicherheit (2004): Conference Report Outcomes & Documentation, Renewables 2004- International Conference for Renewable Energies, 1-4 June 2004, Bonn, Germany

China Agricultural Yearbook (2004), China Agricultural Press (Chinese language only)

China Business Handbook – CBY (2005), 8th edition. Alain Charles Publishing ltd., London ISBN 0-9512512-8-7

China Council For International Cooperation on Environment and Development (2003): Proceedings of the 2nd Meeting. 30 Oct – 1 Nov 2003. China Environmental Science Press

China Ministry of Forestry (2002): Strategic Research on the Sustainable Development of China's Forestry. China Forestry Publishing House, Beijing (Chinese language only)

Chinese Academy of Science (2004): NREL, Newsletter, No. 3, May 2004,

CNN (2002): Without this protein coffee wouldn't work http://edition.cnn.com/2002/TECH/science/08/14/coffee.protein/

Deutsche Bank (2005): Bioenergy fuer die Zeiten nach dem Oel. Deutsche bank Research- Energy Special, August 15, 2005, http://www.dbresearch.de/PROD/DBR_INTERNET_DE-PROD/PROD0000000000189241.pdf

Energy Information Association (2004): Country Analysis Briefs. China http://www.eia.doe.gov/emeu/cabs/china.html

ENVIRON (2003): The case of biodiesel. http://www.chinaeol.net/bell-green/ppt/biodiesel%20final%20report.pdf

ETA (2002): ECHI-T Large Bioethanol project from Sweet Sorghum in P.R. China and Italy, ETA, Florence. ISBN 88-900442-6-8

European Commission- EC (2001): Commission Staff Working Paper – Integrating environment and sustainable development into Energy and transport policies. http://europa.eu.int/comm/energy_transport/library/taiex.PDF

European Parliament (2003): Alternative Automotive Fuels. Supply, technological and environmental scenarios to 2030. working paper http://www.europarl.eu.int/stoa/publi/pdf/stoa121_en.pdf

European Parliament (2005): Winning the Battle against Global Climate. 2005/2049 (INI) Motion for a European Parliament resolution http://www.wijkman.se/climate+report+(English+and+Swe)/352.aspx

Food and Agriculture Policy Research Institute- FAPRI (2005): World Oilseeds and products http://www.fapri.org/outlook2005/text/12_WldOil.pdf

Gesellschaft fuer Technische Zusammenarbeit mbH- GTZ (1995): Jatropha Oil as Fuel. Direction National Hydraulique et Energie, GTZ, Mali

Grassi, Giuliano. (n.y.): Biofuel for Transport, LAMNET.

Grassi, Guiliano (n.y.): Microdestillery for decentralised Bioethanol Production, LAMNET

Green Budget News (2005): European Newsletter on Environmental Fiscal Reform, No 11, 3-2005 http://www.czp.cuni.cz/ekoreforma/EDR/GreenBudgetNews_11.pdf

Institute of Process Engineering, Chinese Academy of Science (2004): Energetic Utilization of Biomass. Proceedings of the Sino-German Workshop on Energetic Utilization of Biomass. Science Press, Beijing

International Energy Agency - IEA (2002): Bioenergy in our community. Task 29 Socio-economic Aspects of Bioenergy Systems. www.iea-bioenergy-task29.hr/pdf/brochure2005.pdf

International Energy Agency - IEA (2004): Biofuel for Transport. Task 39

International Energy Agency (2005): Energy Outlook for China: Focus on Oil and Gas. Hearing on EIA's Annual Energy Outlook for 2005 http://www.iea.org/textbase/speech/2005/jl_china.pdf

Johansson et al., (2005): Linkages between energy use and impacts on health and environment, Background Paper for the revision of Sida's energy policy, Swedish Agency for International Development Cooperation- SIDA www.sida.se/content/1/c6/ 03/81/89/31%20March%202005%20final.doc

LAMNET (2004): LAMNET- News, 5th, 6th issue www.bioenergy-lamnet.org

Li Jingling et al. (2001): Biomass energy in China and its potential. Energy for sustainable development, Vol. V No 4, pp 66-80, December 2001

Li Jungfeng, et al (2002): Policy Analysis of the Barriers to Renewable Energy Development in People's Republic of China. Energy for sustainable development, Vol. 6 No 3, pp 11-20, September 2002

Lindlein P.; Mostert W. (2005): Financing Instruments for Renewable Energy, Final Draft. KFW, Frankfurt http://www.kfw-entwicklungsbank.de/DE_Home/Service/OnlineBibl48/PDF-Dokumente/Report_Final_Draft.pdf

Liu Jiang (2002): Chinese Resources Usage Strategies Researches. Chinese Agriculture Press, Beijing

Murray, G.; Cook, I. (2004): The Greening of China. China Intercontinental Press

National Bureau of Statistics (2004): China Statistical Year book 2004. China Statistic Press

National Development and Reform Commission – NDRC, Energy Research Institute (2004): Report on Renewable Energy and new energy high tech industrialization

National Development and Reform Commission – NDRC (2005): China National Energy Strategy and Policy to 2020

Oekoinstitut e.V. (2005): Criteria for assessing environmental, economic and social aspects of biofuel in developing countries. For download: http://www.oeko.de/dokum.php?setlan=1&vers=&id=234

Oesterreichisches Biotreibstoff Institut (2004): Annual Report 2004. www.biodiesel.at

State Council, Development Research Centre (2003): China's national Energy Strategy and Reform. Background Reports of China Development Forum 2003, Beijing, 15-17 2003 http://www.efchina.org/documents/Briefing_book_031115_EN.pdf

SEPA (2002): Environmental Laws & regulations in China and Rules of WTO. Guangming Daily Publishing House

Wang Tao (2005): A survey of the woody plant resources for biomass fuel oil in China. Science and Technology Review, Vol23.5

Weider, M. (2004): China- Automobil Markt der Zukunft? WZB- discussion paper, Wissenschaftszentrum Berlin fuer Sozialforschung gGmbH

World Bank, MOST, GTZ, BMZ, Swiss Secretariat for economic affairs, Tsinghua University (2004): Clean Development Mechanism in China, 2nd edition

United Nations Development Program – UNDP (2004): World Energy Assessment – WEA , update. http://www.undp.org/energy/weaover2004.htm

Xue Ping (2004): Resources Demonstration. Geology Press, Beijing (Chinese language only)

Conference presentations

Changzhu Li et al. (2003): New Feedstock for Bio-diesel Production. Sino-German Workshop on Energetic Utilization of Biomass, Beijing 8-11 October 2003, Chinese Academy of Science

Du Fengguan (2003): Cirusular Economy Model- taking fuel ethanol and biogas at its core. Proceedings of the International Conference on Bioenergy Utilization and Environment Protection; Dalian 24-26 September 2003 http://www.bioenergy-lamnet.org/publications/source/LamnetPublications/B11-DuFengguang.pdf

Feng Fei (2005): Growth of Chinas Autoindustry vs Oil Supply, oil security http://www.autonews.com/files/china2005/presentations/china_english/Dr_Feng_Fei_English.ppt#1

Fulton, Lew (2005): Biofuels for Transport: An international Perspective. Paper presented at the International Energy Agency Seminar 'Assessing the Biofuels Option', Paris 21-21 June 2005, www.iea.org/Textbase/work/2005/ Biofuels/**biofuels**_Fulton_Presentation.pdf

Gao Hai Yang (2005): Utilization of Biofuels in China- an Automobile researchers's perspective. Proceedings of China bio-fuels and Ethanol outlook 2005, Beijing, 22-23 September 2005

Ji Xing (2004): Sewage Garbage to bio-diesel for Beijing Olympics. Paper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/49_ji_xing_en.pdf

Kohler, H. (2005): Presentation at the "Investoren and Analystenkonferenz der WestLB" at Frankfurt/Main, Germany, 14 September 2005

Lin Weigang; Barz, Mirko (2003): Prospects of Success of the Energetic Utilization of Biomass in China. Sino-German Workshop on Energetic Utilization of Biomass, Beijing 8-11 October, Chinese Academy of Science

Sachs (2005): Bio-fuels are coming of age. Keynote address at the International Energy Agency Seminar 'Assessing the Bio-fuels Option', Paris 20-21 June 2005 http://www.iea.org/Textbase/work/2005/Biofuels/Biofuels_Sachs_Presentation.pdf

Sarlos, Gerard (2004): A recent EU-China cooperation experience on R&D for ethanol production for the transportation based on the ASIATIC project. Paper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/15_gerad_sarlos_en.pdf

Schlowin, F.; Dilger M.: Kaltschmitt, M. (2003): Energy from Biomass- Status and opportunities, Energy Asia 2003 http://www.german-renewable-energy.com/downloads/pdf/energy_asia/energy_from_biomass_china.pdf

Sun Hong (2004): Growing and Cultivation of Sweet Sorghum as high yield energy crop. aper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/45_hong_sun_en.pdf

Tian Yinong et al (2000): Present Situation and Future Potential of Cassava in China. Cassava Potential In Asia in the 21st Century, Present Situation and future Research and Development Needs; 6th Regional Cassava workshop, Vietnam, 21-25 February 2000

Wang Tao (2004): The Investigation, Development and Utilisation of the bio-diesel wood energy plant- Chinese pistachio. Paper presented at the EU-China workshop on bio-fuel; Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/41_tao_wang_en.pdf

Wang Zhaomu, Li Shoushan (2003): Bionergy from Sugar Sorghum in Xinjiang. Proceedings of the International Conference on Bioenergy Utilization and Environment Protection; Dalian 24-26 September 2003, http://www.bioenergy-lamnet.org/publications/source/chi3-int-conf/Biofuel-Conference%20LAMNET-WS-Beijing-Programme-040406.pdf

Wen, Wendy (2005): Biodiesel Production & Consumption in China. Proceedings of China bio-fuels and Ethanol Outlook 2005, Beijing, 22-23 September 2005

Xiao Mingsong (2004): Ethanol Production from Sweet Sorghum Stems. Paper presented at the EU-China workshop on bio-fuel; Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/23_mingsong_xiao_en.pdf

Yuan Zhenhong (2004): Research and Development on Biomass Liquid Fuels in China. Paper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/03_yuan_zhenhong_biofuels_china_en.pdf

Yue GuoJun (2005): Utilization of Ethanol in China- an Ethanol Manufacturer's perspective. Proceedings of China bio-fuels and Ethanol Outlook 2005, Beijing, 22-23 September 2005

Zhang Xiliang (2004): Biomass technology commercialization in China: Opportunities and Challenges. Paper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004

Zhao Hai (2004): Fuel Ethanol Production by Sweet Potato. Paper presented at the EU-China workshop on bio-fuel, Beijing, 4-5 November 2004 http://europa.eu.int/comm/research/energy/pdf/27_hai_zhao_en.pdf

Chinese literature

石村民,陈春原.内蒙古果树生产现状、问题、潜力及发展对策[J].内蒙古农业科技,1997,(6):17-19.

王有信，王迷珍，第三代果树欧李抗旱机理与开发利用，2004

张连翔，孔繁轼，赵桂芝，“石油植物”一个值得关注的研发领域 防护林科技 2004 年 9 月第 5 期(总 62 期)

周萍，祝丽香，多种用途的植物——蓖麻，中国林副特产，2000，5，第 2 期（总第 53 期）48-49

黄维志，荒山绿化的好树种—文冠果，甘肃林业，2004 年第一期

裴宝红，黄连木的栽培技术，中国林副特产，2002 年 5 月第 2 期

张耀奇，王恩，蓖麻及其衍生物生产和应用的探讨，内蒙古石油化工，第 27 卷，61

李正茂，邓新华，刘党训，光皮树经济性状及生物质液体燃料开发研究构想，湖南林业科技，1996：23（2），12-13

梁仰贞，食用油脂树——光皮树栽培技术，中国林副特产，1996 年 5 月第 2 期（总第 37 期），26-27

候传波，观赏树种欧李及其栽培技术，中国林副特产 No.1(GSNO.68)

梁仰贞，光皮树的栽培技术，生产加工，13-14

汪多仁，蓖麻籽与蓖麻油应用进展，粮食与油脂，2000，第 2 期，12

中国油脂植物 China Oil , Seed import s : up and up , and up ,[J] , Inform 1998 (7) .

中国经济植物志，中国科学院植物研究所等 1961,科学出版社

张无敌，从绿色植物中获取石油，云南师范大学学报(自科版)，1992，12(2):20 一 25。

李维莉，扬辉，林南英，徐以礼，谢金伦.可再生能源麻疯树种子油化学成分研究.云南大学学报，2000，22(15):324.

陈冀胜，郑硕主编，中国有毒植物，北京：科学出版社，1987

中国植物志(第四十四卷，第二分册)，北京：科学出版社

广西植物研究所编，广西植物名录(第二册，双子叶植物)，1998

扬钦周主编.四川树木分布，贵州：贵州科技出版社.1997

ANNEX

A Map of China provinces

B. Plant description

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Cerasus humilis (Bge.)Sok

Scientific name： *Cerasus humilis* (Bge.)Sok. (Prunus humilis Bge,Prunus bungeiWalp).

English name： Chinese Dwarf Cherry Seed

Family Name： *Rosaceae*

Chinese name: Ou li

Description:

- Smallest and most dwarf of fruit trees in the world
- Height is from 0.3 m to 1.5 m, average are 0.7 m.
- Until now categorization has hardly been done.

Use

- Fruit: edible fresh or processed
- Kernel: TCM
- Nutritional value of the fruit is high in carbohydrate, protein, vitamin C, with ferrous element and calcium being the highest content in all kinds of fruit (Fe 58 mg/100 g, Ca 360 mg/100 g).

Planting and Harvesting:

- No artificial culture yet, still in research for the developing of cultivars
- Harvested as herb.

Climate and soil requirements

- Very strong drought-resistance.

Output

- Seed has nearly 50% grease, 90% of which is unsaturated fatty acid.

Cornus wilsoniana

Scientific name: *Cornus wilsoniana*

English name: Wilson's Dogwood[355]

Family name: *Cornaceae*

Chinese name: Guang pi shu

Description:

- Shrub or tree.
- Both seed and flesh of the fruit contain oil.
- Oil content of the dry fruit is 33-36%; effective oil content is 25 - 30%.
- Oil contains 77.68 % of unsaturated acid of which 38.3 % is oleic acid and 38.85 % is sub-oleic acid.
- The colour of oil is turns from green to lucid canary.
- Plant grows fast
- Courtyard tree because of its beautiful shape and white flower

Use:

- Edible oil: nutrient value superior to rapeseed oil and tea oil, similar to peanut oil.
- Woods: furniture and buildings
- Flowers: honey
- Leaves: fodder and manure

Propagation System:

- 60 plants per mu
- Saplings like shade
- Fruits: 300 to 600 kg/mu

355 http://en.wikipedia.org/wiki/Dogwood

- Oil: 42 to 84 kg/mu

Climatic and soil requirements:

- Good adaptability
- Excellent for water and soil conservation
- Can be used as both oil plant and protection for lakes and river shoal.
- Adapts to sunlight: edge tree of forest grows better than tree in forest, while tree grown on wide open place and river shore grows even better
- Roots are deep, expanded and have no restrictions to soil quality.
- Suitable to be planted on loose, fertile and wet soil with a pH between 5.5 and 7.5.

Planting areas:

Forests below 1000 m altitude.

Jatropha curcas L.

Scientific name: *Jatropha curcas* L.

English name: Physic nut, Barbados nut

Family name: *Euphorbiaceae*

Chinese name: Ma Feng Shu

Description:

- Shrub or tree up to 6 m tall, with spreading branches and stubby twigs, with a milky or yellowish rufescent exudate.
- Service life: 30-50 years
- Contains
  - 6.2 % of H_2O,
  - 8.0 % of protein,
  - 38.0 % of fat,
  - 17.0 % of total carbohydrate,
  - 15.5 % of fibre,
  - 4.5 % of ash.
- Leaves deciduous, alternate but apically crowded, ovate, acute to acuminate, basally cordate, 3 to 5-lobed in outline, 6 – 40 cm long, 6 – 35 cm broad, the petioles 2.5 – 7.5 cm long.
- Flowers: several to many in greenish cymes, yellowish, bell-shaped; sepals 5, broadly deltoid. Male flowers many with 10 stamens, 5 united at the base only, 5 united into a column. Female flowers borne singly with elliptic 3-celled, triovulate ovary with 3 spreading bifurcate stigmata.
- Seeds

  - High toxicity[356] for humans and animals
  - Contain 32 % to 40 % of plant oil, of which 21 % is saturated fatty acid and 79 % is unsaturated fatty acid.
  - Oil can be processed or directly sold.
- Capsules, 2.5 – 4 cm long, finally drying and splitting into 3 valves, all or two of which commonly have an oblong black seed, these ca 2 x 1 cm[357]
- Apparently the most suitable, renewable raw material for liquid bio-fuel production

Use of *Jatropha curcas* L oil:

- Locally produced natural insecticide
- Suited for soap manufacturing, dyestuff, and other productions.
- Cures diarrhoea
- Residues from oil extraction process serve as fertilizer, because of a high mineral content.
- Raw material for liquid bio-fuel because of its high oil content and fine fluidity.
- Can be adulterated with diesel oil, gasoline and ethanol and the mixture will not decompose in long time

Other uses of *Jatropha curcas* L:

- Leaves, cortices and roots can be used as medicine:
  - Roots: to cure detumescence and haemostats
  - Leaves: fodder for silkworm

Propagation:

- From cuttings or seeds.
- In areas with little rainfall, propagation is easier to achieve with cuttings than with seeds.**System:**
- The planting system can vary widely.
  - Most common are hedges, also serving as live fences and for erosion prevention, where spacing can be 20 cm.
  - In plantation spacing amounts to about 2.5 m.

Planting:

- As many as 3 harvests per year are possible, depending on the amount of rainfall.
- In semi-arid regions a single harvest is more likely.
- For medicinal purposes, the seeds are harvested as needed.

Climate and Soil requirements:

- Tolerates annual precipitation of 4.8 to 23.8 dm (mean of 60 cases = 14.3) and annual temperature of 18.0 to 28.5°C (mean of 45 cases = 25.2)[358].

356 The poisoning is irritant, with acute abdominal pain and nausea about 1/2 hour following ingestion. Diarrhea and nausea continue but are not usually serious. Depression and collapse may occur, especially in children. Two seeds are strong purgative. Four to five seed are said to have caused death, but the roasted seed is said to be nearly innocuous.

357 Morton, 1977; Little et al., 1974).

- Grows on the plain, hill, sloping field, valley and barren mountains between 700 m to 1600 m.
- Adapts to sunlight and warm climate, and can tolerate drought and barren land such as lithosol, skeletal soil and calcareous bare land.
- Favourite conditions: ranging from Tropical Very Dry to Moist through Subtropical Thorn to Wet Forest Life Zones
- Tolerates low temperatures and can survive mild frost.
- Requires little water and can survive long periods of dryness by shedding most of its leaves.

Plant protection:

Very tolerant to pests[359].

[358] James A. Duke. 1983. Handbook of Energy Crops. Unpublished, www.jatropha.de
[359] GTZ, 1995

Manihot esculenta Crantz, M. ultissima Phol, M. aipi Phol

Scientific name: *Manihot esculenta* Crantz, *M. ultissima* Phol, *M. aipi* Phol

English name: Cassava

Family name: *Euphorbiaceae*

Chinese name: Mu Shu

Description[360]**:**

- Woody shrub
- Perennial in tropics and subtropics, annual in temperate zone.
- Mainly made up of H_2O as well as carbohydrate
- Little protein, fat and pectin, major source of low cost carbohydrates for populations in the humid tropics.
- Enlarged starch-filled roots contain nearly the maximum theoretical concentration of starch on a dry weight basis among food crops.
- Highest photosynthesis efficiency among sugar crops.

Use:

- Fresh roots are prepared like potatoes
- Alcoholic beverages can be made from the roots.
- Young tender leaves can be used like spinach, containing high levels of protein[361].
- Most economical material of bio-ethanol.
- Mainly used to produce starch and ethanol.

Propagation:

- 7 - 30 cm portions of the mature stem as propagules, therefore selection of healthy, disease-free and pest-free propagules is essential.

System:

360 FAO, http://www.hort.purdue.edu/newcrop/Crops/CropFactSheets/cassava.html
361 http://www.hort.purdue.edu/newcrop/Crops/CropFactSheets/cassava.html: (8-10% F.W.).

- Typical plant spacing is 1 m by 1 m.
- Cuttings produce roots within a few days and new shoots soon appear at old leaf petiole axes on the stem.
- Early growth is relatively slow, thus weeds must be controlled during the first few months.
- It takes 18 or more months to produce a crop under adverse conditions such as cool or dry weather.

Planting[362]:

- Planting time under southern China conditions: February - March,
- Observing the polarity of the cutting is essential for successful establishment of the cutting.
- Cuttings are planted by hand in moist, prepared soil, burying the lower half.363
- The top of the cutting must be placed up. The cutting must placed up
- When soils are too shallow to plant the cutting in an upright or slanted position, the cutting are laid flat and covered with 2-3 cm soil.
- In areas where freezing temperatures are possible, the cuttings are planted as soon as danger of frost has past.
- Growing period: 9 months, harvesting time is November-DecemberPopular varieties: 19.5 - 30.7 t/ha,
- High-quality varieties 45 - 75 t/ha, starch content higher than 28％ - 33％[364].
- Ethanol output is almost twice of sugar cane under the same soil condition

In recent years traditional cultivars with low yield and economic benefit[365] have been continuously replaced by improved varieties, introduced into China from Thailand, Vietnam.

Climate and Soil requirements:

- Ability to grow on marginal lands and in low-nutrient soils where cereals and other crops do not grow well;
- Tolerates a wide range of soil pH 4.0 to 8.0
- Can tolerate drought: looses leaves to conserve moisture, producing new leaves when rains resume.
- Traditionally grown in a savannah climate, but can be grown in extremes of rainfall.
- Does not tolerate flooding or freezing conditions
- Is most productive in full sun
- Suitable for growing in the tropic and semi-tropic zone with average temperatures of 25-29oC and no frost over 8 months
- Requirements for soil, fertilizer and tend are much lower than sugar cane
- Optimal yields are recorded from fields with average soil fertility levels for food crop production and regular moisture availability.
- Responses to macro-nutrients vary, with *Manihot esculenta* Crantz responding most to P and K fertilization. Fertilizer is only applied during the first few months of growth.

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362 http://www.hort.purdue.edu/newcrop/Crops/CropFactSheets/cassava.html
363 Mechanical planters have been developed in Brazil to reduce labour inputs.
364 GR 891, GR 911, ZM 9057, ZM 8638, South China 124, Nanzhi199
365 South China 201, South China 205

- Commercially produced fungicides and pesticides are seldom used.

Plant protection:

- Easy to grow, few insect pests and plant diseases
- During the harvesting process, the cuttings for the next crop are selected. These must be kept in a protected location to prevent desiccation.
- Removing the leaves two weeks before harvest lengthens the shelf life to two weeks.

The shelf life of *Manihot esculenta* Crantz is only a few days unless the roots receive special treatment.

Pistacia chinensis Bunge

Scientific name： *Pistacia chinensis* Bunge

English Name： Chinese pistachio

Family name： *Anacardiaceae*

Chinese name: Huang Lian Mu

Description[366]:

- Cashew nut family includes 9 species of pistachio, but only one is available in China.
- Woody oil plant, deciduous arbour tree up to 30 m tall
- Service life more than 300 years; main production period: 30 – 38 years.
- Slow growing tree
- Blossoms in March in April
- Fruits ripen from September to October.
- Oil content of the seed: is 42.5%.
- Oil content in the kernel 56.7%
- Effective oil content: 20 - 30%

Use:

- Tree species for cities and sceneries.
- Seed oil:

[366] Wang Tao, 2004

- Edible oil
- can also be used to make soaps and lubricant

- Seedcake can be used as fodder and manure
- Leaves, fruits and cortices contain tannin
- Tannin extract can be distilled and used for black dyestuff.
- Roots, branches and leaves can be used as pesticide.
- Leaves used for aroma oil and tea.
- Woods can be used for furniture, sculptures and buildings.

Propagation:

- By seeds: 10 kg/mu producing about 20,000 to 25,000 saplings.

System:

- 600-700 trees/ha

Planting:

- Seedlings can adapt to shade, but prefer sun.
- Seed production in plantations: 24000-70000 kg/ha/a.
- Seed production in forest: about 7500 kg/ha/a.
- First fruiting to be expected after 8-10 years.
- Fruit production ranges between 40 and 200 kg/tree.
- 15 cm diameter: production of 50 - 75 kg fruits
- 30 cm diameter: production of 100 to 150 kg fruits.
- 2500 kg seed produce 1 t bio-diesel.

Climate and soil requirements:

- Adapts to sunlight but can not tolerate cold temperatures
- Can grow on both acidic soil and alkali soil
- Resists SO_2 and smoke
- Strong adaptability to soil conditions
- Drought, saline, alkaline and barrenness resistant.
- Deep rooting,
- Grows well in sandy or sticky soil, as well on limestone in mountainous areas

Plant protection and care:

- High disease resistibility, but has many pests which are not affecting the plant/fruit itself.

Planting areas:

- Grows at the mountainous land and beach land as well with elevation less than 2000 m,
- But mostly in mountains with elevation less than 700 m,

Ricinus communis L.

Scientific name: *Ricinus communis* L.

English name: castor-oil plant, ricinus

Family name: *Euphorbiaceae*

Chinese name: Bi ma

Description:

- *Ricinus communis* L. bean oil content: 47% to 60%.
- Oil contains 80% to 88% ricinoleic acid
- Siccative oil
- Ricinoleic acid can not be solidified in -18℃
- Ricinoleic acid can be burned at 500 to 600^{0}C.

Use:

- Semi-finished ricinoleic acid can be converted to delicate ricinoleic acid after depickling, washing , dehydrating , decolouring and filtrating .
- TCM and general medical use
- Drying agent for organic soybean production
- Break fluid and motor saw oil:
    - *Ricinus communis L* oil oleic alcohol
    - Production since the end of the eighties,
    - Oil content of *Ricinus communis* L oil has been enhanced to 75%, by mixing with acetone, KOH and minor chemicals.
    - Used as high speed break
    - Serviceable range under -40℃, important for working conditions in winter cold areas.

Production requirements and soil characteristics

Generally, the oil yield is 45% to 51% in dry basis .

Saccharum officenarum. L

Scientific name: *Saccharum officenarum. L*

English name: sugarcane / energy sugarcane

Family name: *Graminiae*

Chinese name: Gan Zhe / Nengyuan Gan Zhe

Description[367]:

- Spermatophyte, belongs to C4 crops.
- High adaptation, strong robustness
- High photosynthesis efficiency, able to convert as much as 2% of incident solar energy into biomass.
- Stalk with rich sugar juice
- Three types of sugar cane according to different uses:
  - sweet sugar cane: sugar content usually 12% to 18%, high effective sugar content;
  - fruit sugarcane: rich in water, sugar content usually 8% to 10%.
  - energy sugarcane: a crossbreed from sugar cane and tropical weed.

Production requirements and soil characteristics

Saccharum officenarum. L is an annual tropical and subtropical crop, able to grow between the latitudes of 35° South and 35° North. The most suitable areas are between the latitude of 10° South and 23° North. The output and sugar content is lower in areas above latitude 23° North and below latitude 10° South.

Propagation[368]:

- Propagated from cuttings of 30 cm lengths, rather than from seed.

367 http://www.nationmaster.com/encyclopedia/Sugarcane
368 http://www.nationmaster.com/encyclopedia/Sugarcane

- Each cutting must contain at least one bud
- A stand of cane can be harvested several times; after each harvest, the cane sends up new stalks, called ratoons.
- Depending on agricultural practice, 2–10 harvests may intervene between each planting.
- Usually, each successive harvest gives a smaller yield.

System:

- Normally planted either as two- or three-budded setts in furrows, or as whole stalks cut into 30 cm lengths and covered with soil.
- Row and plant spacings are 1.0-1.3 m x 0.5 m for manual planting.
- The row spacing is 1.4-1.6 m for machine planting.
- In the case of double row planting, there is 30 cm spacing between double rows and 1.3 m (1.00-1.40 m) between rows.
- Watering and fertilizing of plants during the first 11 months is essential.

Planting[369]:

- Most cane is planted manually, but machine planting is also practiced.

*Saccharum officenarum. L*Yield of 180 to 240 t/ha, twice of sweet sugar cane.

Climate and Soil requirements[370]:

- Grows best in deep, well drained soils of medium fertility with loamy to loamy-sand soil textures,
- pH range between 6.1-7.7
- Organic matter content of at least 1.5 percent.
- Clay-textured soils are unfavorable to sugarcane growth.
- Optimal temperatures are between 20 and 35 degrees Celsius.
- Under rain-fed conditions, good distribution of rainfall is required.
- The water requirement is 1.2-1.6 m/year.

Salix viminalis

Scientific name: *Salix viminalis*

English name： willow

Family name： *Salix*

Chinese name: Liu Shu

369 http://www.foodmarketexchange.com/datacenter/product/sugar/detail/dc_pi_sugar_02_01.htm
370 http://www.foodmarketexchange.com/datacenter/product/sugar/detail/dc_pi_sugar_02_01.htm

Description:

- Most common species in energy forestry is the basket willow
- During the establishment year the plantation is susceptible to drought and weeds,
- Rapid growth
- Resistance to diseases.
- High production is maintained by short rotation periods of about three to five years.
- After each harvest the established root system and the nutrients stored in the roots and stumps guarantee vigorous growth for the shoots.

Use:

- Actually fuel wood

Propagation:

- Stem cuttings about 20 cm long
- Should be soaked in water for about two days before planting

System:

- Planting density is about 18.000 cuttings per hectare

Planting:

- Immediately after preparing the land
- With planting machines four rows at a time.
- 1 hour to plant 1 ha.
- In establishment year the dry matter production is usually less than 1000 kg per ha.
- The first years after the establishment are part of the establishment phase.
- During subsequent rotations, annual yield increase.
- If planted as a pioneer species, yield may decrease already after the third growing season.

Soil requirements:

- Root penetration and shoot development stimulated by
  - high moisture of the soil in the spring
  - amount of sunshine in the early summer

Plant care:

- Irrigation and efficient weed control in the first year.
- After the first summer the shoots are cut
- Harvested in winter after leaf fall, when the soil is frozen
- Most efficient harvesters are heavy self-powered machines, which cut and chip the shoots on a loading platform. Chipping harvesters can be attached to a tractor.
- About 3 hours to harvest 1 ha with chipping harvesters.
- When the shoots are harvested as whole stems they are easy to storage
- Scheduling subsequent operations is also more flexible.
- Stems can be dried for combustion: moisture content of the wood will decrease to about 30% on average during 9 months.

Sorghum bicolor (L.) Moench var. saccharafum Kouern

Scientific name: *Sorghum bicolor (L.) Moench var. saccharafum Kouern*

English name: Sweet sorghum

Family name: *Magnoliophyta : Liliopsida : Cyperales : Poacea*

Chinese name: Tian Gao Liang

Picture of plantation and kernel

Description of the plant[371]:

- Grain crop, feed and forage crop, sugar crop or energy crop – raw material making alcohol and fuel production.
- Cereal grass reaching 2 m or more in height
- Drought resistance, waterlogging resistance, saline - alkali resistance and wide adaptabilities
- Low water demand, stress tolerant, crop with considerable potential for future small and large-scale exploitation.
- Can be grown on degraded soils
- Can also decrease the areas required for fodder crops and therefore increase the area of grain crops in order to solve the problems of grain shortages
- Very high biomass yielding, high quality crop
- Residues from processing the *Sorghum bicolor (L.)* stalks which remain after refining sugar can be used a raw material for making paper without pollution.

Propagation:

- by seeds[372]
- Hybrids developed by the National "863" Programme have demonstrated good results Chinese experts from the involved agricultural research institutions judge these hybrids as largely extendible and appropriate for bio-ethanol production.

[371] FAO, http://ecoport.org/ep?Plant=1982&entityType=PLCR**&entityDisplayCategory=full

[372] There are more than 1000 varieties and hybrids including native and introduced species being cultivated throughout the country

System:

- Typical layout: inter-row spacing of 0.75 m and a between plant spacing of 10 cm. At Beijing Botanic Garden the sorghum breeding plots are intercropped with mushrooms.
- Advantages in sowing into dry soil early in the season, as yields are higher with a longer growing period[373].
- Produces a higher yield with crop rotation following the cultivation of a leguminous crop, like soybeans or peas. [374]
- Deep sowing is advantageous because more moisture is accumulated in the soil before germination.

Planting:

Three methods of planting are recommended:

- By hand in uniformed rows and distances.
- Drill planting: The recommended rows spacing is 60 cm and about 5 cm depth.
- Hill planting: The recommended spacing is 60 x 30 cm with 3 plants per hill. Two weeks after germination, seedlings should be thinned leaving only 1 plant per hill with the distance between hills being 10 cm[375]. Planting time: recommended in the late rainy season.
- 1 ha can produce
  - 3 to 6 t kernels
  - 45 to 67.5 t of stalks.
- Sugar juice content above 10ºBrix, mostly between 15ºBX and 20ºBX
- Effective juice content about 60%.[376].
- Generally can be harvested within 110-150 day.
- In areas with warm climate two harvests per year are possible.

Climate and Soil requirements[377]:

- Can be grown successfully on a wide range of soil types
- Tolerates a range of soil pH from 5.0-8.5 and is more tolerant to salinity
- Soil temperature should be above 18.5°C.
- Adapted to a wide range of environmental conditions
- Is particularly adapted to drought and in regions where the conditions of precipitation are limited (300-1100 mm by year).
- Can also be grown in high rainfall areas.
- Morphological and physiological characteristics that contribute to its adaptation to dry conditions, including an extensive root system, wax on the leaves that reduces water loss, and the ability to stop growth in periods of drought and resume again when conditions become favourable[378].

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[373] Dendy A.V. 1995, http://ecoport.org/ep?Plant=1982&entityType=PLCR**&entityDisplayCategory=full
[374] Echi-T, 2002
[375] Sruttaporn C., Iamsupasit N., http://ecoport.org/ep?Plant=1982&entityType=PLCR**&entityDisplayCategory=full
[376] According to a comparison with other crops made by America and Brazil, the ethanol output of sweet sorghum per mu is about two times of that of corn, sugar beet or wheat, and even a quarter high than that of sugar cane.
[377] African Journal of Biotechnology Vol. 4 (7), pp. 575-579, July 2005

- Tolerant to water logging
- Major radicular system allows it to be planted on grounds prone to erosion
- Strong root system takes up nutrients and water from lower soil layers.

Plant protection:

- Resistant to the attacks of several herbivores, fungi and bacteriological diseases, due to the presence of a cyanogenenic glycoside.[379]

[378] the leaves of sorghum are covered with waxes and have the tendency to be rolled up under the conditions of dryness. These characteristics result into the reduction of evapotranspiration under conditions of hydrous stress.

[379] African Journal of Biotechnology Vol. 4 (7), pp. 575-579, July 2005

Xanthoceras sorbifolia Bunge

Scientific name： *Xanthoceras sorbifolia* Bunge.

English name： Yellowhorn

Family name： *Sapindaceae*

Chinese name: Wen Guan Guo

Description:

- Famous woody low branching oil plant
- Flower bud forms within propagation year,
- Produces flowers and fruits after 2-3 years .
- Each fruit contains more than 20 grains of germs.
- Grows fast

Use:

- Cultivated for bio-diesel in large scale,
- But mainly used for food oil.
- Various uses:
  - Branches and leaves: medicine to treat arthritis.
  - Leaves: drinks with sterilization function.
  - Woods: firm and compact, high-grade timbers.
  - Shuck of seed and fruit: raw material for ethanol.
  - Calyces: sleeping pills
  - Several components of the plant: medicine treating dementia.

Production

10-year old tree can produce 50 kg fruits,

- 30- to 60-year-old tree can produce 15 to 35 kg fruits

- Each fruit contains more than 20 grains of germs
- Yield of oil: 50% - 70%.

Climatic and soil requirements:

- Roots are highly developed
- Adapts to sunlight
- Tolerates various kinds of atrocious land such as saline-alkali land, fallow land,
- Resists coldness and can even passes the winter in Harbin with temperatures of -41.4°C.
- Resists aridity since there are also trees in Ningxia whose annual precipitation is only 148.2 mm.
- Can not resist water logging

C. Chinese National Standards

Denatured Fuel Ethanol GB18350-2001 153
Ethanol gasoline for motor vehicles GB18351-2001 154
Light diesel standard GB252-1994 156

Denatured Fuel Ethanol GB18350-2001

Item		Quality Parameter
Appearance	≥	Light lipid liquid without visible suspension and deposit
Ethanol, %(V/V)	≤	92.1
Methanol, %(V/V)	≤	0.5
Actual gelatine, mg/L	≤	5.0
Water, %(V/V)	≤	0.8
Abio-chlorine (Cl^-), mg/L		32
Acidity (acetic acid), mg/L		56
Copper		0.08
pH value		6.5~9.0
* pH value should between 5.7~9.0 when executed before Apr.1,2002.		

http://www.greencarchina.org/Chinese/PS_cn/FQ_cn/denatured_ethanol_cn.htm

Ethanol gasoline for motor vehicles GB18351-2001

Executed in Beijing, Shanghai and Guangzhou since the standard has been issued in 2001, executed in the whole country since Jan.1, 2003

Item	Quality Parameter			Experiment method
	90#	93#	95#	
Counter-explosion quality: Investigate octane number (RON) ≥ Counter-explosion index (RON+MON)/2 ≥	90 90 85	93 93 88	95 95 90	GB / T 5487 GB / T 503 GB / T 5487
Lead content[1], g/L	≤ 0.005			GB / T 8020
Distillation： 10% vaporize temperature, ℃ 50% vaporize temperature, ℃ 90% vaporize temperature, ℃ distill-end temperature, ℃	≤ 70 ≤ 120 ≤190 ≤205			GB / T 6536
Remnant, %(V/V) ≤	2			
Steam pressure，kPa from Sep.16 to Mar.15 ≤ from Mar.16 to Sep.15 ≤	88 74			GB / T 8017
Actual gelatine, mg/100mL ≤	5			GB / T 8019
Induce period[2], min ≥	480			GB / T 8018
Sulfur content[3], %(m/m) ≤	0.10[4]			GB / T 380 GB / T 11140

		SH / T 0253
Vitriol (meet one of the demands below): Doctor experiment Sulfur content of vitriol, %(m/m) ≤	 Pass 0.001	SH / T 0174 GB / T 1792
Sheet copper erode (50C,3h) ,class ≤	1	GB / T 5096
Water-solubility acid or alkali	None	GB / T 259
Machine impurity	None	Eyeballing[5]
Water, %(m/m) ≤	0.15	SH / T 0246
Ethanol content, %(V/V)	9.0 ~ 10.5	SH / T 0663
Other oxygen compound, %(V/V)	Test none[6]	SH / T 0663
Benzene content, %(V/V) ≤	2.5	SH / T 0693
Arylehydrocarbon content, %(V/V) ≤	40	GB / T 11132
Alkene content, %(V/V) ≤	35[7)]	GB / T 11132

1. Manganese content: test limit should not be above 0.018g/L, experiment method see appendix A of the standard guideline.
2. Iron shouldn't be added artificially. Considering the pollution from oil refining process, the storage and transportation of products, test limit should not be above 0.01g/L, experiment method see appendix B of the standard guideline.
3. Effective depurative should be added into ethanol gasoline for motor vehicles since the standard is executed.

1) The standard prescribes the max limit of lead content, adding lead artificially is not allowed.
2) Induce period can use GB/T 256, but the arbitrate experiment is GB/T 8018.
3) Sulfur content can use GB/T 11140, SH/T 0253, but the arbitrate experiment is GB/T 380.
4) In order to the demand of city environmental protection, sulfur content should not be above 0.08%(m/m) when executed in Beijing, Shanghai and Guangzhou since the standard is executed.
5) Poured into a 100 ml glass graduated flask to observe, must be transparent, without aerosol and subsidence impurity and the lamination. When there is an objection, take GB / T 511 methods as criterion.
6) Advanced alcoholic is permitted to add as assist-impregnant..

(http://www.greencarchina.org/Chinese/PS_cn/FQ_cn/Ethanol_cn.htm)

Light diesel standard GB252-1994

Brand number		**10**	**0**	**-10**	**-20**	**-35**	**-50**
Solidifying point,	max.	10	0	-10	-20	-35	-50
CFPP,	max.	12	4	-5	-14	-29	-44
FP (PM),	min.	65			60	45	
Cetane number*	min.	45					
Distillation, 50% vol. recovered at 90% vol. recovered at 95% vol. recovered at	 max. max. max.	 300 355 365					
Density at 20,	kg/m^3	report					
Viscosity at 20,	mm^2/s	3.0-8.0		2.5-8.0		1.8-7.0	
Particulates		nil					
Aqueous acid or alkali		nil					
Copper corrosion rating (50, 3h)	max.	1					
Ash, %	(m/m) max.	0.01(super and premium); 0.02(regular)					
Carbon residue on 10% distillation residue, %	(m/m) max.	0.3 (0.4 for 10# and 0# of regular grade)					
Acidity, mg KOH/100 ml	max.	7(premium); 10(regular)					
Water, % (v/v)	max.	trace					
Sulfur, % (m/m)	max.	0.2(super); 0.5(premium); 1.0(regular)					
Sulfur of mercaptan, % (m/m)	max.	0.01(super and premium); no requirement for regular					
Color number	max.	3.5					
Iodine number, g I/100 g .	max	6(super); no requirement for premium and regular					
Oxidation stability (insoluble), mg/100 ml	max.	2.0(premium); no requirement for super and regular					
Existent gums, mg/100 ml .	max	70(regular); no requirement for super and premium					

*40 minimum for diesel fuels made from naphthenic or paraffin-naphthenic crude oils, and for diesel fuel containing catalytic cracking components (http://www.oilgas.com.cn/News/NewsItem.aspx?id=27031)