ADB

RURAL BIOMASS ENERGY 2020

Cleaner Energy
Better Environment
Higher Rural Income

People's Republic of China

Asian Development Bank

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Contents

Abbreviations

ADB	–	Asian Development Bank
ASEAN	–	Association of Southeast Asian Nations
CDM	–	Clean Development Mechanism
CH_4	–	methane
CHP	–	combined heat and power
CIAD	–	Center for Integrated Agricultural Development
CIDA	–	Canadian International Development Agency
CO	–	carbon monoxide
CO_2	–	carbon dioxide
CSPCB	–	Crop Straw Pricing Consultation Board
E_{10}	–	10% ethanol and 90% gasoline
E4ALL	–	Energy for All Partnership
EIRR	–	economic internal rate of return
EU	–	European Union
FECC	–	Foreign Economic Cooperation Center
FIRR	–	financial internal rate of return
GDP	–	gross domestic product
GEF	–	Global Environment Facility
GHG	–	greenhouse gas
GTZ	–	German Agency for Technical Cooperation
HC	–	hydrocarbons
HH	–	household
IFI	–	international financial institution
KfW	–	Kreditanstalt für Wiederaufbau
LPG	–	liquefied petroleum gas
MEP	–	Ministry of Environmental Protection
MOA	–	Ministry of Agriculture

MOF	–	Ministry of Finance
MOST	–	Ministry of Science and Technology
NDRC	–	National Development and Reform Commission
N_2O	–	nitrous oxide
NH_3	–	ammonia
NO_2	–	nitrogen dioxide
NOx	–	nitrogen oxide
O&M	–	operation and maintenance
LGOP	–	Leading Group Office of Poverty Alleviation and Development
PM_{10}	–	particulate matter with a diameter of 10 micrometers or less
PRC	–	People's Republic of China
SEPA	–	State Environment Protection Agency
SIDA	–	Swedish International Development Cooperation Agency
SO_2	–	sulfur dioxide
TA	–	technical assistance
TSP	–	total suspended particles
UNDP	–	United Nations Development Programme
USAID	–	United States Agency for International Development

Weights and Measurements

cm – centimeter
GJ – gigajoule
GW – gigawatt
GWh – gigawatt-hour
ha – hectare
kg – kilogram
km – kilometer
KW – kilowatt
kWh – kilowatt-hour
m^3 – cubic meter
mm – millimeter
MJ – megajoule
mt – metric ton
mtce – million tons of coal equivalent
mu – 1/15 of a hectare
MW – megawatt
t – tons
tce – tons of coal equivalent

Note on Data

1. Unless otherwise attributed, all statistical data is from the *China Statistical Yearbook* 2009 or the *Rural Energy Statistical Data* of the Ministry of Agriculture (of the People's Republic of China). In some cases, data is the result of an analysis between these two government sources.
2. Unless otherwise attributed, all boxes, tables, and figures have as their source ADB-financed technical assistance to the People's Republic of China for Preparing National Strategy for Rural Biomass Energy Development.

Foreword

Before the United Nations Climate Change Conference in Copenhagen, the State Council of the People's Republic of China (PRC) announced that the PRC will reduce the intensity of carbon dioxide emissions per unit of gross domestic product in 2020 by 40–45% compared to its 2005 level, the baseline year for measuring climate and environmental progress in the country. This publication goes to press with a good measure of confidence that its data, lessons, and recommendations will be of much value to not only the PRC as it embarks on its post-Copenhagen promises, but also the rest of the developing world, which is looking for effective and creative ideas for addressing rural poverty, ailing natural environments, and the energy gap.

PRC Rural Biomass Energy 2020 is grounded in universal development issues and the pressures they are causing on the rural poor, the environment, and energy supplies. The Asian Development Bank (ADB) with its ever widening and deepening experiences with renewable energy projects in the PRC, is finding new paths through these uncharted, but promising frontiers. Biomass energy is the least developed form of renewable energy in the PRC, and largely because its resource base is not directly provided by nature as is the case with wind, solar, and hydropower. Rather, biomass energy production involves an intricate system of collection and distribution between the farmers who supply agricultural wastes (crop straw, manure, etc.) to manufacturers who transform it into modern energy. Biomass energy in the form of household biogas systems has progressed a great deal in the PRC and elsewhere. This publication, however, extends the exploration beyond the promise of household biogas systems to look at the opportunities and challenges of industrializing biomass energy. It is time that biomass energy development graduates to a scale greater than the household level, given the projected demands for energy from rural areas and the growing supply of biomass.

ADB and the PRC's joint efforts have recently involved energy crops development, biomass power plant development, and most related to this publication, biomass energy development from a variety of agricultural wastes. Since 2005, the PRC, through its Ministry of Agriculture, has been implementing the Efficient Utilization of Agricultural Wastes Project with a $33.1 million loan from ADB and $6.4 million from the Global Environment Facility.[1] The project aimed to improve the welfare of farmers through the development of household and medium-size biogas digesters.

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[1] ADB. 2002. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the People's Republic of China for the Efficient Utilization of Agricultural Wastes Project.* Manila. The project implementation began in 2005, and was completed in December 2009. Quantitative results of the project's impact are compared in this report to the 2005 baseline data, which is a relatively recent baseline year. Where possible, more current data is also added to the analysis in both the text and footnotes.

Experiences from this successful project have pointed to the need for a national strategy to upscale the biomass energy development from the household level to community or industry levels, and the need to consider the potential of other biomass resources such as agriculture residues and energy crops. Thus, ADB provided the PRC with a technical assistance (TA) study to prepare a national strategy for rural biomass renewable energy development.[2]

This publication revisits the TA study's main findings and conclusions in light of what they mean for rural development, environmental protection, and energy security. This publication often attributes information to "the TA" but, as a point of clarification, this publication is also informed by experiences from and discussions of the above-mentioned ADB-financed project and various other ADB–PRC initiatives on rural biomass energy development.

This publication intends to provide a strategy and policy guide for national and local PRC government officials, multilateral and bilateral development agencies, civil society groups, the private sector, and stakeholders from other developing countries looking to utilize biomass resources for rural energy.

Preparing this publication has provided us and other developing member countries with an opportunity to learn from the PRC's practical experiences. In return, we hope that we have been able to transfer experiences from elsewhere in the world to help the PRC on the road to achieving its 2020 goals of developing rural biomass energy.

Through the dissemination of this publication, ADB and the PRC government hope to build consensus and commitment among stakeholders in the development of an industry for rural biomass energy. Such an industry is needed to help the country develop its rural communities, protect the environment, and increase rural access to clean energy. It is ADB's belief that economic and social development can be achieved alongside environmental protection, and *PRC Rural Biomass Energy 2020* shows us how.

Klaus Gerhaeusser
Director General
East Asia Department

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2 ADB. 2006. *Technical Assistance to the People's Republic of China for Preparing National Strategy for Rural Biomass Renewable Energy Development*. Manila. Available: www.adb.org/Documents/Produced-Under-TA/40108/40108-PRC-DPTA.pdf. A consultancy team used 2005 as a baseline to project the rural energy demand and available biomass resources up to 2020, assess the various conversion technologies that produce biomass energy, analyze the current institutional and policy barriers, and propose a national strategy for addressing rural biomass energy development.

Acknowledgments

This publication was prompted partly by the recent completion of a national strategy for rural biomass energy development, which was supported by an ADB-financed technical assistance (TA),[3] and also by the successful implementation of the Efficient Utilization of Agricultural Wastes Project, which was financed by a $33.1 million loan.[4]

The publication was prepared from conception to printing by the task manager of the above mentioned TA and loan, Qingfeng Zhang, with contributions from ADB staff members Makiko Watanabe and Tun Lin, and staff consultant Melissa Howell Alipalo.

Kunhamboo Kannan and Katsuji Matsunami provided inspiration and support for this activity. Several reviewers in ADB offered valuable comments during the preparation of this report, including Anil Terway, Ashok Bhargava, Kangbin Zheng, Merlita Pajarillo, Feng Yue-Lang, Frank Radstake, Jiwan Acharya, Toru Kubo, and Samuel Tumiwa.

TA consultants Pat DeLaquil (the international team leader), Wang Gehua (the national team leader) and their teams prepared the draft national strategy and partnership framework for rural biomass energy development in the PRC. The teams included Jerry Yan, Mengjie Wang, Tian Yushui, Jia Xiaoli, Zhi Hua Fu, Liu Xin, and Daniel Wang Dexiang.

This publication also benefited from the close support of and collaboration with the Ministry of Agriculture (MOA) and the Ministry of Finance (MOF). The information in this report is possible because of their strong implementation of the TA. ADB is particularly grateful to Wei Chaoan, the vice minister of MOA for his leading the cross-ministry steering committee for the national strategy preparation. ADB would also like to thank Bai Jinming, Wang Jiuchen, Kou Jianping, Hao Xianrong, and Zhao Lixin from MOA as well as Wang Wei and Zhang Ping from MOF, who coordinated the TA implementation. Wang Jiuchen, who initiated the TA and served as the director for the TA management office, demonstrated excellent coordination and technical capacity in dealing with this cross-agency work. ADB is also grateful to the representatives of various ministries and institutions for their detailed comments on the drafts of the TA final report.

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3 ADB. 2006. *Technical Assistance to the People's Republic of China for Preparing National Strategy for Rural Biomass Renewable Energy Development*. Manila.

4 ADB. 2002. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the People's Republic of China for the Efficient Utilization of Agricultural Wastes Project*. Manila.

This publication was also supported by the findings and experiences from the above mentioned ADB loan. ADB is grateful for the excellent implementation coordinated by the Foreign Economic Cooperation Center of MOA and the four participating provinces (Henan, Hubei, Jiangxi, and Shanxi). Tang Zhishao, the project director, provided valuable background information for this publication.

The contents of this publication were supported by and reflect comments made by the participants of the International Conference on Rural Biomass Renewable Energy, held on 19–21 June 2008 in Beijing. This conference was opened by MOA vice minister and ADB East Asia Regional Department director general, and also served as the Association of Southeast Asian Nations (ASEAN)-Plus Three Forum on Biomass Energy.

Consultants Jeff Boyer, Daniel Johnson, and Melissa Howell Alipalo contributed to editing and producing this report at various stages. ADB staff Anthony H. Victoria led the design work as part of the overall ADB publications team that carefully produced and delivered the final report.

Executive Summary

The People's Republic of China (PRC) is the world's second largest producer and consumer of energy. While the country as a whole depends largely on coal and oil, nearly 50% of its 200 million rural households in 2008 still relied on burning firewood and various agricultural wastes to heat their homes and cook their meals[1]—a real and serious hazard to the environment and health. The demand for energy among urban and rural industries and households is only going to grow as the country continues its tenacious climb out of poverty. As an indicator of that growth and the impact on energy demand, the number of private vehicles in the PRC more than doubles every 5 years, increasing from 300,000 in 1980 to more than 46 million in 2009.

The need and desire for more energy and more convenient forms of it is only natural, and is an indicator in itself of development underway, whetting appetites for more meat and dairy and a variety of modern, energy-powered conveniences. All of this progress comes at a cost, though, in the forms of greater extraction of natural resources and more productive agriculture, leaving a long trail of waste or residues. Even organic waste, when left unused, is not only lost source of economic opportunity but it is toxic to the environment. In 2003, 20% of the country's total climate-altering greenhouse gas emissions came from agricultural production and the wastes left behind in fields and livestock farms.[2]

The PRC government is giving more attention to renewable energy sources in general—mainly wind, solar, and hydro—but the value of biomass resources (waste generated from livestock and crop production) as an additional renewable energy source has been largely underestimated. Government initiatives to address the urban-rural energy gap with biomass energy projects have been modestly successful at the household level. Public and private efforts at industrial-scale production, however, have been piecemeal and generally unsuccessful because of technological and cost constraints. Most rural biomass energy produced in the country comes from small-scale projects that do not have any significant capacity to utilize the biomass resources that are available.

The government is aware of these problems, and has made the development of rural biomass energy (a subset of renewable energy) an essential part of its long-term development strategy. Most significantly, the Renewable Energy Law, effective on 1 January 2006, promotes the development of biomass energy. The country's primary

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1 Estimates from *China Statistical Yearbook* 2009 and the *Rural Energy Statistical Data* of the Ministry of Agriculture.

2 Pew Center on Global Climate Change. 2007. *Climate Change Mitigation Measures in the People's Republic of China.* Washington, DC.

macroeconomic planning agency, the National Development and Reform Commission, set targets for renewable energy to comprise 10% of the country's total energy consumption by 2010 and 15% by 2020. The Ministry of Agriculture also set 2020 goals for the implementation of specific rural biomass energy technologies.

Biomass energy is a sensible renewable energy option and it can be cost-effective if guided effectively by the government. This publication represents a joint effort by the Asian Development Bank (ADB) and the government to develop a clear road map, sensible policies and well-considered investment to achieve the 2020 goals of developing rural biomass energy in the PRC. This publication explores the potential of biomass energy to close the energy gap in rural areas, raise farmer incomes, and mend the environment. The report is based on lessons and experiences from the ADB-financed Efficient Utilization of Agricultural Wastes Project in the PRC, as well as findings and conclusions from a technical assistance study to help the government draft a national strategy for developing rural biomass energy.

A Promise for Cleaner Energy, Better Environment, and Higher Income

Biomass energy has great potential to make a significant impact on two of the PRC's most pressing development challenges: rural poverty and environmental damage. By harnessing these valuable but wasted resources, biomass energy offers a triple opportunity at advancing (i) rural access to energy, (ii) environmental protection, and (iii) rural development. Here's how:

(i) **Rural access to energy.** Rural biomass energy can help fill the gap left from inefficient traditional energy forms and insufficient electricity supplies. While 98% of rural households have access to electricity, they must augment it with other energy sources to meet their heating and cooking needs. And although 98% is significant coverage, it still leaves out 30 million rural people, who have no electricity and still depend on kerosene lamps for lighting. In 2007, only 30% of rural energy consumption came from commercial sources, such as coal and liquefied petroleum gas. This figure accounts for only 3% of the total national consumption of commercial energy that year. Depending on how aggressive the PRC government pursues renewable energy development, rural energy consumption could experience annual increases from 1.88% to 3.44% over the next 15 years since 2005, which would average from 34% to 71% growth by 2020. The supply-demand gap is enormous, with plenty of room for renewable energy sources to grow.

(ii) **Environmental protection.** The condition of the PRC's environment and natural resources is widely known to be worrisome. The development of the biomass industry, and the policies to fuel it, could bring economic and environmental interest into mutual benefit. While sparing the environment from threatening agricultural wastes, households and industries could economically benefit from the inherent "reduce, reuse, recycle" character of biomass conversion systems. The environment could also benefit from the subsidy and tax incentive policies that generate the initial commercial interest in modern biomass energy development. Likewise, stricter emission and discharge standards and enforcement could spur industries to invest in on-site biomass energy conversion systems.

(iii) **Rural development.** Agricultural households play the dual role of "supplier–consumer" in developing the biomass energy industry. The biomass generated on their farms can either supply their own household biogas system or be sold to industrial-size plants. Either way, farmers save and earn from using their biomass for energy conversion. By burning biogas, they produce enough energy to meet their needs while save time, expenses, and energy. They also save on healthcare expenses and loss of productivity as a result of the side effects of indoor and outdoor air pollution that comes from traditional stoves or openly burning agricultural waste. A third way they save and earn from biomass energy is by using the organic fertilizer that results as a by-product of the biogas conversion process. The high-quality, sludge-like fertilizer can be applied directly to backyard gardens and orchards, saving farmers the expense of commercial fertilizer while improving their yields and crop value. The income and savings opportunities mean households can afford greater personal investments in education, health, housing, and other physical and social assets that will increase their long-term security, standard of living, and productivity.

In addition to using existing agricultural wastes, biomass energy also involves the opportunity of producing alternative energy fuels, such as bioethanol and biodiesel, by cultivating non-staple, non-grain crops of high-energy content for the purpose of converting them into alternative fuels.

The recently completed ADB-financed Efficient Utilization of Agricultural Wastes Project demonstrated the triple benefits that rural energy projects can bring to rural communities. From 2005 to 2009, this ADB $33.1 million investment provided clean energy to 34,080 households in 145 villages across four provinces of the PRC. It also reduced about 84,429 tons of carbon dioxide emissions annually, and lifted 9,000 households out of poverty. A beneficiary impact assessment undertaken by the China Agriculture University in May 2008 showed that household income rose 86% compared to non-beneficiary households; firewood consumption decreased by 61% and coal by 30%; women's time on household chores was reduced by 40%; and household sanitation and health conditions improved substantially.

Biomass Resources, Technology Options, and Barriers

Biomass resources. Current and 2020 projections of biomass availability underscore the potential for achieving the country's 2020 goals of developing sustainable rural biomass energy—but only if these wastes can be harnessed. As a large agricultural country, the PRC has a variety of biomass resources in substantial quantities across wide areas. The forms of biomass discussed in this publication come from two kinds of wastes—livestock manure and crop stalks—and another type of biomass that is actually produced for creating energy is energy crops for liquid biofuels. As an example of the loss and opportunity currently found in the countryside's biomass resources, the amount of livestock manure alone in 2005 could have met 28% of rural household energy needs—if it had been converted into biogas. Unfortunately, only 12% of animal waste from household farms was put to energy use and worse, only 0.5% of animal waste from industrial livestock farms was used for energy.[3] The scenario for crop residues is similar. About 0.4% of the total amount of straw biomass was used in renewable energy systems.

Technology options. Encouragingly, the PRC government has already planted the seeds to grow a rural biomass energy industry. Knowledge that biomass can be converted into a clean, convenient fuel is also growing at national and local levels. Proving that biomass energy is catching on, household biogas production increased 340% from 2000 to 2008, while animal waste increased by only 112%. While there is still room for improving household biogas digesters, their further deployment does not face the same challenge as do the larger, more centralized systems. The report evaluated 15 technologies that can convert biomass resources to heat, electricity, solid fuel, liquid fuel (ethanol, biodiesel, etc.), and gaseous fuel (biogas, biomass fuel gas, hydrogen). Through economic, environmental, and social assessment, six technologies that ranked the highest in this assessment are discussed in the report: (i) rural household biogas systems, (ii) medium and large biogas plants, (iii) straw briquette/pellet fuel, (iv) electricity from straw, (v) crop straw gasification, and (vi) bioethanol and biodiesel. These more sophisticated technologies need to be developed through research and piloting if they are going to contribute significantly to meeting rural and national energy demands. This publication, using a scorecard system, summarizes the results of a comprehensive study of the above six technologies. The technology barriers can be overcome, though, as Chapter 4 explains, through adequate research and piloting.

Barriers. Even though the country is endowed with rich biomass resources, rural biomass energy is still the least developed form of renewable energy in the PRC. The key barriers preventing the full utilization of rural biomass resources are comprehensive, ranging from financing, to operational factors, to environmental regulation. While the poorest households could benefit the most from biogas digesters, the technology remains too costly without the help of substantial government subsidies and other extension supports. Larger scale systems, on the other hand, are undermined by expensive imported equipment and weak arrangements with local farmers, whose biomass is needed to fuel the plants. Farmers inevitably are disadvantaged without the advocacy and helpful involvement of local government. The double-edged enabling and preventive role of environmental regulations is also missing from current biomass energy development. Weaker enforcement of environmental standards, such as restrictions on field burning and wastewater discharge standards, contribute to the totality of lost opportunities to turn agricultural waste into renewable energy.

[3] The amount of livestock manure in 2008 could have met 30% of rural household energy needs—if it had been converted into biogas. Estimate from *China Statistical Yearbook* 2009 and the *Rural Energy Statistical Data* of Ministry of Agriculture.

A Holistic Strategy to Achieve 2020 Objectives

Despite the magnitude of the barriers, the PRC has an unprecedented opportunity to develop its rural biomass energy. The national promotion of low-carbon growth helps rural biomass energy development as a viable energy option. This publication concludes with a holistic strategy covering policy instruments, institutional arrangements, and financial investment that are essential to the furtherance of rural biomass energy in the PRC by 2020.

Policy. Technologies that provide commercial biomass energy will only be successful if they are developed according to the proper industry scales, supply chains, and research and development needs. In offering the PRC government a way forward with biomass energy, ADB technical assistance study proposed a set of changes to policy, institutional arrangement, and financing—the enabling environment—that would spur development from various sides. Tighter environmental standards and enforcement can lead more industries toward considering the reduce, reuse, recycle benefits that biomass systems offer. Subsidies targeting poor households for biogas digesters and farmers who could use marginal land for cultivating energy crops could address persistent poverty in rural areas. And tax incentive policies could strengthen the financial viability of the larger systems. These instruments are driven by four objectives: (i) ensure biomass resources are being used rather than wasted; (ii) stimulate research, development, and demonstration; (iii) support technology dissemination; and (iv) promote the industrialization of rural biomass energy development.

Institutions. This publication also suggests new organizational arrangements to ensure these policies receive proper implementation and coordination across the lead ministries as well as at various levels of government. What needs strengthening at the subnational level is technical capability. For example, design standards, training programs, and technical support for household biogas systems have been developed and refined over many years and are quite effective. But other biomass technologies and applications (such as large-scale biogas systems) are not as well developed and need to be developed at the national level and transferred to the provincial and local levels.

Financing. Achieving the 2020 strategic goals will require forward-looking policies and programs from government as well as investments by households, developers, manufacturers and others, which will require financing. A total investment of CNY413.5 billion through 2020 is necessary to achieve all of the strategic goals of rural biomass energy development plan. Of this total, about 76% (CNY314.3 billion) targets rural household beneficiaries; about 4% (CNY16.5 billion) is for centralized gas plant projects; and the remaining 20% (CNY82.7 billion) is for power generation and liquid fuel production. An additional CNY1.5 billion is needed for research, development, demonstration, and piloting. As of now, developing rural biomass energy is a costly endeavor, and thus careful investment planning is very important.

Since such a huge investment cannot and should not be shouldered by any one entity, the final chapter in this publication offers a framework for organizing an investment partnership among the international development institutions.

International finance institutions, such as ADB, can be a catalyst in helping raise the necessary project financing, which is one of the significant challenges of rural biomass energy development.

This publication presents a road map, strategy and partnership for the PRC to achieve its ambitious 2020 goals of developing rural biomass energy. Through this process, new enabling policies, coordinated institutional capacity, and effective investments made today mean PRC's rural communities would enjoy cleaner energy, better environment, and higher rural income by 2020.

Introduction

The People's Republic of China (PRC) is at a crucial stage in its social and economic development, and energy concerns are acting as both a catalyst and a constraint. As a catalyst, the country's growing capacity to deliver more energy to more people is helping fuel national growth and raise living standards. No developed country has reduced poverty without increasing household access to modern energy services. The power of energy to transform economies and lives in the rapidly developing PRC, however, is constrained in rural areas largely because of costs and other access issues.

Fortunately, the PRC knows it must explore new resources, promote efficient energy, and use renewable energy, which includes biomass-based energy. At the Beijing International Renewable Energy Forum in 2005, President Hu Jintao pointed out that strengthening "exploration and utilization of renewable energy is the only way to deal with the increasingly severe problems of energy shortage and environmental pollution, and it is also the only way to the sustainable development of our society."

Policy and targets. The PRC government has made development of rural biomass energy, specifically, an essential part of its long-term development strategy in rural areas. Most significantly, the Renewable Energy Law (effective January 2006) supports the development of bioenergy in all its forms—wind, solar, hydro, and biomass. The law calls for the exploration and use of bioenergy in rural areas and for local government authorities to devise renewable energy development plans and provide financial support to rural projects. It also sets the overall goal for 2020 to produce energy from various waste-based sources, including biogas from animal farms, crop residues, agro-processing, municipal waste, and sewage sludge.

The country's primary macroeconomic planning agency, the National Development and Reform Commission, set targets for renewable energy to comprise 10% of the country's total energy consumption by 2010 and 15% by 2020. The commission also set targets for generating power from hydro, wind, solar, and biomass. The commission has set a remarkably ambitious goal of 30 gigawatts (GW) of biomass power by 2020.[1] The government's interest is also growing in developing biofuels, such as ethanol and biodiesel, to reduce oil imports. The PRC will also import 1 million tons of ethanol each year from Brazil, a development that definitely paves the way for new business opportunities.

[1] Voegel, E. 2009. Report: China's Renewable Energy Sector Expected to Grow. *Biomass Magazine*. 8 January. Available: www.biomassmagazine.com/article.jsp?article_id=2339

Biomass energy. Because the PRC is a large agricultural country, its biomass resources can generate multiple forms of energy from these resources and in substantial quantities across a wide distribution area. Under the right conditions, the biomass energy industry can produce clean energy from many materials that are currently considered waste, while offering a more sustainable development pathway than energy development, which is driven solely by increased use of fossil fuels and importation.

Biomass energy, however, as opposed to wind, solar, or hydro renewable energy, faces some significant barriers. Due to a lack of technology and funding and a low level of awareness among local farmers, the country's biomass resources are not being used effectively, thereby wasting abundant resources and contributing to environmental pollution, climate change, and social inequalities.

Yet it remains a sensible and cost-effective way to address rural energy gaps, improve farmer income and overall rural social development, and improve the rural environment.

Biomass energy is created using animal wastes and crop residues, and is produced with solar energy through photosynthesis, creating carbon-hydrates from carbon dioxide and water. Biomass energy products used in the PRC include biogas, gases from straw and stalk gasification, electricity from biomass power generation, and various solid and liquid biofuels. These systems can be affordably established at both household and livestock farm scales, use readily available agricultural wastes, have few recurrent costs, need no highly specialized skills, and have high potential for extra revenues through the Clean Development Mechanism because of the potential for greenhouse gas reduction.

Energy transition. As part of an effort to rebalance its economic development, the country's rural areas must be transitioned from traditional to modern uses of biomass energy. Traditional uses of biomass involve farmers burning crop straws and other residues in low-end stoves for cooking and heating, whereas modern uses involve more efficient household stoves and conversion processes and in some cases centralized distribution systems that utilize a variety of biomass types.

If successfully employed, rural biomass energy could substantially address the three major trouble spots discussed in this chapter. In general, here's how:

(i) **Rural Energy Supply.** Biomass energy—in its various forms—can help meet increasing demands for fuel and electricity in rural areas, which are opportunities in themselves to address inequalities in living standards and allow for more productive households.
(ii) **Environmental Protection.** Greater utilization of biomass residues will relieve the environment of the harmful effects of disposing these biomass wastes, which are currently ruining soil, groundwater, and water resources, as well as contributing to greenhouse gas emissions.
(iii) **Rural Development.** Participating farmers will gain considerably from supplying commercial biogas producers with biomass from their farms while also benefiting from increased field productivity as a result of using the organic fertilizer that is generated from the biogas processing. Communities would also benefit from direct employment by biogas plants and from the various work along the supply chain and throughout the biomass industry.

The background of this publication. The uneven development of the sector to date requires a comprehensive strategy and wide financing. The purpose of this publication is to propose such a national strategy and a financing partnership that would support that strategy. This publication is a summary of lessons and experiences from the Asian Development Bank–financed Efficient Utilization of Agricultural Wastes Project in the PRC, as well as findings and conclusions from a technical assistance (TA) study to help the government draft a national strategy for developing rural biomass energy (see the Foreword and Box 1).

For the TA project, a consultancy team undertook three main studies: (i) current and projected rural energy consumption, (ii) available biomass up to 2020, and (iii) the various conversion technologies that produce biomass energy, based on cost-benefit indicators and the possible environmental and social impacts of each technology's use (this was accomplished by a systematic analysis of existing literature, a field survey, interviews with experts, workshops, and case studies).

The culmination of these studies was the drafting of a comprehensive strategy document that includes a policy, institutional, and financial framework for developing a rural biomass industry in the PRC. Guiding the strategy development was a steering committee chaired by the vice minister of the Ministry of Agriculture and with members from the National Development and Reform Commission, the Ministry of Finance, the Ministry of Science and Technology, and the Ministry of Environmental Protection.

A workshop to discuss the TA project's final report was held during the International Seminar on Rural Biomass Renewable Development from 19–21 June 2008, alongside the ASEAN-Plus Three Forum on Biomass Energy. Over 150 international participants shared lessons and discussed the prospects of rural biomass energy. Participants agreed with the conclusions and recommendations of the TA's final report and expressed support for publishing a summary of the report.

Organization of this publication. This publication is divided into three sections and seven chapters. Section 1 explores current and future supply and demand sides of both rural energy and biomass resources, and presents a summary of how various technologies fared in a comprehensive assessment. Section 2 looks at the goals the PRC government has set for itself in producing more rural biomass energy and a technology road map for meeting those targets. The road map, an output of ADB-supported TA study, focuses on research and development activities that must happen to bring the technologies to the level needed to meet the targets. But as Chapter 5 explains, technology alone will not ensure successful development of a biomass energy industry. There are four major barriers standing in the way of the PRC government's targets. Section 3 outlines a strategy to overcome these barriers. Chapters 6 and 7 look at the policy objectives, institutional arrangements, and financing plan for developing a sustainable biomass energy industry.

Box 1: Summary of the Efficient Utilization of Agriculture Wastes Project

This project provided funding to small farms for the installation of on-farm biogas digesters and to commercial livestock farms for medium-scale biogas plants. These were developed as part of an integrated farm production system that utilizes livestock waste while expanding vegetable, fruit, and grain crops.

The project is expected to benefit over 34,080 households in 145 villages across four provinces (Henan, Hubei, Jiangxi, and Shanxi), and to lift 9,000 households out of poverty. The project is also expected to reduce about 84,429 tons of carbon dioxide emissions every year.

A pilot Clean Development Mechanism project has also been implemented in Henan province for 12 pig farms. The project has piloted various types of technologies on these farms and played a catalytic role in developing biogas systems for medium-sized pig farms.

A Beneficiary Impact Assessment undertaken by the China Agriculture University in May 2008 showed that income per household rose by 86.43% compared to non-beneficiary households; firewood consumption was reduced by 61% and coal by 29.8%; women's time on household chores was reduced by 40%; and household sanitation and health conditions improved substantially. Overall, 80% of the beneficiaries said they were satisfied with the project.

Section 1

Supply, Demand, and the Technologies

Chapter 1
Energy, Environment, and Rural Development: Why Rural Biomass Energy Matters

The past 30 years have witnessed the fastest rate of economic development in the history of the People's Republic of China (PRC). Accounting for 20% of the world's population, the nation of 1.3 billion people has transformed from a primarily agrarian economy to a highly industrialized one. This rapid change and growth is expected to continue, and with it all the economic, environmental, and social difficulties, contradictions, and problems that other countries have experienced during industrialization. Except, in the PRC, because of the rapid rate of change and the population factor, these changes are occurring in a much more concentrated and intense manner than what has been experienced elsewhere.[1]

In particular, energy security in rural areas, rural environmental challenges, and urban-rural inequality are constraints on the government's ability to achieve its socioeconomic development objectives. Ultimately, the country must rebalance its economic development so that its rural population, agricultural sector, and environment also benefit from this growth. To make this happen, the TA study found that the government must invest in rural energy, particularly biomass-based energy, which can convert agricultural wastes into various energy forms, such as biogas, fuels, and electricity. No developed country has significantly reduced poverty and sustained growth without improving households' access to energy.

Table 1.1: PRC Population Trends (2004–2020)

	2004	2010	2020
Population (million)	1,299.8	1,360.0	1,450.0
Proportion of urbanized area (%)	41.7	47.0	53.0
Rural population (million)	757.2	720.8	681.5
Number of rural households (million)	249.7	237.9	224.9

Source: National Population Development Strategy Report. 2006. Available: www.china.com.cn

1 Jinfu Bai, et al. *Great Challenges During the 11th Five-Year Plan Period*. Available: https://studentweb.hhs.se/courseweb/CourseWeb/Public/9998/0803/Water%20pollution%20in%20China.pdf

Energy Demand

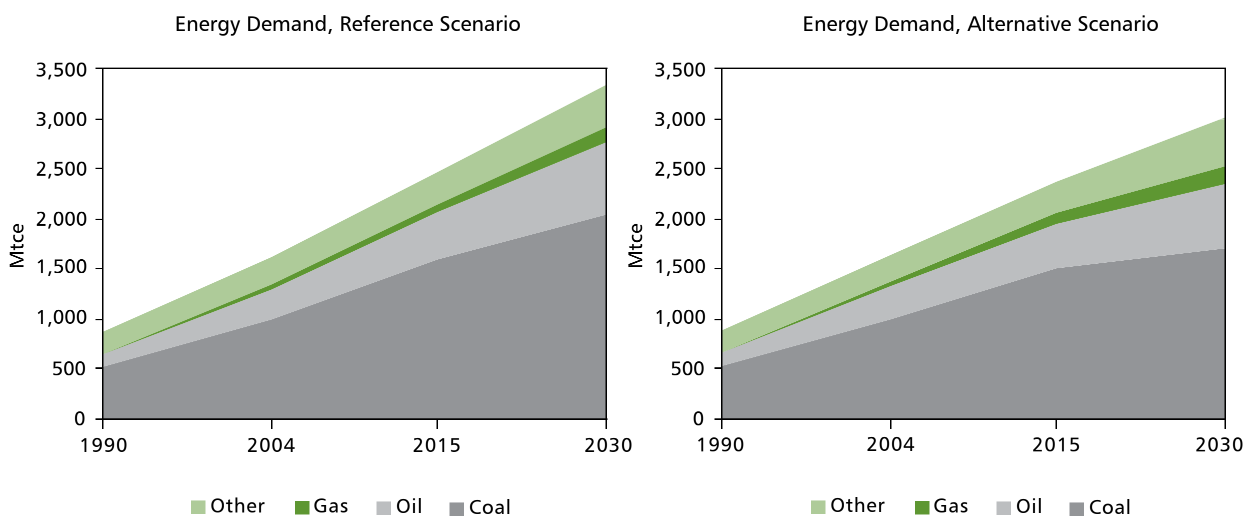
As a result of increasing industrialization, urbanization, and socioeconomic development, the PRC's overall demand for energy has skyrocketed. The PRC is already the second largest energy producer and consumer in the world. In 2008, the country produced 2.6 billion tons of coal equivalent (tce) of primary energy and consumed 2.85 billion tce. In the same year, coal accounted for 68.7% of the PRC's total energy consumption, whereas oil accounted for 18.7%, natural gas 3.8%, and hydropower 8.9%.[2]

Driven by a huge increase in the number of privately-owned vehicles, the PRC alone accounted for more than 30% of the world's incremental consumption of liquid fuels in the past two years.[3] The number of private vehicles in the PRC more than doubles every five years, increasing from 300,000 private vehicles in 1980 to 46 million in 2009.

In 2006, the 11th Five-Year Plan set a target for a 20% cut in the energy intensity of gross domestic product (GDP) by the end of 2010. The start was slow, but by the end of 2008, it had managed 10% and it now looks on track for its target. This would mean a reduction in carbon emissions of 1.5 billion tons per year by 2010.[4]

More alarming, the energy intensity of the PRC's economy, measured by primary energy use per unit of GDP (at constant prices), began creeping back during the 10th Five-Year Plan (2001–2005) after a long decline starting in the late 1970s. While this is closely related to the strong growth of energy-intensive industries, it also underscores the government's continued difficulty in implementing its well-expressed sustainable development strategies. If the PRC's energy intensity had stayed on its descending course, over 1 billion tons of coal consumption could have been avoided between 2001 and 2005.[5] That would have prevented about 20 million tons of sulfur dioxide (SO_2) emissions and 2 billion tons of carbon dioxide (CO_2) emissions. The power of energy efficiency multiplies in a fast growing economy.

Figure 1.1: PRC Energy Consumption Scenarios, 1990–2030 (million tce)



Mtce = million tons of coal equivalent.
Source: World Energy Outlook. 2006. International Energy Agency.

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2 Government of the People's Republic of China. 2009. *China Statistical Yearbook*. Beijing.
3 Asian Development Bank. 2009. *Promoting Environmentally Sustainable Transport in the People's Republic of China*. Manila.
4 The Economist, *A Long Game: China Sees Opportunity as well as Dangers in Climate Change.* 5 December 2009.
5 One tce in physical terms equals 29.3 gigajoules (GJ) of energy. On average, one ton of coal in the PRC contains about 1% (weight) of sulfur and about 20.9 GJ of energy.

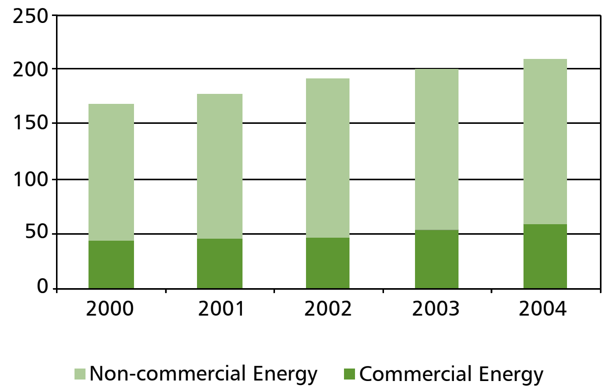
The PRC's energy track for the next 20 years is laden with coal and oil. Figure 1.1 shows the impact that policy can have on coal dependency. According to the International Energy Agency, policies that are pro-energy efficiency and pro-renewable energy can lead to a decline in the PRC's coal dependence (as shown in the "Alternative Scenario" in Figure 1.1). If the current trends and policies continue, though, the share of coal will even increase in the mid term (2015) (the "Reference Scenario" in Figure 1.1).[6]

Showing an understanding of the current energy challenges, PRC President Hu Jintao said at the Beijing International Renewable Energy Forum in 2005, "Exploration and utilization of renewable energy is the only way to deal with the increasingly severe problems of energy shortage and environmental pollution, and it is also the only way to the sustainable development of our society." And the structure of the PRC's energy production is indeed likely to shift toward a more renewable path, according to the country's commitments expressed before the Copenhagen climate talks in December 2009.

Rural energy demand. By 2008, 50% of the rural population in the PRC—about 100 million households—still relied on burning wood and agricultural crop wastes (residues) for cooking and heating. According to the Ministry of Agriculture (MOA) statistics, rural energy consumption in 2008 was nearly 125% higher than 1980s levels, representing an average annual increase of 2.9%. During that same period, consumption of commercial energy increased four-fold.

From 1980 to 2004, though, commercial energy consumption (such as processed coal and liquefied petroleum gas [LPG]) has been gradually rising as compared to that of non-commercial energy (directly burning coal, firewood, biomass). To be more precise, rural energy consumption in 2004 was nearly 480 million tons of coal equivalent (mtce), of which 209 mtce was used at the household level. Out of that 209 mtce, about 59.15 mtce is commercial energy, accounting for about 3% of the national total (Figure 1.2).

Figure 1.2: Household Energy Consumption by Rural Residents (million tce)



Source: ADB. 2006. *Technical Assistance to the People's Republic of China for Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

The 209 mtce used at the household level can be further understood according to its uses. The TA study conducted a detailed analysis of rural households' energy sources and uses, finding that cooking and water heating account for the majority of rural energy demand (62%). Space heating is a distant second (33%). Of the 209 mtce used by households in 2004, about 129 mtce went to cooking and water heating. An estimated 3.56 megajoules (MJ) of energy was consumed in 2004 for cooking and water heating per capita per day in rural areas.

"Exploration and utilization of renewable energy is the only way to deal with the increasingly severe problems of energy shortage and environmental pollution, and it is also the only way to the sustainable development of our society."

—Pres. Hu Jintao

[6] World Energy Outlook. 2006. International Energy Agency.

The proportion of energy consumed for cooking and water heating is higher because of the inefficiency of both the resource being used (straw and firewood) and the end-use device. While still high, the 2004 consumption-demand figure already represented wide utilization of energy-saving household stoves. By the end of 2004, the PRC had promoted energy-saving firewood stoves in 190 million rural households—70% of all households, including commercialized stoves in 46.5 million households. The energy-saving stoves have a thermal efficiency twice that of indigenous stoves.

Much of the remaining balance on that 209 mtce used by households in 2004—70 mtce—was used for space heating, of which straw, firewood, and coal are the main fuels. Firewood stoves (*kang*) and coal stoves are mainly used for heating. Of that 70 mtce for space heating, firewood stoves consumed 53.13 mtce and coal stoves consumed 16.35 mtce.[7] One third of the country's population live in the two coldest regions, requiring space heating.[8] The country's vast territory, though, means that great differences exist in the need and means of heating (as well as air conditioning). For example, in January, the northernmost region is about 40°C lower than the southernmost region.

The TA study also warned that as energy becomes more affordable, households will use more of it to heat their homes. The annual number of heating days, according to the TA study, could increase by 27%, from about 110 days in 2010 to 140 days in 2020.

With nearly 98% of the country's rural areas having access to electricity for lighting and appliances, total electricity consumption by rural residents in 2004 reached 35.8 billion kilowatt hours (kWh) for lighting and 498.21 billion kWh for appliances. From 2000 to 2005, the number of appliances per 100 rural residents increased as follows: 35.3 more televisions for a total of 84, 7.8 more refrigerators for a total of 20.1, and 11.6 more washing machines for a total of 40.2.

Despite these trends, about 30 million people (8 million households) across 20,000 villages still rely on kerosene lamps for lighting because there is no public grid connection. In pastoral areas of Inner Mongolia, people generate power from windmills or diesel engines. In regions with plentiful water resources but no public grid connection, such as Guizhou Province, people generate electricity from mini-hydropower generators.

Future projected energy use. To model rural energy needs in the future, the study developed three scenarios based on degrees of changes to the energy structure and the achievement of policies related to end-use energy efficiency (and also based on assumptions regarding population changes and rising incomes and living standards).

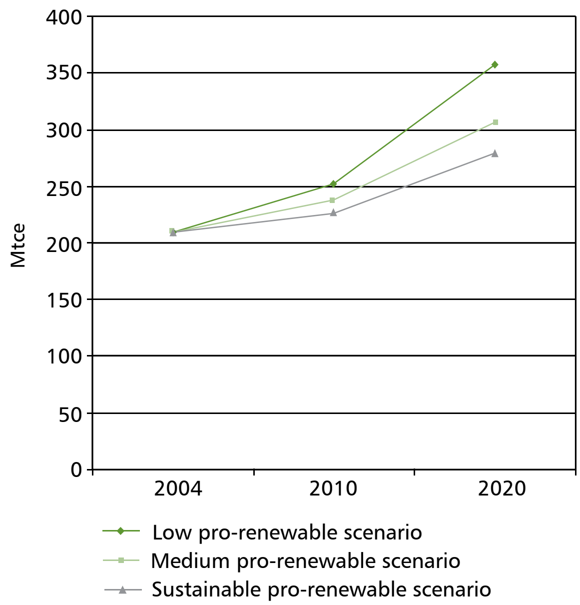
(i) **Low pro-renewable scenario.** Reforms and energy efficiency do not achieve projected levels because of failed market reforms and non-sustainable implementation, sending rural energy consumption on a steep incline.
(ii) **Medium pro-renewable scenario.** State policy is enforced and energy conservation and renewable energy are promoted with the effect of slowing rural energy consumption to more moderate level of increase.
(iii) **Sustainable pro-renewable scenario.** The government institutes strong policies and regulations that promote bioenergy and energy–efficient technology, bringing rural energy consumption within a sustainable rate of increase.

Remembering that 209 mtce was consumed in 2004 by rural households, consumption levels in 2020 could range from 280–358 mtce depending on which development scenario the government

7 These calculations assume that (i) fuelwood stoves accounted for 65% of total heating facilities in the PRC with an energy efficiency of 40%; (ii) coal stoves accounted for 35% of the total, with an energy efficiency of 70%; and (iii) the average heating duration was 3 months.

8 The space-heating region includes Beijing, Gansu, Hebei, Heilongjiang, Henan, Inner Mongolia, Jilin, Liaoning, Ningxia, Qinghai, Shaanxi, Shandong, Shanxi, Tianjin, Tibet, and Xinjiang.

Figure 1.3: Three Scenarios for Rural Energy Development (million tce)



Source: ADB. 2008. *Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

follows (Figure 1.3). Annual increases could range from 1.88%–3.44% and total increases over the 15-year span range from 34%–71%. The power of energy inefficiency multiplies in a fast-growing economy.

Achievement of the Sustainable Pro-Renewable Scenario could save about 78 mtce, or 25% of the 358 mtce that would be consumed under the Low Pro-Renewable Scenario. These potential energy savings—through more efficient rural consumption—can be achieved through effective implementation of strong policies, such as diversification and optimization of rural fuels, technical improvements, and increases in energy efficiency standards.

One of the key energy conservation and renewable energy policies is to promote rural biomass energy.

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To mitigate the pending strain on and between energy supplies and demands, a comprehensive policy package is needed to (i) increase rural households' access to more efficient energy stoves and increase their knowledge about effectively using biomass; and (ii) develop more successful large-scale, commercial biomass-to-energy systems. Without successful policy implementation in these areas, rural energy consumption will follow an unsustainable upward trend.

Rural Development

The difference in living standards between urban and rural areas as well as between rural areas across different regions is becoming more pronounced, leading to concerns that long-term prosperity could be undermined by increasing social inequality.[9] Contributing to this situation, agriculture in the PRC has developed more slowly than industry over the past two decades. Rural development in the poor western regions faces unique challenges involving persistent poverty and damaged ecosystems. When farmers fail, many migrate to cities in search of factory jobs.

The PRC's new "Five Balanced Development Strategies," prioritizes balanced development between rural and urban economies and balanced development of more-developed and less-developed regional economies. Such a strategy takes for granted that the level of rural income and its growth are fundamental measures of success.

To create an environment that integrates the rural economy into the nation's economic development, the most important policy tools

[9] The TA study benefited from The China Council for International Cooperation on Environment and Development, which established the Agricultural and Rural Development Task Force in 2003 to produce policy-oriented ideas and recommendations that will help the PRC's leaders to create a vision for agricultural and rural development in the coming years. The mandate of the task force was to make policy change recommendations that are consistent with national goals of income growth, poverty reduction, and environmental sustainability. The task force also examined how the proposed policy changes will affect food security given its prominence in current policy making and its inextricable relationship with the rural economy.

are those that raise the quality of the rural PRC's human and physical resources and accelerate the construction of infrastructure relevant to the rural economy. Energy infrastructure is essential to the rural economy and, by this study's analysis, it is lacking significantly in the rural PRC. While some farmers in richer coastal regions are shifting toward commercial energy, such as coal and natural gas, most rural households still rely on burning wood and agricultural crop wastes for cooking and heating. And while the majority of rural households have access to electricity (98%), few have access to clean fuels needed to augment insufficient electricity for cooking and heating. Only a small fraction of rural residents have biogas or could afford LPG for cooking, and the percentage who use natural gas is negligible.

For policy to be successful at reducing poverty, developing rural areas, and protecting the environment, it must recognize that modernization (and long-running income growth) is a slow process that depends on maintaining a healthy rural economy. Rising incomes in rural areas can fund household investments in education and health and other human and physical assets that will increase productivity in the longer run. While average farm income will continue to benefit from the growth of the general economy, income disparity between rural and urban, among regions, and among farmers within regions will increase further in the coming years if appropriate policies and reforms are not implemented.

Food security. Food security is an important national goal. With its unique historic legacy and the nation's large population and limited resources, it is reasonable that the PRC continues to give food security high priority. This has led the government to recognize the inherent conflict between first-generation biofuels and food production. The government's biofuels policy ensures that the technology moves forward in a way that does not compete with arable land and in which grain is not used as feedstock for biofuels. Construction has halted on new maize-based ethanol plants.

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Rural Environmental Challenges

In the PRC, farm incomes are now under pressure partly because of degradation of their resource base and partly because agricultural wastes from animals and crops and their traditional uses are exacerbating problems in rural environments. Environmental problems include desertification, soil erosion, grassland degradation, salinity on irrigated land, organic matter and fertility loss, burning of crop residues, aquifer depletion, high levels of heavy metals, nitrates and pesticide residues in soils and water, animal wastes, and loss of biodiversity.

Most rural households continue to rely on directly burning coal or biomass, such as crop stalks and firewood, which are typically burned in low-efficiency stoves for cooking, water heating, and space heating. Most crop straw and fuel wood stoves are 2.5 times less efficient than a biogas or LPG cooker.

Direct combustion of these biomass fuels causes serious air pollution and health risks for the PRC's rural population (about 740 million people). Burning traditional biomass continues to be a major cause of indoor air pollution and respiratory disease in the PRC. Fluoride poisoning is a common health problem in Guizhou province, where some 1.9 million poor farmers are affected, mostly women, children, and the elderly—often from minority ethnic groups—because of inequitable gender roles in the house and inequitable access to efficient stoves or household biogas systems.

Excessive use of crop residues and firewood also exploits forest resources, which has led to significant environmental damage—deforestation, soil erosion, biodiversity reduction, and damage to watersheds. This practice also makes it difficult to recycle chemical elements (e.g., nitrogen, potassium, and phosphorous contained in crop stalks and firewood) into the fields, thus reducing the fertility of the soil. In addition, the practice has a heavy social cost, as women and children carry the burden of gathering fuel and preparing the fire for cooking each meal.

Animal wastes from growing livestock farms are constantly introducing massive quantities of non-point source pollutants to waterways. Based on ADB studies,[10] the rural chemical oxygen demand load in 2001 was 1.42 times the load from industry and urban sewage discharges. By 2020, the study projected that the rate of livestock production will have increased by 167% of the 2000 levels. A 40% reduction in rural nonpoint source pollution by 2020 will be needed just to stabilize pollution at its current high levels, which poses a considerable challenge to livestock producers.

The PRC Pollution Census, released on 9 February 2010, concurred the above findings. According to this census, agriculture is responsible for 43.7% of the nation's chemical oxygen demand (the main measure of organic compounds in water), 67% of phosphorus and 57% of nitrogen discharges. Livestock farming as well as the excessive use of fertilizer and pesticides are the major contributors to agricultural pollution.[11]

In 1994, the last year that the PRC officially released its inventory of greenhouse gas (GHG) emissions, the agricultural sector accounted for 17% of the PRC's total GHG emissions. Further, agriculture was responsible for 50% of the country's total methane (CH_4) emissions and 92% of the country's nitrogen oxide (NO_x) emissions. More recent estimates made by The Pew Center on Global Climate

Box 1.1: Multisector Policies Stimulating Rural Biomass Energy Development

Under the banner of creating a "New Socialist Countryside," the PRC government has been launching a number of policies and programs since 2003 to help rural areas and protect the environment. Some initiatives have specifically focused on rural biomass energy. For example, it is an important element in the "*Decision on New Socialism Countryside Development*," promulgated by the Central Committee of the Communist Party on 21 February 2006.

The new socialism countryside development policy will promote (i) advanced farm production methods, (ii) improved livelihood, (iii) a civilized social atmosphere, (iv) clean and tidy villages, and (v) democratic management. Biomass energy would support many of these objectives.

The Renewable Energy Law, ratified by the National People's Congress in 2005, has been effective since January 2006 and supports biomass electricity generation. It requires companies distributing electricity via the power grid to purchase biomass-generated electric power at a CNY0.25 per kWh premium.

Finally, the Ministry of Environmental Protection, as the national environmental administrative authority, is tightening wastewater treatment requirements for livestock farms, setting strict discharge standards, and promulgating environmental management regulations. These policies range from command-and-control measures to economic incentives, but share a common goal of stimulating biomass energy development in rural areas.

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[10] ADB. 2006. *Technical Assistance to the People's Republic of China for the Study on Control and Management of Rural Nonpoint Source Pollution*. Manila. Nonpoint source pollutants and their 2001 estimated million tons of rural discharge are: chemical oxygen demand, 19.95 mt; total nitrogen, 11.54 mt; and total phosphate, 3.33 mt.

[11] Jonathan Watts, Chinese farms cause more pollution than factories, says official survey, 09 February 2010. Available: www.guardian.co.uk/environment/2010/feb/09/china-farms-pollution

Change estimated that, in 2003, emissions from agriculture accounted for 20% of the country's total emissions.[12]

The Economic–Environmental Balance

In dialogues with the international community, the PRC government has recognized the need to better manage its environment and natural resources alongside economic growth. For example, in the leadup to the December 2009 United Nations Climate Conference, the PRC government announced it will reduce the ''carbon intensity'' of its economic growth. Specifically, the government said it will reduce the carbon dioxide emitted per unit of economic output by 40%–45% by 2020 compared to its 2005 levels. This latest commitment would contribute to reducing the carbon factor, though emissions would still increase.

Biomass energy represents an opportunity to contribute not only to the overall mitigation effort, but also to other socioeconomic objectives as these benefits are inherent in the production cycle of biomass energy. While sparing the environment, including water resources, from harmful effects, biomass energy—when pursued with the principles of sustainability—can increase farm incomes and provide clean energy to millions of households living without. And as Chapter 2 points out, the PRC has the biomass resources to achieve just that.

[12] Pew Center on Global Climate Change. 2007. Climate Change Mitigation Measures in the People's Republic of China.

Chapter 2
Biomass Resources: Current Versus Potential

As a large agricultural country, the PRC is rich in agricultural wastes, which should have great potential for producing biomass energy. The various forms of biomass energy all originate from solar energy (through photosynthesis), and they all share several characteristics that are unique to other forms of renewable energy (Box 2.1).

Box 2.1: Important Characteristics of Biomass

- Biomass in its solid, liquid, and gaseous forms can be directly substituted for fossil fuels.
- Biomass can generally be stored over relatively long periods of time, but its low energy density requires large volumes and leads to high handling and transport costs.
- Biomass is the only renewable energy not "freely" available (as opposed to wind and water) and has a long supply chain from planting, growing, harvesting, pre-treatment, and conversion.
- Biomass cuts across several policy areas, including energy, agriculture, forestry, environment, land use, regional development, taxation, and trade.
- Because of limited arable land, the use of biomass for energy must be balanced against the need for food, materials, biochemicals, and natural forests.

Biomass renewable energy can be produced from many materials that are currently considered waste, and their utilization mitigates pollution from the disposal of unused waste. Potential supplies of waste-based biomass include:

(i) **Animal waste.** As a source for energy, animal waste—mainly from pigs and cattle—can be utilized in two ways: direct combustion after drying and production of biogas. Animal waste is good for producing biogas because of its high content of organic matter.

(ii) **Agricultural waste (or residues).** In the PRC, the major crops whose residues are used in generating electricity are corn, wheat, cotton, and rice. The biomass from these crops is often called "crop straw," which refers to all by-products of the harvested crops, including the stalk, stem, leaf, shell, and core. The shape and composition of crop straw vary due to the soils, fertilizers, and farm practices used in cultivation. Crop straw is an important biomass resource with potential for the commercial generation of electricity.

Another potential source of biomass is **energy crops**, which are agriculture or forest products that are grown specifically for their ability to be used in creating alternative fuels, such as bioethanol and biodiesel. They are characterized by high photosynthetic ability and high output. This study focused only on agriculture products for biofuels, not forest products.

Through a number of conversion technologies (Table 2.1), these biomass resources can be used to produce heat and electricity, solid fuel (pellets), liquid fuel (ethanol, biodiesel, biomass pyrolysis oil), and gaseous fuel (biogas, biomass fuel gas, hydrogen).

This chapter summarizes the results of the TA study on current and future supplies of rural biomass for clean energy in the PRC. The chapter also identifies regional disparities in available biomass resources, which provide a useful insight into potential regional priorities for biomass energy development. Rural biomass supplies from eight regions were studied:

(i) Northeast—Heilongjiang, Jilin, Liaoning
(ii) North—Beijing, Hebei, Henan, Shandong, Tianjin
(iii) Loess Plateau—Shanxi, Shaanxi, Gansu, Ningxia
(iv) Middle and Lower Reaches of the Yangtze River—Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan
(v) South—Fujian, Guangdong, Guangxi, Hainan
(vi) Southwest—Chongqing, Sichuan, Guizhou, Yunnan
(vii) Qinghai-Tibet Plateau—Qinghai and Tibet
(viii) Inner Mongolia and Xinjiang

Animal Waste

The recent rapid growth of the livestock industry in the PRC has led to massive increases in animal waste. The volume of livestock and poultry manure grew from an estimated 3.85 billion tons in 2000 to about 4.44 billion tons in 2005.[13] Most of this is being underutilized as a source of clean energy in rural areas. Instead, much of it is disposed improperly into ponds, channels, and sewers, or left in fields, eventually polluting the area and waterways, with impacts on the quality and safety

Table 2.1: Conversion Technologies for Biomass Resources

Raw Materials	Source	Technology Used	Output	Common Use
Animal manure	Rural households	Rural household biogas	Biogas	Cooking
	Intensive livestock farms	Medium-to-large-scale biogas plants	Biogas, electricity	Cooking, electricity, transportation
Crop residues, farm produce	Agricultural production	Direct combustion for electricity generation	Electricity	Electricity, heating
		Co-combustion for electricity generation		
Byproduct (rice husk, corncob, bagasse, etc.)		Gasification and electricity generation		
		Pelletizing fuel technology	Solid fuel	Cooking, heating
		Dry digestion	Biogas	Cooking, heating
		Hydrolyzation	Fuel ethanol	Transportation
		Fischer-Tropsch synthesis	Biodiesel	
Energy crops	Sweet sorghum	Fermentation	Fuel ethanol	
	Sugarcane			
	Cassava			
	Rapeseed	Chemical	Biodiesel	
	Cottonseed			

13 According to the recent MOA estimates, the volume of livestock and poultry manure increased to 4.88 billion tons in 2008.

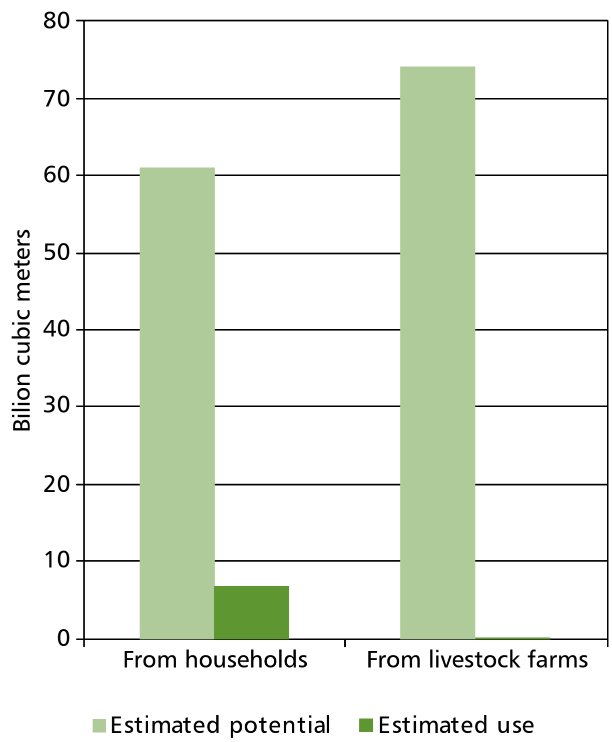
of agricultural crops and other agro-products. The wastes from intensive animal production units have become the top source of chemical oxygen demand, exceeding the combined amount from industrial wastewater and urban sewage. If disposal methods of livestock waste are not improved, environmental problems will certainly worsen, as the livestock population is growing rapidly.

The TA study suggested that potential biogas production from animal waste in 2005 was nearly 135 billion cubic meters (m^3), which is equivalent to 96 mtce, or about 28% of current total rural household energy consumption.[14] Biogas production could come from two sources—small rural households and large-scale, industrial ("intensive") pig, cattle, and chicken farms.[15]

Rural household production. Considering current social, economic, and climate conditions, the TA study determined that approximately 148 million rural households who raise pigs or cattle are suitable for developing biogas. The study determined that if all of these households were to develop biogas, approximately 60 billion m^3 of biogas could be produced (based on 411.39 m^3 of average biogas production per digester in 2005). This is just less than half the total amount of estimated biogas that could have been produced in 2005 from current animal waste supplies.

While the PRC has endeavored to promote household biogas production, the utilization ratio is still very low relative to the huge amount of animal waste available. By the end of 2005, only about 18 million rural households—only 12% of those suitable—were using biogas digesters.[16] The combined annual output of these household-scale systems reached about 7 billion m^3, equivalent to about 5.04 mtce. This amount is far less than the potential output—about 12% of potential output (Figure 2.1).

Figure 2.1: Use of Livestock Waste for Biogas in the PRC Falling Well Short of Potential (2005)



The national program and several donor-funded programs are increasing the use of these systems by several million units per year. If these efforts progress, respectable utilization rates can be achieved. While animal waste increased by 118% between 2000 and 2005, household biogas production increased 278%.

If disposal methods of livestock waste are not improved, environmental problems will certainly worsen, as the livestock population is growing rapidly.

[14] This was based on an estimate of the utilizable quantity of manure. From there, the potential amount of biogas production from this manure was based on the conversion rate of the organic content of the animal waste, which is different for each type of animal waste (e.g., cattle produce the most biogas per kg of animal waste).

[15] The potential biogas production from animal waste in 2008 was nearly 148 billion m^3, which is equivalent to 105 mtce, or about 30% of current total rural household energy consumption. This estimate is based on the *China Statistical Yearbook* 2009 and the rural biogas statistical data of MOA.

[16] By the end of 2008, only about 30 million rural households—only 20% of those suitable—were using biogas digesters.

Livestock operation production. Biogas can also be produced at large, intensive livestock farms, where animal waste is much easier to collect. The TA study estimated that if all medium-to-large pig, cattle, and chicken farms converted their animal waste into biogas, approximately 74 billion m³ of biogas could have been produced in the PRC in 2005.

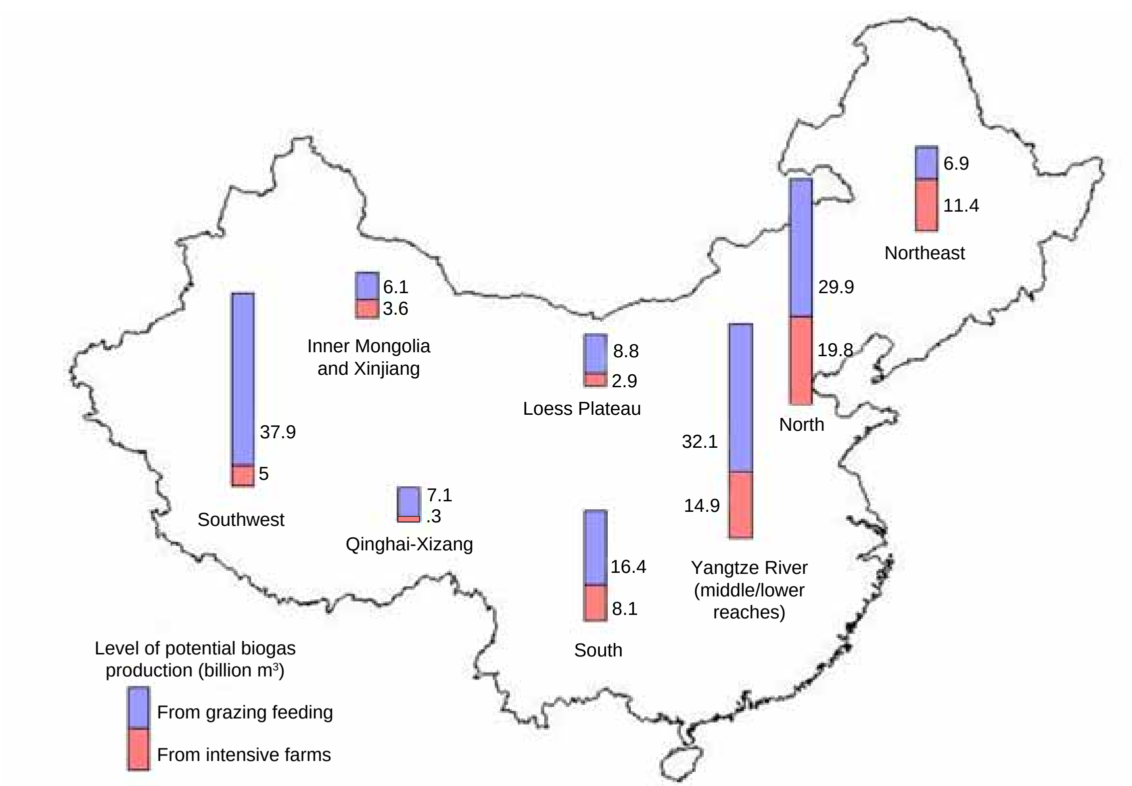
These larger livestock operations can support the use of medium and large biogas plants. These can provide biogas for heating, cooking, and electricity generation for the farm operation and the local community.[17] In addition, like the smaller versions, the digester effluent is a liquid organic fertilizer, which can be sold to adjacent farms. By the end of 2005, 3,556 medium-to-large biogas systems had been installed and produced 0.23 billion m³ of biogas, which is 0.16 mtce. As is the case with biogas production from household systems, this amount fell well short of the potential—less than a half-percent of the potential amount.

Regional production. Three key factors determine biogas production in a particular area: overall numbers of livestock in the province, the corresponding rate of biogas production for each type of manure, and the proportion of intensive operations to traditional (grazing) feeding.

The TA study also looked at potential biogas production for each of the country's 31 provinces in 2005. This report focuses on potential from pig and cattle manure, which is the more suitable animal waste for biomass energy in the PRC.

Grouped by region, the North, Southwest, and middle and lower reaches of the Yangtze River have the most abundant animal waste resources (Figure 2.2). Provinces especially rich in animal waste (capable of producing 10 billion–20 billion m³ of biogas) include: Sichuan and Yunnan in the southwest; Hebei, Henan, and Shandong in the north; and Hunan in the Yangtze valley.

Figure 2.2: Regional Comparison of Potential Biogas Production from Manure



Source: ADB. 2008. *Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

17 Large plants can typically produce more than 600 m³/day of biogas (or more than 60 KW), while medium plants produce 300–600 m³/day (or about 30–60 KW).

Three key factors determine biogas production in a particular area: overall number of livestock in the province, the corresponding rate of biogas production for each type of manure, and the proportion of intensive operations to traditional (grazing) feeding.

This regional analysis also considered the proportion of potential biogas production that could come from intensive livestock farms, where medium-to-large biogas plants might have more promise. Provinces with the potential to produce over 4 billion m^3 from intensive operations are Guangdong, Hebei, Henan, Hunan, Jilin, and Shandong.

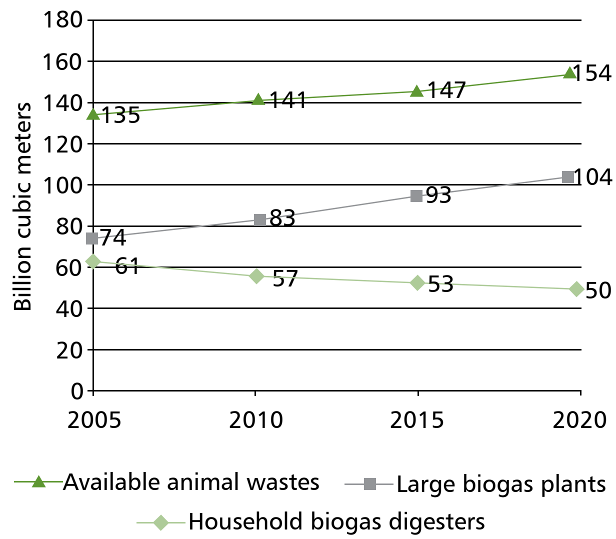
On the other end of the spectrum are provinces with few intensive operations, such as Guizhou, Qinghai, Xizang, and Yunnan. In these provinces, a larger proportion of pig and cattle are raised on smaller, more scattered farms and thus biogas production is more limited to smaller household systems. In these places, animal waste is typically more difficult and costly to collect, so larger biogas systems tend to be less feasible.

Estimated Future Potential

Current upward trends in livestock production are expected to continue for a long time, as the per-capita consumption of meat and milk is still much lower in the PRC than in developed countries. Correspondingly, the total quantity of potential biogas from animal waste will continue to increase.

Along with this general increase in potential, biogas production will likely happen more at centralized plants in coming years. As living standards increase, so too will meat consumption, and this will drive up the scale and number of intensive livestock farms. At the same time, fewer rural households will be raising livestock. The TA study projected that the number of households suitable for small-scale biogas production will decrease (from 139 million in 2010 to 121 million in 2020) as a consequence of agriculture modernization and progressing urbanization.

Figure 2.3: Estimated Available Quantities of Biogas Production from Animal Waste (2005–2020)



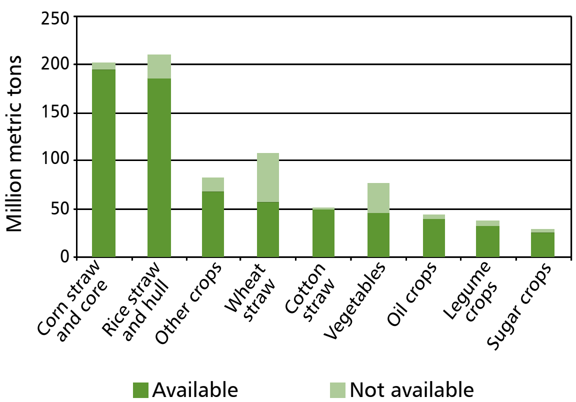
Considering these trends, the TA study projected that, from 135 billion m^3 in 2005, the potential biogas production from livestock waste will grow to 154 billion m^3 in 2020 (Figure 2.3).

Agriculture Waste

The TA study estimated that, in 2005, the total yield of available agricultural residues was more than 700 million tons.[18] This includes more than 600 million tons of crop stalks and more than 100 million tons of other residues (e.g., rice husk, corncob, peanut hulls, and sugarcane bagasse). Of the total amount, about 54% was rice straw and corn straw (Figure 2.4).

[18] The available quantity of straw resources means the maximum quantity of straw that can be collected and utilized under realistic farming conditions, especially harvesting conditions. In 2008, the total yield of available agricultural residues increased to about 750 million tons.

Figure 2.4: Straw Production from Food and Economic Crops in the PRC (2005)



Straw resources in the PRC are available throughout eight regions (Figure 2.5). Among these regions, the middle and lower reaches of the Yangtze River produced the most straw in 2005. Rice is the dominant crop in the river delta, which contains the most fertile soil in the country.

Another important measure of straw availability is the density of resources (annual straw production divided by land area). This criterion reflects the degree of richness in local resources and can be used to evaluate suitable utilization approaches (Figure 2.5). In 2005, the average density of available straw in the PRC was 88.55 tons per square kilometer (km^2).[19] Less than one-third of the country's land produced more than three-quarters of the total available straw in 2005.

Straw resources are especially rich in the north, which is home to the largest plain in the country, Huang-Huai-Hai. On its 18 million hectares (ha) of arable lands, the main crops are wheat, corn, cotton, soybean, and peanuts. In this region, as well as in the lower and middle reaches of the Yangtze River, centralized utilization of straw resources can be developed.

In planning the development of rural biomass energy from crop straw, it is important to consider that straw can be used for a number of purposes, including fuel, feed, fertilizer, industrial material, and a base for edible fungus.

In planning the development of rural biomass energy from crop straw, it is important to consider that straw can be used for a number of purposes, including fuel, feed, fertilizer, industrial material, and a base for edible fungus. In 2005, half of the total available straw (338 million metric tons) was used for fuel (direct combustion by farmers), while only 2.75 million metric tons was used for renewable energy development (Figure 2.6).[20]

A number of conversion technologies are generating electricity from crop straw. These include direct crop straw combustion, crop straw gasification, and co-combustion of coal and crop straw, as described in the next chapter.

Estimated Future Potential

The TA study developed projections for the production of straw resources to 2015 based on estimates of arable land utilization and crop productivity. While straw production per hectare will likely increase in the future, the amount of arable land will likely decrease. Thus, amounts of available crop straw will likely increase only modestly in the next couple of decades. The TA study forecasted that the available quantity of straw resources in 2015 will be 716.67 million metric tons, increasing by 18.19 million metric tons from 2005 (Figure 2.7).[21]

However, use of available straw resources is likely to change significantly. In the next couple of decades,

19 In 2008, the average density of available straw in the PRC was about 95 tons/km^2.

20 Data comes from the Department of Science, Technology, and Education and the Center for Energy and Environmental Protection Technology Development, both in the Ministry of Agriculture, and Statistics of Renewable Energy in Rural Areas of China for 2003, 2004, and 2005. In 2008, 43% of total (about 324 million mt) was directly combusted by the farmers while only about 5 million mt was used for renewable energy development.

21 Because the grain yield increased by 9% from 2005 to 2008, the actual straw resources in 2008 (750 million mt) was more than forecasted.

Figure 2.5: Distribution of Straw Resources (total available quantity and density)

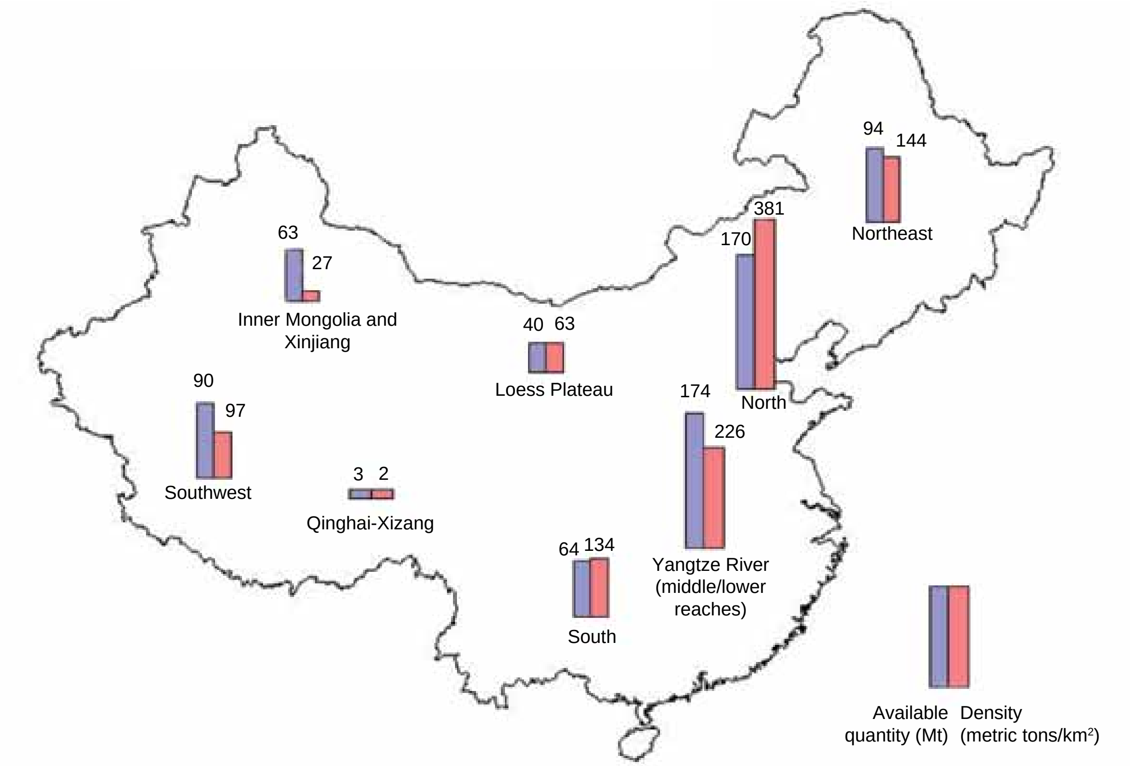


Figure 2.6: Uses of Crop Straw in the PRC in 2005 (Million metric tons)

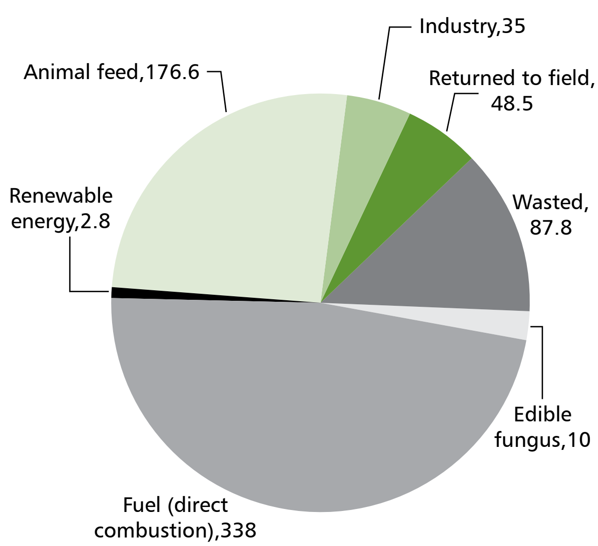
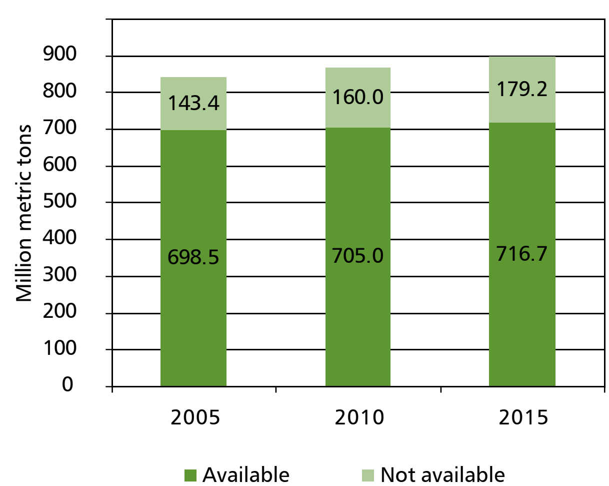


Figure 2.7: Estimated Straw Resources in the PRC (2005–2015)



Resources are concentrated in the eastern regions of the country where centralized utilization at the proper scale can be developed, while distributed utilization can be developed in other regions.

with the increasing enforcement of environmental regulation, rural households will gradually shift away from directly burning biomass in fields, making straw resources more available for other uses. At the same time, the amount of crop straw needed for animal feed and industrial materials will increase significantly, creating more market competition for straw resources. As competition increases, far less straw will be wasted.

A competitive market between straw producers and users is only starting to take shape, and it will require a long period of commercial activity to become a regular practice in the PRC. The growth of a competitive market will depend on how quickly the scale of straw utilization grows for renewable energy, industrial processing, construction materials, and feed industries.

Based on these trends, the TA study concluded that, by 2015, at least 300 million metric tons of straw resources will be available for conversion into modern biomass energy if the amounts currently wasted can be captured for use. Resources are concentrated in the eastern regions of the country where centralized utilization at the proper scale can be developed, while distributed utilization can be developed in other regions.

Further analysis from the study showed that the PRC could readily utilize 60 million–100 million metric tons of crop straw for electricity generation between 2010 and 2020, which is enough to fuel 350 power plants of 25 megawatts (MW) each. Operation of a 25-MW biomass power plant would reduce carbon dioxide (CO_2) emissions by 100,000 tons per year, compared with that from a same-sized coal-fired power plant. An additional benefit of biomass combustion is the ash residue it produces, which can be used as high-quality potassium fertilizer.

The northeast, south, and southwest regions are the most suitable for converting straw into energy. The Northwest, Loess Plateau, and Qinghai-Xizang Plateau regions have the least amount of straw and are therefore not as suitable for developing biomass energy schemes.

Furthermore, in rural areas close to populated areas, there is a greater opportunity to sell electricity from biogas operations to the public grid. The greatest potential for this may be in the Yangtze River region, where the urban build-up in this region may be the largest concentration of adjacent metropolitan areas in the world.

Energy Crops

Finally, the TA study looked at energy crops used to produce bioethanol and biodiesel.[22] Bioethanol is made by fermenting the sugars of a high-carbohydrate crop. In the PRC, common crops used for this are sweet sorghum, cassava, and sweet potato (Table 2.2). These biofuels can be blended with gasoline at a ratio of up to 10% or can be used directly if an adapted engine is used. Biodiesel is a mixture of biofuel and diesel to make a cleaner substitute for traditional diesel. The only notable crop for biodiesel production in the PRC is rapeseed. The fuel can be used directly in diesel engines without modification or can be blended with diesel oil.

The production of energy crops for bioethanol and biodiesel is relatively low in the PRC. Arable land in the PRC is already limited and growing more scarce every year. The per capita amount of arable land in the PRC is 0.27 ha, which is 40% less than the world per capita average, 12.5% of the United States (US) average, and 50% of the average in India. So satisfying the food demands for more than 1 billion inhabitants is already problematic. Thus, there is limited land area for growing crops solely for the purpose of alternative transport fuels.

[22] In the TA study, only sweet sorghum, cassava, sweet potato, and rapeseed are considered, as they are the main agricultural energy crops grown in the PRC. It only comprises a small portion of total biomass resources because PRC regulation limits energy crop production to non-arable land.

Table 2.2: Characteristics of the PRC's Main Energy Crops

Crop	Biofuel Potential	Characteristics
For Ethanol Production		
Sweet sorghum	Excellent energy crop, with high biomass-conversion efficiency and yield. Stem juice has high sugar content for fuel ethanol conversion. Cellulose material can also be used to produce fuel ethanol via acidic and enzyme processes. Hydrocarbons synthesized on each mu (1/15 of a ha) of soil per day can produce 3.2 liters of ethanol, compared to only 1 liter with corn, 0.5 liter with wheat, and 0.6 liter with common edible sorghum.	Cross-cultivated sweet sorghum is highly productive, with high photosynthetic abilities and biological output. Maximum output reaches 3 tons of dry matter per mu, which is 1–2 times more than the output of corn and sugarcane. Insensitive to arid, water logging, and salty environments. One kilogram (kg) of dry biomass needs 250 kg of water, compared to the 500–700 kg of water that wheat and various types of beans need and 1,000 kg that trees need. Grows satisfactorily in soil that has a pH value of 5.0–8.5.
Sweet potato	Feedstock suitable for ethanol production and is a traditional and already mature process. Rich in starch, has only little cellulose, has sufficient protein, is easy to process, and has thorough starch utilization.	High-output crop; rich, arable fields can produce 5,000 kg per mu. Very flexible and strong, with high regenerative abilities. Sustains in infertile, acidic, and alkali-rich land and endures drought. Defensive against wind, hail, bugs, and other natural disasters. Prefers higher temperatures. Safe storage very important. The quality of the harvest directly affects its storage conditions.
Cassava	The main resource of the ethanol industry, which is traditional yet matured (and nearly identical to processing sweet potato). Fresh roots can produce starch. The starch, bagasse, can be utilized as cattle feed or for brewing alcohol, and has a high value for integrated utilization (i.e., its recycling process produces useful by-products and reduces costs and unnecessary natural resource consumption). Starch output is much higher than that of cereals, and has very good processing properties.	Does not compete with edibles. In subtropical and tropical areas, the plant can grow in all four seasons, which is beneficial for year-round feedstock supply (once per year in tempered zones). High growth flexibility, sustains in drought and infertile land, and can grow on various kinds of soil. Cultivation has already spread throughout southern PRC, primarily in Guangdong, Guangxi, and Hainan provinces.
For Biodiesel Production		
Rapeseed	Rapeseed is an important oil plant in the PRC. Its seed has an oil content of 33%–50%.	Widely distributed in the PRC and is classified by ecological conditions as either winter rapeseed or spring rapeseed. Yangtze is the main production area for winter rapeseed, accounting for 83.5% of the country's total output, and is the world's largest rapeseed production area.

Table 2.3: Ministry of Agriculture's Standard Definition of Suitable, Free Arable Land

Classification system			Standard
1. Surface angle			<25°
2. Soil quality			Not sand and gravely soil
3. Efficient soil depth	Northern areas	Yellow Huaihai area, Northeast, Yellow Earth high grounds, dry regions of the Northwest, highlands of Qingzang	>30 centimeters (cm)
	Southern areas	Sichuan Basin and mid-to-down-stream of the Yangtze River	>20 cm
		Highlands of Yunnan	>10 cm
4. Soil salinization			Soil salt content <2%
5. Water conditions			Land with guaranteed irrigation or dry land where dry cultivation can be developed; during growth period of the crop, rainfall is normally not below 160 millimeters
6. Temperature conditions			Where cold-resistant plants can grow stably

In addition, government policy strongly discourages using arable land for anything other than food crops. While the PRC's 11th Five-Year Plan (2006–2010) encourages production of liquid biofuel from energy crops, an important stipulation is that it should not compete with growing strategic goods, such as food and cotton. The principle of no competition with food for land, and no competition with humans for food is strictly followed in planning the development of bioethanol and biodiesel.

Energy crops can only be planted on "suitable, unused, arable land," the standard definition of which is shown in Table 2.3. This land mainly includes natural grasslands, sparse woodlands, bush land, and other non-utilized areas, except for protected lands, such as natural forest, wildlife areas, watersheds, water and soil conservation areas, and other protected forest and bush regions. Fortunately, energy crops are the most durable, being able to survive and even thrive in poor conditions such as drought and salinized soils. This makes them ideal for the most marginalized, stubborn, unused land.

The principle of no competition with food for land, and no competition with humans for food is strictly followed in planning the development of bioethanol and biodiesel.

The Ministry of Land and Resources carried out a detailed survey of the national reserves of arable land from 2000 to 2003. The survey measured arable land reserve for 31 provinces (Taipei,China; Hong Kong, China; and Macau were not included) and found the amount of usable arable land suitable for energy crops is 6.537 million ha.

Reserve, arable land resources are unevenly distributed in these 31 provinces and exist mainly in the northern and western arid areas (Figure 2.8). Reserves of arable land are concentrated in Mongolia-Xinjiang region with 52%, Loess plateau area with 12%, and northern PRC area with 10% of the national total. Reserves of arable land in the south and east are scarce.

Table 2.4 presents those energy crops that are suitable for every region. Suitability was determined by the biological characteristics of crops, environmental requirements, development status,

Figure 2.8: Available Land Area for Bioenergy Crops (millions of hectares)

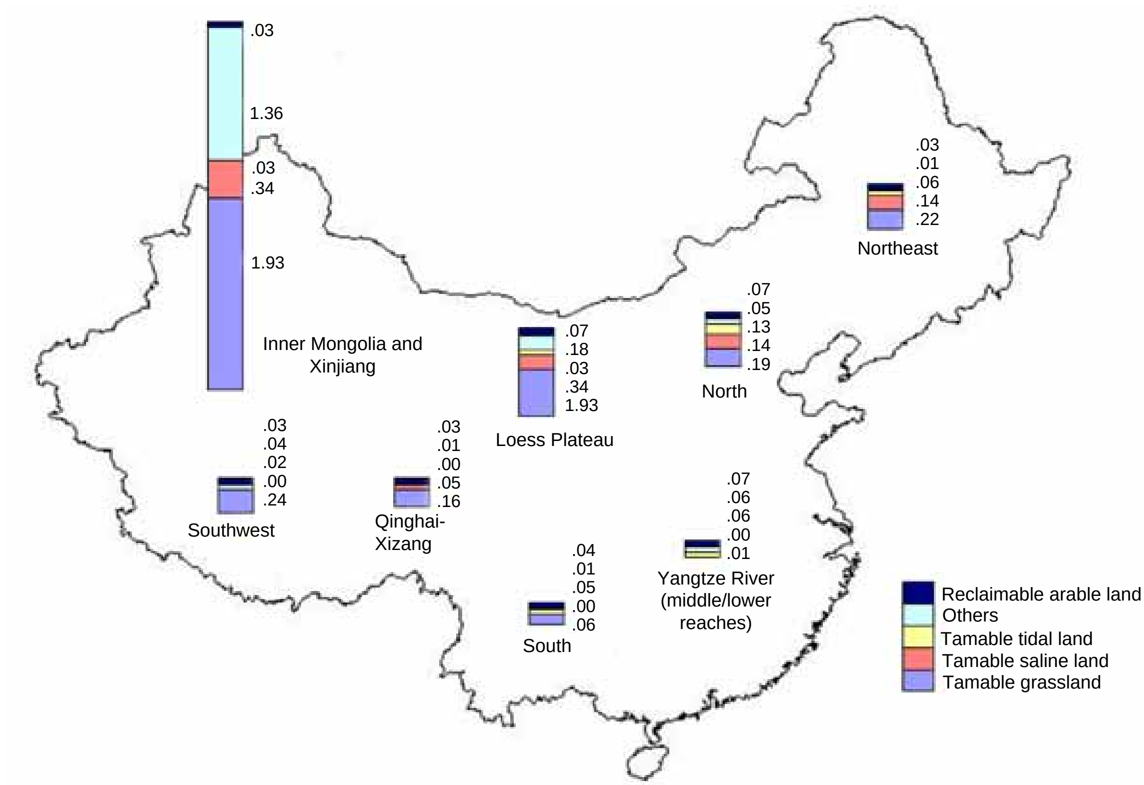


Table 2.4: Suitable Energy Crops by Region

Region	Suitable energy crops
Northeast	Sweet sorghum
North	Sweet potato, sweet sorghum, Jerusalem artichoke
Loess plateau area	Sweet sorghum
Lower Yangtze valley	Sweet potato, Jerusalem artichoke
Southwest	Sweet potato
South	Sweet potato, cassava
Inner Mongolia-Xinjiang	Sweet sorghum, sugar beet
Qinghai-Xizang	Temporarily not considered

and differing farming system and geographic conditions. The Qinghai-Xizang region is ecologically fragile and not considered suitable for energy crop cultivation.

Estimated Future Potential

The TA study estimates the country's potential for developing biofuel production based on (i) the capacity of the usable arable land reserve, and (ii) the annual ethanol yield of each region's suggested energy crop. This estimate assumes that, by 2010, 10% of usable arable land reserve could be converted to energy crop production and 50% by 2020.

Ethanol output per unit area in different regions was calculated based on the lowest average yield of energy crops. For example, potential ethanol yield for cassava is 4.41 tons/ha in 2010 and 6.62 tons/ha in 2020. The total potential production of fuel ethanol from energy crops was then calculated as 2.44 million tons in 2010 and 12.96 million tons in 2020 (Table 2.5).

Table 2.5 Potential of Fuel Ethanol Production[a] on Arable Land Reserve

Region	2010			2020		
	Ethanol output (t/ha)	**Land Used** (%)	**Potential** (10^3 t)	**Ethanol output** (t/ha)	**Land Used** (%)	**Potential** (10^3 t)
Northeast	3.92	10	178	3.92	50	889
North	3.67	10	209	3.92	50	1,118
Loess Plateau	3.92	10	344	3.92	50	1,721
Inner Mongolia–Xinjiang	3.92	10	1,449	3.92	50	7,246
Lower Yangtze Valley	3.67	10	72	5.64	50	554
South	4.41	10	71	6.62	50	530
Southwest	3.67	10	118	5.64	50	905
Total	**27.18**	**70**	**2,441**	**33.58**	**350**	**12,963**

t = ton; ha = hectare.

[a] Ethanol output per unit area in different regions was calculated using the lowest average yield of energy crops.

Chapter 3
Technologies: What's Working, What's Not, and Why

Agricultural households play the double role of "supplier-consumer" in the development of the biomass energy industry. As supplier-consumers, they produce the agricultural wastes needed to create biomass energy, and they are often the end-user, the consumer. Their role as supplier-consumer is most prevalent at the household level: by feeding their agricultural wastes to a biogas digester on their property, they can produce biogas for household cooking and heating, as well as an organic fertilizer for use in their fields.

The supplier-consumer household may also be involved in larger biomass energy schemes. Where biomass resources are especially abundant, farmers may sell their agricultural waste to village-scale or full industrial-size plants that convert the biomass into various forms of energy, such as piped-in biogas, solid pellet fuel, or electricity. Depending on the type of plant, it may use the biogas it produces for its own internal plant operations or distribute the biomass energy through a piped network or electrical grid to the surrounding community.

Aside from farmers, certain agro-industries, such as intensive livestock farms, represent another type of supplier-consumer relationship, which could benefit from on-location biogas plants. These kinds of farms produce huge amounts of animal waste, which is really not waste when it is processed in an on-site, industrial-scale biodigester. The biogas can be used internally or piped to surrounding areas.

Table 3.1 presents a number of scenarios for utilizing biomass (Box 3.1 offers further explanation). A fundamental difference between them is their progress. Household biogas digesters have advanced impressively in the PRC. And while there is room for improvement, their deployment does not face the same challenges as the larger scale, more centralized systems. These more sophisticated technologies need developing if biomass energy is going to contribute as significantly as it should—and as significantly as the government is planning—to meeting rural and national energy demands.

Table 3.1: Deployment Modes of Rural Biomass Energy Systems

		Consumption	
		Decentralized	**Centralized**
Production	**Decentralized**	*Relevant technologies*: Household biogas digesters Systems are distributed to or purchased by the household or small farm to produce biomass energy that is consumed on-site.	*Relevant technologies*: Bioethanol and biodiesel A large number of farmers produce energy crops for large, centralized liquid fuel production plants, who then distribute the biofuel to a large consumer base.
	Centralized	*Relevant technologies*: Straw pellet fuel, straw biogas, straw gasification, and mid-to-large size biogas plants A centralized plant and a regional distribution network make these systems relatively complex.	*Relevant technologies*: Straw power plants Electricity produced in a specific locale where there is large amount of available crop straw. To sell raw material to the power plant, farmers must live within the collection radius of a plant.

Box 3.1: Characteristics of Centralized Production and Decentralized Consumption

This model of industrial biomass energy service is often pursued for straw pellet fuel, straw biogas, straw gasification, and mid-to-large biogas plants. Facilities are usually built according to the scale of the area being supplied, and they depend on a strong relationship between the feedstock suppliers (farmers), the producer, and the end user. Plant operations depend on steady collection, transport, and storage of inputs, as well as the regular collection of fees from customers.

Alternative payment schemes could be arranged for rural households that are both feedstock suppliers and consumers. They could exchange an amount of crop straw in return for the biogas or pellet fuel, or they could agree to pay a processing fee for converting delivered crop straw into fuel.

For all types of centralized fuel production plants, a professional group is necessary for engineering design and construction. The PRC has accumulated enough experience in this field and its industry profile shows good capacity. Presently, the PRC also has excessive manufacturing capacity for mechanical equipment, so new manufacturing plants are not needed for this purpose.

This chapter explains the fundamentals of these scenarios and technology options, along with their advantages and limitations, and contains recommendations to either leverage existing advantages or address the challenges currently undermining them. The text is based on conclusions from the final report of the TA study. This assessment scored a number of technologies according to three end-use applications:

(i) high-quality cooking and heating fuel for rural households,
(ii) electricity from crop straw for rural electrification, and
(iii) energy crops to increase farmer income and provide the national market with oil substitutes.

The six technology areas that ranked the highest in this assessment are discussed in individual sections

Centralized production schemes need to be developed if biomass energy is going to contribute as significantly as it should to meeting the government's 2020 goals.

of this chapter: (i) rural household biogas systems, (ii) medium and large biogas plants, (iii) straw briquette/pellet fuel, (iv) electricity from straw, (v) crop straw gasification, and (vi) bioethanol and biodiesel.[23]

The analysis may appear to be PRC-centric, yet many countries face the same issues, and this market development truth is universal. The optimal utilization of biomass resources depends on the right mix of resources, technology, and a number of locally-specific factors, such as land-use patterns, level of economic development, agricultural products, current use of agricultural wastes, costs and logistics of acquiring and transporting biomass, processing requirements, and consumer preferences.

For instance, many areas in the PRC with significant biomass resources are remote and poor. Biomass-burning power generation in these areas is not the most cost-effective option in terms of investments, resource use, and social development objectives. Instead, disseminating household-based technologies, such as modern biomass stoves, may be more appropriate. These can produce significant economic, social, and environmental benefits.

For more centralized deployment modes, projects must determine the appropriate scale of the operation because some technologies rely on large and consistent resource streams. If transportation costs, infrastructure, and administrative conditions make it possible to absorb materials from a broader region, larger projects may become economically feasible.

Household Biogas Systems

Household biogas technology has developed rapidly with the support of central and local governments and is already at the dissemination stage. Under the 2003–2010 National Rural Biogas Construction Plan, the government provided household subsidies for the construction of biogas digesters.

Ultimately, though, it has been government support that has catalyzed the great progress in developing design standards and construction techniques for these systems. The most common configuration, the 3-in-1 system, combines three household elements. The first is the household biogas digester, which is a device for biogas fermentation with volumes ranging from 6–10 m^3. Biogas fermentation, commonly called anaerobic digestion, produces methane gas by microbial decomposition of organic substances under anaerobic conditions.[24] The biogas is most commonly used for cooking. The second element is the manure, which is the most common organic waste stream for biogas production in the PRC. The final element involves using the fermented sludge and effluent as an organic fertilizer for agriculture, such as vegetable gardens, orchards, or fish ponds.

As shown in Table 3.2, the overall assessment ranked this option very highly. It offers very good economic, environmental, and social benefits to household users. The social benefits were identified from a beneficiary impact assessment undertaken by the Asian Development Bank (ADB) with the Center for Integrated Agricultural Development of China Agricultural University. Box 3.2 highlights the environmental benefits of household biogas systems.

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23 Scores presented are likely to change over time due to many factors, including the rate of technology development and changes in rural energy needs. More advanced technologies, including cellulosic ethanol production, Fischer-Tropsch synthesis, and fast pyrolysis, are still in the research and development stage, and their technical, economic, environmental, and social impacts were not analyzed. In addition, the scoring for village-scale gasification technology is not presented because it performed poorly both technically and institutionally over the past 10 years. However, there are currently new plants being built in Liaoning Province, the Beijing suburbs, and a few other locations. These projects should be evaluated carefully to see if previously identified technical and institutional challenges are being addressed. If dramatic improvement can be achieved, village-scale gasification technology should be reconsidered.

24 The biogas produced by anaerobic digestion of animal waste typically contains about 60%–70% methane, 30% CO_2, and a 5% mixture of hydrogen, nitrogen, ammonia, hydrogen sulfide, and water vapor.

Table 3.2: Scoring for Household Biogas Systems

Criteria	Score	Comments
Technical Evaluation	★★★★★	Especially applicable to less developed rural areas for supplying farmers with clean energy for cooking and lighting. Not appropriate for farmers: (i) in regions rich in coal, solar, wind, and hydropower resources; (ii) who lack stable supplies of raw materials, such as in nomadic areas; (iii) in developed regions with access to modern energy; (iv) in underdeveloped areas lacking support for building and maintaining digesters; and (v) in regions that experience severe cold.
Economic Assessment	★★★★★	Biogas digesters have a low investment cost. In addition to cooking gas for household use, another valuable output is high-quality fertilizer, which can be used to enhance the output and quality of a variety of agricultural products, resulting in high economic and financial returns. For a sample village with 200 households, 200 biogas digesters are constructed with an investment of CNY1,420,000, a cost in annual operation and maintenance of CNY3,942,000, and annual economic benefits of CNY6,812,780; therefore, its financial internal rate of return (FIRR) is 54% and economic internal rate of return (EIRR) is 55%.
Environmental Impact	★★★★★	Utilizing livestock manure in a household digester can improve the local environment by avoiding wastewater pollution, providing clean cooking gas (which reduces indoor air pollution from traditional cooking stoves), and reducing chemical fertilizer use when the digester effluent is used as fertilizer.
Social Impact	★★★★★	Project household income rose by 86.4% compared to non-project households through increased income from pig and fruit sales and reduced expenses on fertilizers, pesticides, and fuel. Time for house chores also decreased for project households (77.8% for cooking and 67.5% for boiling water). Household sanitation and household health were improved due to improved cooking and sanitation facilities. Job opportunities created by biogas development mainly occur in digester unit construction and biogas-related enterprises.
Comprehensive Result	★★★★★	

Table 3.3: Cost–Benefit Analysis for Household Biodigesters for Cooking and Heating Application (200 Households)

Initial Investment (CNY)	**Annual O&M Cost** (CNY)	**Annual Economic Benefit** (CNY)	**Net Benefit** (CNY)	**EIRR** (%)	**FIRR** (%)	**Benefit–Cost Ratio**	**Payback Period** (years)
1,420,000	3,942,000	6,812,780	2,971,532	55	54	1.56	0.5

EIRR = economic internal rate of return, FIRR = financial internal rate of return, O&M = operation and maintenance.

Given their significant advantages, the government should continue to support and promote the household biogas systems in rural villages.

Box 3.2: Environmental Benefits of Rural Household Biogas Systems

Cofinanced with the Global Environment Facility grant, Loan 1924-PRC undertook an energy and environmental monitoring and assessment program that included over 340 farm households in the provinces of Shanxi, Hubei, Henan, and Jiangxi.

Over two years, household energy and material use were measured and samples of soil, biogas yard water, fertilizer, and agriculture products were gathered and tested and comparative measurements were made on indoor air quality. The findings provided important quantification on the economic, environmental, and health benefits of rural biogas systems.

Compared to non-project households:

- Crop production increased 42% and production value increased 25%.
- Chemical fertilizer use decreased 37.1% and fertilizer cost decreased by 39.3% per household.
- Pesticide use decreased by 33.7% and pesticide cost by 98.6% per household.
- CO_2 discharge decreased 53%, SO_2 by 39.4%, NO_X by 47%, and TSP by 52%.
- CO_2 decreased 80%, PM_{10} by 55%, SO_2 by 7.8%, NH_3 by 7.8% and Fluoride decreased by 24%.

Based on these results, the overall impacts on the environment are considered to be significantly positive. The project is expected to reduce about 84,429 tons of CO_2 annually.

Recommendations. Given their significant advantages, the government should continue to support and promote the household biogas systems in rural villages. It will continue to be the main approach for upgrading and improving the cleanliness of residential cooking fuel and improving rural household sanitation.

Ethnic minority regions could be targeted, building on recent efforts by the State Ethnic Affairs Commission. Weather conditions in the southwest, where many ethnic minorities live, are suitable for biogas development.

The government, however, should revise its subsidy policy for rural biogas. Under the current program, subsidy levels are based on regional differences when they should be based on household income levels within the community. Substantially higher subsidies should also be supported for especially poor farmers. This affordability issue is discussed in more detail in Chapter 5.

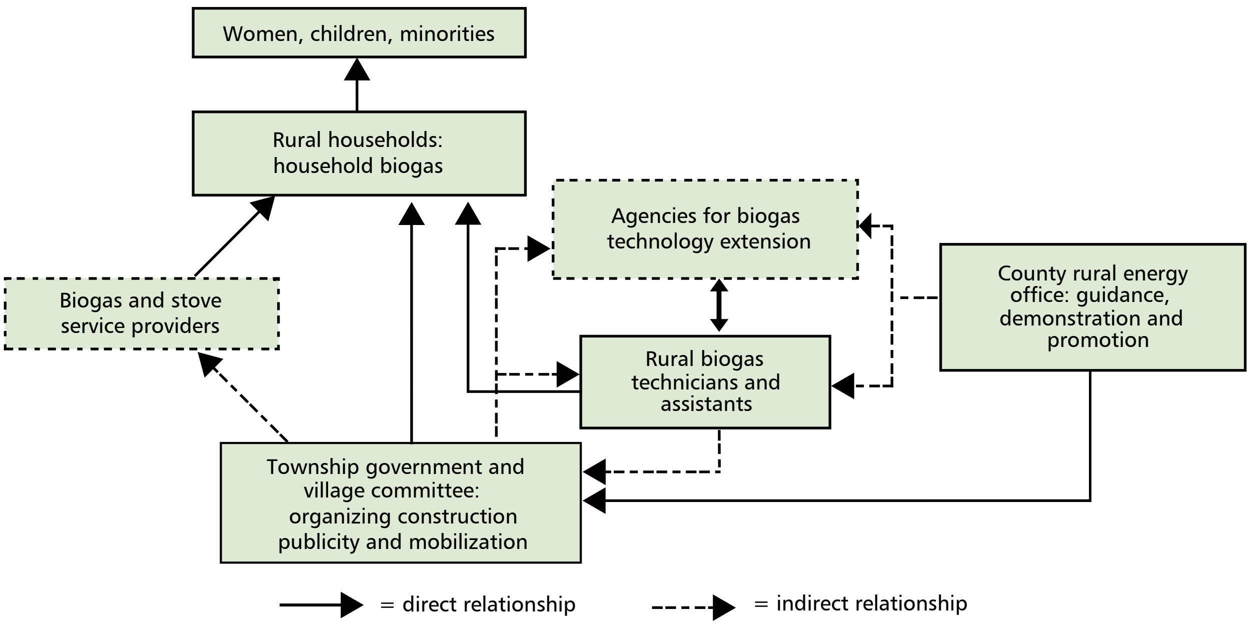
The PRC could further improve its already successful industry framework for household biogas systems (Figure 3.1). This framework includes:

(i) construction of biogas digesters at the county level, dependent on trained technicians and small-scale industries;
(ii) supply of auxiliary products, such as biogas stoves, which is mainly dependent on mid-to-large-scale industries with procurement at the provincial level and distribution at the county level; and
(iii) technical support and service centers at the county level, with training of technicians at the provincial level and carried out at the county level (some 150,000 farmer technicians have received professional certificates for biogas production, issued by the Ministry of Agriculture).

Two main improvements can be made to this framework. First, the availability of technical support service centers should be strengthened, as it is currently inconsistent between counties. As a result, many rural households have stopped using biogas because technical support was not available after their systems were constructed and problems occurred. To address this problem, a tertiary service network at county, township, and village levels should be set up.

Secondly, household biogas systems are of special significance to women, children, and ethnic groups,

Figure 3.1: Household Biogas Operational Model



and the design and implementation of these systems need to be more sensitive to their special needs. Consultancy services from sociologists can help feature more participatory and relevant project designs for communities.

Figure 3.1 illustrates how several stakeholders could be more involved: government implementation and executing agencies; rural grassroots coordinating and organizing agents; major beneficiaries in households; special interest groups (e.g., rural biogas technicians, women, and ethnic minorities); and technology extension institutes, biogas research institutions, and associations for rural biogas service providers.

Recently, however, the government has been paying more attention to the biogas production potential of medium-to-large biogas plants and is calling for their accelerated development on large-scale livestock farms.

Medium and Large Biogas Plants

Historically, medium-to-large biogas plants in the PRC were set up mainly for processing liquid effluents from the agricultural sector for the purpose of environmental protection. Recently, however, the government has been paying more attention to the biogas production potential of these facilities and is calling for their accelerated development on large-scale livestock farms. In addition, some domestic biogas engineering companies have started to introduce European technology with local modifications, and some European biogas equipment suppliers have entered the market by founding PRC companies (e.g., ENVITEC Beijing; COWATEC Shanghai). However, the capacity to build and operate these plants is still insufficient.

These plants have good environmental and social effectiveness because they provide clean and convenient energy, and reduce wastewater pollution, a strong driver for the technology. When used for electricity generation, they typically have better financial returns than if the gas is used only for rural cooking and heating (Table 3.4). These systems can overcome the cost inefficiencies

Table 3.4: Scoring for Medium and Large Biogas Systems

Criteria	Score	Comments
Technical Evaluation	★★★★	Can be designed according to environmental wastewater discharge requirements (the "energy–environmental protection design"), or can be integrated into the surrounding agricultural system (the "energy–ecological construction design").
Economic Assessment	★ (at village level)	Compared with household systems, larger systems that provide cooking gas at the village level have lower economic and financial returns due to the higher investment needed for the gas distribution system. A sample livestock farm biogas plant that can supply the gas to 200 households will need an investment of CNY1,560,000, cost CNY138,473 in annual operation and maintenance, and provide annual economic benefits of CNY193,770; therefore, its financial internal rate of return (FIRR) is negative and economic internal rate of return (EIRR) is only 7%.
	★★ (if includes electricity generation)	A sample power plant with a medium-to-large biogas plant with 75 KW installed capacity entails an initial investment of CNY1,017,000 and payment of CNY256,250 in annual operation and maintenance costs, while resulting in annual benefits of CNY351,000; so the FIRR is 4% and EIRR is 34%.
Environmental Impact	★★★★★	Offers an effective method of dealing with pollution from the livestock industry. The environmental benefits of biogas production are evident in the amounts of (i) livestock wastes that are properly treated, (ii) harmful wastes disposed, and (iii) bacteria removed. Systems also reduce greenhouse gas emissions by substituting biogas for coal (biogas is carbon neutral) and by capturing methane from animal manure.
Social Impact	★★★	Various government incentives can be important in attracting private sector participation and investment, but government subsidies for medium and large biogas plants may become a huge burden for the government.
Comprehensive Result	★★★ (at village level for cooking and heating) ★★★1/2 (if it includes electricity generation)	

Table 3.5: Cost–Benefit Analysis for Medium and Large Biogas Plants for Rural Heating, Cooking, and Electricity (200 Households)

System Size	Initial Investment (CNY)	Annual O&M Cost (CNY)	Annual Economic Benefit (CNY)	Net Benefit (CNY)	EIRR (%)	FIRR (%)	Benefit–Cost Ratio	Payback Period (years)
Cooking and heating (200 households)	1,560,000	138,473	193,770	140,561	7	Negative	1.04	11.1
Power generation (75 KW)	1,017,000	256,250	351,000	432,348	34	4	1.86	2.4

EIRR = economic internal rate of return, FIRR = financial internal rate of return, O&M = operation and maintenance.

of smaller anaerobic digester projects. These inefficiencies are most evident when combined heat and power (CHP) production or biogas refining to bio-methane for gas grid feeding or vehicle use is applied.

While the motivation of livestock enterprises to build medium and large biogas plants is high and large-scale biogas plants have good market prospects, a number of issues limit their development, including operational practices and biogas production efficiency in terms of power production.

While the PRC typically uses animal manure in these plants, it is also possible to undertake crop straw digestion, also called dry digestion. This is an emerging technology for fermenting crop stalks. Straw is co-composted with enzyme-producing bacteria and then introduced together into the digester to generate biogas. This technology is still in the development stage, although it has been demonstrated in more than 12 provinces, achieving good initial results.

Recommendations. Currently, levels of required investments are high compared to the capabilities of the industry, which has led to slow growth for this important technology. To help address this problem, the government has already increased subsidies for large-scale biogas plant construction on livestock farms, but more targeted subsidies and tax incentives are needed. These are discussed in more detail in Chapter 5, "Breaking the Cost Barrier."

While the motivation of livestock enterprises to build medium and large biogas plants is high and large-scale biogas plants have good market prospects, a number of issues limit their development, including operational practices and biogas production efficiency in terms of power production.

The commercial side of biogas plants will need to be developed through energy and fertilizer sales, co-feedstock treatment fees, and certified emissions reductions under the Kyoto Protocol's Clean Development Mechanism.

Separate from investment-related recommendations, MOA should strengthen the capacity of training centers to ensure the reliable performance of biogas plants in their region. Training programs can improve how local technicians design and operate systems, improve their business practices, and develop the operational models required for the centralized biogas plants.

Pellet/Briquette Fuel

Production of biomass pellet/briquette fuel refers to the process of pressing loose agricultural residues and wood wastes into pellets or briquettes. Typical biomass fuels include pellet and briquettes of corn and wheat straw. The fuel has an energy density similar to that of mid-quality bituminous coal. Biomass stoves, the predominant equipment using pellet fuel, burn at a higher efficiency and expel less pollution than traditional firewood stoves.

The government has committed to increasing its support in developing pellet fuel. The equipment for producing and using the fuel has greatly improved in recent years. However, as a whole, the biomass pellet/briquette fuel industry is still in the demonstration stage. General application of biomass pellet fuel depends on scaling-up manufacturing of pelletizing equipment and stoves. Through early commercial projects, the technology is expected to continually improve.

According to the overall assessment, pellet/briquette technology has good integrated performance, with high environmental, economic, and social effectiveness (Table 3.6). The technology is clean and convenient, and provides a high economic return because it replaces conventional fuel when used for winter heating.

Briquette/pellet fuel can be promoted as an emerging approach to modernize and improve rural energy. It has a broad range of applicability and, in certain areas, can be supplementary to biogas for cooking

Table 3.6: Scoring for Pellet/Briquette Technology

Criteria	Score	Comments
Technical Evaluation	★★★★	High energy density ensures high combustion temperatures and improved combustion characteristics. Biomass stoves, the predominant equipment using pellet fuel, burn at a higher efficiency and expel less pollution than traditional firewood stoves.
Economic Assessment	★★★★★	Their financial return depends on the affordability of the pellet fuel price. Therefore, government policies to support more affordable biomass pellet technologies are likely to be needed to achieve wider utilization. Because it minimizes labor and straw collection costs, small-scale production appears to be more economically viable than large-scale production. A sample biomass pellet plant that can supply pellets to 200 households for cooking and heating will invest CNY1,330,000, pay annual operation and maintenance costs of CNY194,500, and obtain annual economic benefits of CNY400,000; therefore, its FIRR is 12% and EIRR is 27%.
Environmental Impact	★★	Air quality in rural households using biomass pellets is reasonably better than households that mainly burn coal, with low emissions of particulate matter, SO_2, NH_3, and CO, while reducing pollution and respiratory diseases.
Social Impact	★★★★	Farmer supply of raw materials for pellet fuel increases direct household revenue. Job opportunities occur mainly in production of pellet/briquette fuel, manufacturing of pellet/briquette-fueled stove equipment, and collecting raw materials. In regions with high labor and straw collection costs, production of biomass pellet/briquette fuel is likely to be economically unprofitable unless the government provides a subsidy to compensate for the difference in production costs and revenues.
Comprehensive Result	★★★1/2	

CO = carbon monoxide, EIRR = economic internal rate of return, FIRR = financial internal rate of return, NH_3 = ammonia, SO_2 = sulfur dioxide.

Table 3.7: Cost–Benefit Analysis for Pellet/Briquettes for Cooking and Heating Application (200 Households)

Initial Investment (CNY)	**Annual O&M Cost** (CNY)	**Annual Economic Benefit** (CNY)	**Net Benefit** (CNY)	**EIRR** (%)	**FIRR** (%)	**Benefit–Cost Ratio**	**Payback Period** (years)
1,330,000	194,500	400,000	303,425	27	12	1.43	4.4

EIRR = economic internal rate of return, FIRR = financial internal rate of return, O&M = operation and maintenance.

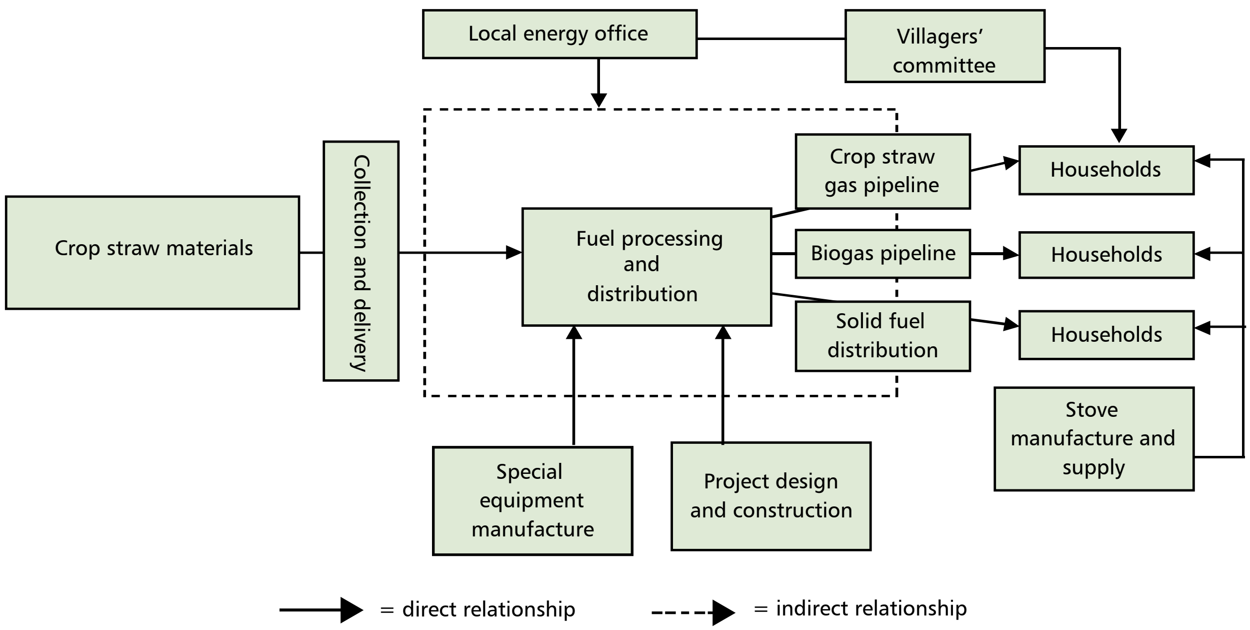
Source: ADB. 2008. *Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

applications. Because pellet technologies provide both cooking and heating energy (in contrast to the many other options that only provide cooking gas), they are especially suitable in northern PRC.

Recommendations. Several options are open for guiding industrial development, either through a network of local producer-distributors or a centralized system. A centralized plant would produce pellet fuel (or fuel gas) using biomass feedstock that is collected from surrounding farmers and distribute it to regional households either through a pellet fuel distribution system or pipeline network for fuel gas. Centralized systems rely on the effective management of collection, transportation, and storage of straw. The industry supply chain is shown in Figure 3.2.

In the long run, enterprises should be the main player in the pellet/briquette fuel market. As such, subsidies for enterprises and households should be gradually replaced by commercialized mechanisms. Key issues for small- and medium-sized enterprises seeking to engage in this industry include (i) getting external financing in addition to government subsidies, particularly for research and

Figure 3.2: Industry Supply Chain for Pellet/Briquette Fuel



development—which could come from venture capital and joint ventures with research institutes—and (ii) outsourced processing schemes, which are practical arrangements used while the industry remains at an initial demonstration and extension stage. Meanwhile, for heating and cooking stoves, outsourced processing contracts with enterprises that produce boilers, solar energy, and heating and/or cooking stoves will greatly reduce investment and processing costs.

Village committees can be instrumental in promoting and coordinating pellet/briquette fuel use. Rural households will also play an important role in supplying raw biomass and consuming the fuel. Other major stakeholders will include local rural energy offices, research and development enterprises, and intermediaries in collecting raw materials from rural households for sale to pellet/briquette fuel-processing factories.

Power Generation from Straw

Direct combustion technology means that biomass is burned in steam boilers to generate high-pressure steam, which drives a steam turbine that transfers the power to the generator to create electricity.

The major differences between this technology and traditional power generation using fossil fuels lie in the need for pretreatment of biomass feedstock and in the design requirements for biomass boilers, which guarantee effective combustion, heat transfer efficiency, and stable long-term operation using crop straw residues.

Internationally, biomass combustion technology is developed to a relatively mature level. In the PRC, however, pertinent experience is still lacking in design, manufacturing, and operation of pretreatment equipment and boilers adopted for straw-fired power generation. In early 2006, the Renewable Electricity Law set a tariff premium that, after about 18 months of implementation, resulted in approval of more than 50 biomass power plants by the National Development and Reform Commission and their local counterparts (Box 3.3). The total planned capacity is 1,500 megawatts (MW), and the total planned investment is about CNY10 billion. It is estimated that in 2007, at least 10 power plants were put into operation with installed capacity of about 200 MW.

A second option is co-combusting (or co-firing) of crop straw in existing coal-fired power plants and is attractive in terms of technological adaptation and

Box 3.3: Biomass Power Plants in the PRC

Until recently, power generation with agricultural residues in the PRC has mostly taken place at sugar refineries in the south, where they use crushed sugar cane residue (called bagasse) as the fuel and most of the plant output is consumed by the sugar refinery. There are 300 power plants of this kind (with a total capacity of 800 megawatts [MW]) in Guangdong Province and Guangxi Zhuang Autonomous Region. A number of others are located in Yunnan Province.

The PRC has recently started developing a new batch of power plants fueled with crop residues (husks and stalks).

The first plant, developed by Guoneng Bio-Energy Corporation in Shandong Shanxian, began operating and selling power to the grid on 1 December 2006. The project used imported foreign technology. By 20 December 2006, a second plant in Jiangsu Suqian, developed by CECIC Biomass Investment Corporation, started operation and is regarded as the first straw-fired project exclusively utilizing domestic technologies.

By the end of 2007, about 25 large-scale biomass power plants with an installed capacity of more than 600 MW began operating and selling power to the grid. These projects are expected to generate 3,000 gigawatt-hour of power, more than 4 million tons of biomass will be converted into clean fuel, and farmer income in the plant areas is projected to increase by more than CNY1.2 billion annually. In addition, 2 mtce of coal will be saved and 6 million tons of CO_2 emissions will be avoided, all of which will contribute to significant economic, social, and environmental benefits.

economic benefits. This method is employed on a commercial basis in Europe and has been proven through demonstration projects in many other countries. However, it has not been promoted in the PRC because of a lack of a verifiable approach for measuring and monitoring the actual percentages of biomass and coal used in the boiler. As a result, despite its many benefits, this technology does not qualify for incentives under the Renewable Energy Law. Once this problem is resolved, co-firing technology should develop significantly.

According to the assessment of the TA study, power generation and combined heat and power systems are an efficient and clean approach for large-scale utilization of straw resources, and an effective solution for unmanaged burning and piling of straw waste (Table 3.8). However, its assessment would improve if the domestic technology could be developed to perform better.

The main obstacles confronting straw-to-power technology include securing a stable and long-term straw residue supply, and managing the variations in the heat load demand for combined systems. The location of these power plants should be decided after more a comprehensive study of regional straw availability.

Co-firing of crop straw with coal is an even more attractive option among biomass power generation technologies, in terms of technological adaptation and economic benefits. Its financial and economic returns are significantly higher than other options, because it is a low-cost technical modification that allows existing coal power plants to burn biomass and reduce coal supply for the same plant output (Table 3.9).

Recommendations. In addition to securing government support through tax incentives (discussed in Chapter 5), the private sector must

The major differences between power generation from straw and traditional power generation using fossil fuels lie in the need for pretreatment of biomass feedstock and in the design requirements for biomass boilers, which guarantee effective combustion, heat transfer efficiency, and stable long-term operation using crop straw residues.

Table 3.8: Scoring for Direct Crop Straw Combustion

Criteria	Score	Comments
Technical Evaluation	★★★★	This technology has several advantages: a fairly large construction scale, high-energy conversion efficiency, and no secondary pollution. Several technical problems still need to be solved, including boiler corrosion and slag formation, fuel pretreatment, technological localization, and domestic manufacturing development. With several new straw-fired power plants being put into operation, such technical obstacles can gradually be overcome.
Economic Assessment	★★★	Plants require collection and transporting of large amounts of biomass to the plant site. These costs can be high and need to be managed well. Economic and financial returns are lower than the gasification option because it currently relies on imported (expensive) technology. A sample direct combustion power plant with 25 MW of installed capacity entails an initial investment of CNY308,420,000 and payment of CNY29,500,000 in annual operation and maintenance costs, while resulting in an annual benefit of CNY72,600,000; so the FIRR is 11% and EIRR is 16%.
Environmental Impact	★★★	Operation of biomass power plants can significantly reduce field-burning of crop straw in rural areas, thereby reducing air pollution and improving the rural environment. Compared with the same-sized coal-fired power plant (1.38 gigawatts per year), a crop residue power plant can save more than 100,000 tons of coal and reduce 400 tons of SO_2 emissions. Through the modern technology, burning crop residues instead of coal does not produce harmful waste gases, making desulphurization and NOx scrubbing unnecessary. Operation of a 25-megawatt biomass power plant could reduce carbon dioxide emissions by 100,000 tons per year, compared with the same-sized coal power plant. The smoke and dust produced has no water-soluble component, so discharged wastewater needs no special treatment, except filtering of suspended particles. The ash residue from biomass combustion can be used as a high-quality potassium fertilizer.
Social Impact	★★★★	Farmer revenue from crop straw sales to biomass power plants can have significant economic impacts, especially in poverty-stricken agricultural counties that have sufficient biomass resources. A household with four family members could earn about CNY600 in crop straw sales, equivalent to 40% annual income of poor farmers in western provinces. Employment opportunities will mainly come from construction and operating jobs at power plants and in collecting crop straw.
Comprehensive Result	★★★1/2	

EIRR = economic internal rate of return, FIRR = financial internal rate of return.

Table 3.9: Scoring for Co-combustion of Coal and Crop Straw

Criteria	Score	Comments
Technical Evaluation	★★★★★	The boiler design does not need to be changed as long as energy content of the crop straw is not more than 20% of total heat input to the boiler. The critical elements of the technology are the crop straw handling, preparation, and feed equipment needed to get proper mixing of the coal and biomass to ensure good combustion of the mixture.

continued on next page...

Table 3.9 continued

Criteria	Score	Comments
Economic Assessment	★★★★★	A sample power plant for co-combustion of coal and straw with a 32-MW installed capacity entails an initial investment of CNY83,570,000 and payment of CNY7,360,000 in annual operation and maintenance costs, while resulting in annual benefits of CNY35,162,400, so the FIRR is 30% and EIRR is 53%. This assumes 10% biomass co-firing (although 20% is technically possible).
Environmental Impact	★★★	Co-combustion of coal and crop straw for power generation at existing coal power plants has good environmental and social effectiveness, as do the other crop straw technologies.
Social Impact	★★★	
Comprehensive Result	★★★★	

EIRR = economic internal rate of return, FIRR = financial internal rate of return, NOx = nitrogen oxide.

Table 3.10: Cost–Benefit Analysis for Power Generation from Straw

Technology	Number of Plants	Initial Investment (CNY)	Annual O&M Cost (CNY)	Annual Economic Benefit (CNY)	Net Benefit (CNY)	EIRR (%)	FIRR (%)	Benefit–Cost Ratio	Payback Period (years)
Direct Crop Straw Combustion	25	308,420,000	29,500,000	72,600,000	57,543,910	16	11	1.46	5.4
Co-Combustion of Coal and Crop Straw	32	83,570,000	7,360,000	35,162,400	47,763,394	53	30	3.55	1.7

EIRR = economic internal rate of return, FIRR = financial internal rate of return, NOx = nitrogen oxide, O&M = operation and maintenance, SO_2 = sulfur dioxide.

also be able to negotiate economic arrangements for the collection and transportation of raw materials within the power plant's collection radius to reduce long-term supply risks and keep supply lines short. Also, crop residues are highly seasonal and arrangements are needed to store the biomass resources to ensure a stable supply to the plant over the course of a year. Farmers' participation also relies on such arrangements.

Thus, it is important to develop clear organizational arrangements between farmers and power plants. The following two arrangements are possible:

The "company + household" model. The power plant directly signs an agreement with rural households on annual supply of crop straws, and the power plant purchases the raw materials according to the contract signed. In this arrangement, the plant must manage a large number of contracts and organize the collection, storage, and transportation of the crop straw.

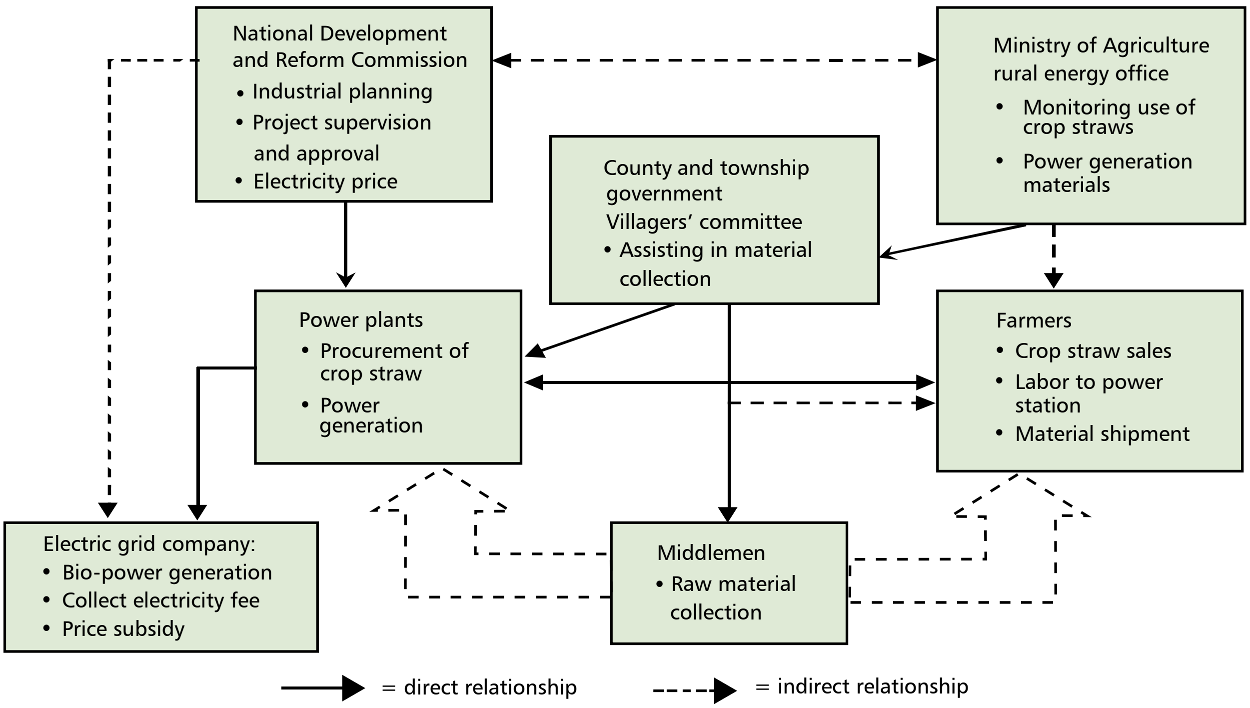
The "middlemen" model. The power plant signs an agreement with one or more supply agents, who purchases the crop straw from the farmers and arranges for the collection, storage, and transportation to the power plant. In this arrangement, the power plant can establish a fixed price with the middleman, which provides more certainty to their economics. See Figure 3.3.

The latter model may be more prevalent and has been adopted in pellet/briquette fuel production.

Given the typical county-sized collection radius, county governments can also play an important role in facilitating and mediating between power plants

It is important to develop clear organizational arrangements between farmers and power plants.

Figure 3.3: Industry Supply Chain for Power Generation from Straw



and rural households on crop straw supply, at least in the early stages before a competitive market can be established.

Small and scattered rural households hold the weaker position, so local governments can emphasize farmer benefits. One solution may be a tripartite Crop Straw Pricing Consultation Board (CSPCB) representing county government, power plants, and households to promote transparency in pricing and the interests of farmers confronting large power plants in less-than-competitive markets.

Crop straw gasification for electricity generation has good economic, environmental, and social effectiveness, but its adoption faces several technical and institutional challenges.

Crop Straw Gasification

Straw gasification for generating electricity entails a process of gasifying biomass to drive an internal combustion engine or gas turbine that drives a generator to produce electricity. Biomass gasification, on the other hand, refers to the chemical process of converting biomass into a combustible gas through a high-temperature partial oxidation process.

Internationally, a few "combined cycle" biomass gasification projects, which offer both biogas and electricity, have been developed commercially. However, since the technology for this is not mature and not yet competitive, biomass gasification power plants have not operated on a large scale commercially. At the end of 2006, about 50 MW of electricity generation from rice husk gasification was operating in the PRC (however, this type of

Table 3.11: Scoring for Crop Straw Gasification

Criteria	Score	Comments
Technical Evaluation	★★★	The volumetric heat content of the producer gas will vary depending on the gasifier design and the amount of air used in the gasification process. The gas produced in the gasifier contains tar, ash, and alkaline metals that can be difficult to remove at a low cost.
Economic Assessment[a]	★★★★	It provides a reasonable FIRR, because of the subsidy provided under the Renewable Energy Law. A sample power plant for 6-MW crop straw gasification entails an initial investment of CNY39,039,000 and payment of CNY7,800,000 in annual operation and maintenance costs, while resulting in annual benefit of CNY17,820,000, so the FIRR is 21% and EIRR is 29%.
Environmental Impact	★★★	The environmental impact is similar to that of electricity generated by direct straw combustion.
Social Impact	★★★★	The social impact is similar to that of electricity generated by direct straw combustion.
Comprehensive Result	★★★	

[a] The data used for evaluation of this power generation option came from the 4-MW crop straw gasification project in Xinghua, Jiangsu Province surveyed by Jia Xiaoli (consultant of biomass power generation of the TA team) in 2007.

EIRR = economic internal rate of return, FIRR = financial internal rate of return.

Table 3.12: Cost–Benefit Analysis for Crop Straw Gasification

Number of Plants	Initial Investment (CNY)	Annual O&M Cost (CNY)	Annual Economic Benefit (CNY)	Net Benefit (CNY)	EIRR (%)	FIRR (%)	Benefit–Cost Ratio	Payback Period (years)
6	39,039,000	7,800,000	17,820,000	13,839,068	29	21	1.80	2.8

EIRR = economic internal rate of return, FIRR = financial internal rate of return, O&M = operation and maintenance.

Source: ADB. 2008. *Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

gasifier technology cannot meet large-scale power generation applications). In Jiangsu, a 4-MW entrained flow biomass gasification power plant has also been operating for several years.

Crop straw gasification for electricity generation has good economic, environmental, and social effectiveness, because it provides clean electricity, utilizes agricultural waste, and can help increase farmer income (Table 3.11). However, there are a number of obstacles to expanding the use of this technology.

Most significantly, the electricity generated is difficult to sell to the grid because (i) the utility company may not be interested in such a small amount of electricity, and (ii) the inclusion of required grid protection and safety equipment are not economical at small plants. In addition, the gas produced contains tar, ash, and alkaline metals that must be removed to safe levels before the gas can be burned in a gas engine or gas turbine for power generation. Doing so at low cost has been difficult.

Biofuels

Interest in biofuels as a substitute to fossil fuels will continue to increase because of concerns over the environment, energy security, and climate change. However, development of this industry must be carefully considered, as the recent food-versus-fuel debate has shown, and the full life-cycle of biofuel benefits must be considered. Marginal lands, including desolated hills and slopes, river-basin flood areas and winter idle lands, will be the most suitable for growing energy crops.

ADB's assessment noted that the three main feedstocks for bioethanol production—sweet sorghum, cassava, and sugarcane—have good environmental, economic, and social effectiveness, although each raises concerns regarding impacts on the efficient use of rural land, structuring of energy plantations, and equity of farmer income and employment.

Technologies for bioethanol and biodiesel are in the test phase or just entering commercialization; their industrialization is expected within the next 5–10 years. Other biofuel technologies, such as fast pyrolysis oils, biomass-based Fischer-Tropsch synthesis gas, and biohydrogen production face technology and cost barriers.

The TA study considered the potential of energy crops for bioethanol and biodiesel production. It did not, however, study forestry resources (e.g., oil seed trees) as another potential resource for biofuels.

Bioethanol. After years of trials in selected provinces, the government has begun pouring huge investments into ethanol. The country produced 1.02 million tons of bioethanol from stored corn stocks and other raw materials in 2005. The ethanol is added to petrol at a ratio of 1:10 for automobiles.[25] The government estimates that by 2010, ethanol-mix petrol will account for half of the country's petrol consumption.

Large firms have announced ambitious plans for bioenergy investments. China National Petroleum Corporation signed an agreement with the government of Sichuan Province in southwest PRC to develop facilities to produce 600,000 tons of automotive-grade ethanol from sweet potatoes annually and 100,000 tons of biodiesel from the seeds of the jatropha curcas tree. China National Cereals, Oils and Foodstuffs Corporation said in October 2007 it would invest CNY1 billion to build a major ethanol plant in the Guangxi region, also in southwest PRC. The plant, with a capacity of 400,000 tons, will lift 1.1 million farmers out of poverty by growing cassava as the raw material for the plant, said Yue Guojun, head of the corporation's bio-chemical and bioenergy division.[26]

ADB's assessment noted that the three main feedstocks for bioethanol production—sweet sorghum, cassava, and sugarcane—have good environmental, economic, and social effectiveness, although each raises concerns regarding impacts on the efficient use of rural land, structuring of energy plantations, and equity of farmer income and employment. Important differences in their relative cost-effectiveness stem from regional factors, such as climate and water availability, feedstock costs, and by-product values.

The highest score went to sweet sorghum, as it has higher economic and financial returns than the other two crops. Ethanol production from sweet sorghum is best suited to the northeastern and northwestern regions, the middle and lower reaches of the Yellow River, and the Qinghai-Xizang tableland.

The assessment gives sugarcane ethanol a moderate priority because of its attractive regional potential. Production is best suited to southern and tropical regions, such as Guangdong, Guangxi, Hainan, and Yunnan. The government should support enterprises using sugarcane for ethanol by offering modest subsidies according to the environmental and social benefits generated in the process.

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25 Xinhua News Agency. 2006. China to Provide Subsidies to Bio-Energy Sector. Beijing Pioneer Technology Co. Ltd. 1 December. Available: http://210.51.191.165/show.php?contentid=20866

26 Ibid.

Table 3.13: Scoring for Biofuels

Criteria	Score	Comments
Bioethanol (from sweet sorghum, cassava, and sugarcane)		
Technical Evaluation	★★★★	Sugarcane, sweet sorghum, and cassava have ethanol conversion ratios that are two to three times larger than those for corn or wheat, and are considered nonfood agricultural products. Production of fuel ethanol involves fermentation, a process by which microbes convert sugar or starch into ethanol and carbon dioxide. Cellulosic materials can also be used, after hydrolysis, for ethanol fermentation.
Economic Assessment	★★★ (for sweet sorghum) ★ (for cassava and sugarcane)	Sweet sorghum has a higher conversion ratio and lower feedstock cost than cassava. Compared with sugarcane, sweet sorghum seeds have a significant by-product value that offsets its slightly lower conversion ratio. Also, sweet sorghum can tolerate soil infertility and saltiness and can be planted in any type of soil. The cost–benefit analysis of typical bioethanol projects shows that sweet sorghum provides the highest economic benefit with an FIRR of 12% and an EIRR of 15% for a plant capacity of 5,000 tons per year and an initial investment of CNY17,500,000.
Environmental Impact	★★★ (for sweet sorghum) ★★★★ (for cassava and sugarcane)	Testing of ethanol fuel mixtures with both gasoline and diesel has generally shown positive benefits. E_{10} (gasoline mixed with 10% ethanol by volume) reduced Pm by 44%, CH_4 by 26%, and CO_2 emissions by 15%[a] compared to gasoline, but NOx emissions increased under some combustion conditions.[b] A 10%–15% mix of ethanol into diesel has been shown to reduce particulate matter by approximately 20%–40% and NOx emissions by 4%–5%.[c] Can be considered carbon-neutral because the carbon dioxide absorbed from the atmosphere during crop growth is returned to the atmosphere when fuel is burned. However, under certain conditions, energy crops can undermine their environmental potential: (i) they require phosphorus and nitrogen fertilizers, which can result in physicochemical changes in soil character and produce additional greenhouse gases (N_2O); (ii) may cause loss of habitat, biodiversity, and basic ecosystem functions if their cultivation is not properly planned and managed; and (iii) may also diminish soil as a carbon sink and increase greenhouse gas emissions to the atmosphere.
Social Impact	★★★★★	The biofuel industry will drive the growth of energy crop plantations. The development of this industry can significantly impact rural employment and poverty reduction and could be the most critical biomass technology for rural household income generation and participation of women and ethnic minorities. Job opportunities from biofuel development mainly occur in energy crop cultivation, raw material collection, and biofuel production. Small farmers dominate energy crop production in the biofuel industry.
Comprehensive Result	★★★★ (for sweet sorghum) ★★★1/2 (for cassava and sugarcane)	

continued on next page...

Table 3.13 continued

Criteria	Score	Comments
Biodiesel (from Rapeseed)		
Technical Evaluation	★★★★	Biodiesel has many advantages, such as low sulfur and good combustion properties, lubrication properties, and safety performance. Fuel can be used directly in diesel engines without modification or blended with diesel oil (current mixes of biodiesel in diesel oil range from 2%–30%) Provides an alternative fuel not only for public transport vehicles, trucks, and other diesel vehicles, but also for marine transportation, mining, and electricity generation. Can be directly applied in the heating and transportation sectors on a large scale without changing the existing distribution network.
Economic Assessment	★	The cost–benefit analysis of typical biodiesel projects shows that the economic benefit is very low and that both the FIRR and EIRR are negative.
Environmental Impact	★★★★	Biodiesel is a biodegradable, nontoxic fuel. Its positive characteristics (high cetane number, low sulfur and alkyl aromatic compounds, and low volatility) mean reduced emissions of CO_2, HC, and particulate matter compared to conventional diesel. Rapeseed planting on land lying fallow in winter may require additional water for irrigation, which may also lead to biodiversity loss. Similar environmental impacts as bioethanol in terms of potential habitat loss and use of fertilizers. Like bioethanol, can also be considered carbon-neutral.
Social Impact	★★★★	In general, low net income from cultivating rapeseed can be attributed to the high cost of labor. In addition, the government does not subsidize rapeseed cultivation and sets no guaranteed floor price. Low returns from cultivating rapeseed increase its opportunity costs. Farmers hardly profit from current prices.
Comprehensive Result	★★1/2	

CH_4 = methane, CO_2 = carbon dioxide, E_{10} = 10% ethanol and 90% gasoline, EIRR = economic internal rate of return, FIRR = financial internal rate of return, HC = hydrocarbons, N_2O = nitrous oxide, NO_x = nitrogen oxide.

[a] Hu Zhiyuan and Lou Diming. 2005. *Impact Assessment in Life Cycle of Fuel Ethanol Gas Engine Transaction*. 3 (23).
[b] Hu Zhiyuan and Lou Diming. 2005.
[c] Spreen, K. 1999. *Evaluation of Oxygenated Diesel Fuels*. San Antonio, Texas: Southwest Research Institute.

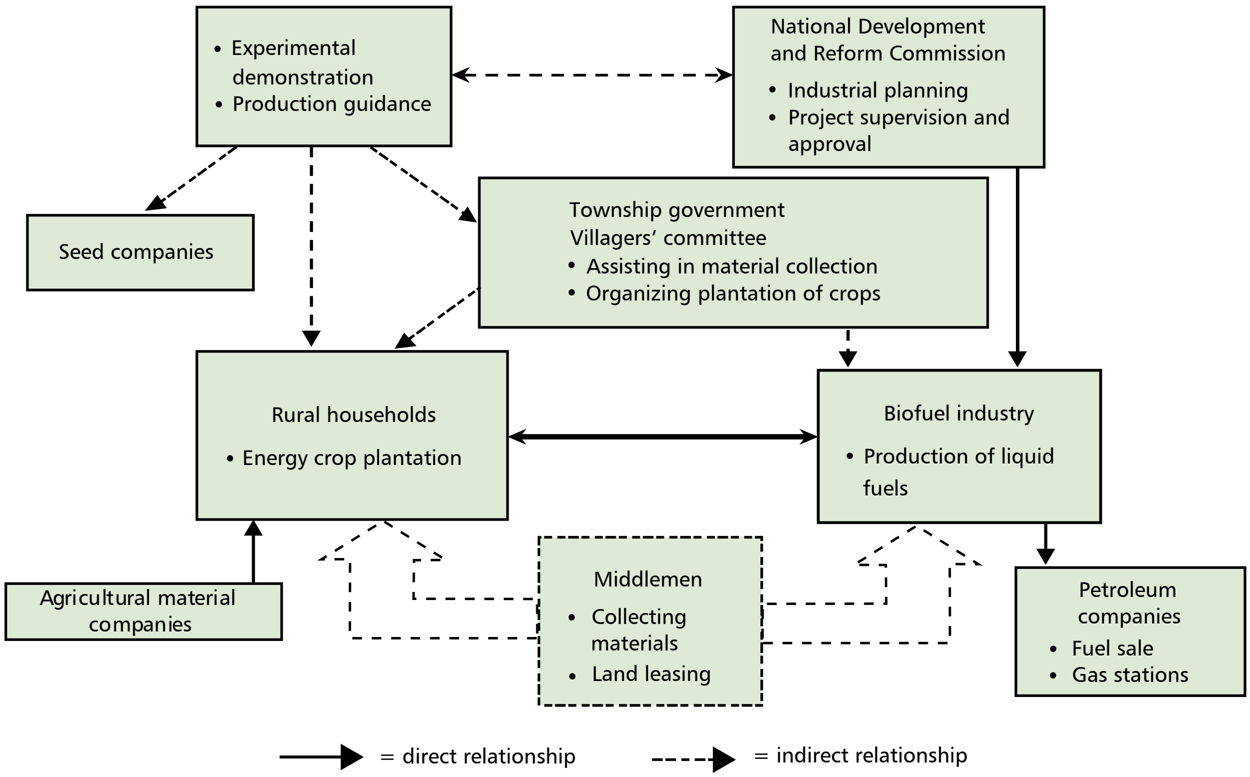
As with sugarcane, the assessment gave cassava and sweet potato moderate priority because of their attractive regional potential. Production is best suited to southern and southwestern regions.

Biodiesel. The PRC also has a national standard for biodiesel and diesel fuel blending, but the country's biodiesel development is still at an initial stage compared with other countries. Private enterprises still face many disadvantages, such as small-scale equipment, low technical experience, inadequate supplies of raw materials, unreliable quality, irregular circulation and a low level of comprehensive utilization.[27]

Production of biodiesel is mainly derived from rapeseed oil, which scored similarly to bioethanol on the technical, environmental, and social criteria, and also shares some similar concerns with bioethanol production. The main difference is that rapeseed oil is a major cooking oil in the PRC and will only be promoted for biodiesel as a winter crop or on marginal lands.

[27] Comprehensive utilization or integrated utilization means that its life cycle process tends to minimize the wastes by reusing or recycling its by-products.

Figure 3.4: Industry Supply Chain for Energy Crop Production



Planting rapeseed in rotation with other crops helps improve soil quality and rebalances soil nutrients for other crops. However, the development of biodiesel from rapeseed is hampered by the relatively high price of rapeseed, which is set by the cooking oil commodity market. As a result, production of biodiesel from rapeseed is not economically or financially attractive, and it appears difficult to commercialize in the near term. Thus, the assessment indicated a low priority.

Recommendations. The development of the biofuel industry depends on the organization of farmers' production and the coordination between farmers and the fuel production industry, which also involves many other stakeholders. The industry supply chain is shown in Figure 3.4.

Initially, the private sector's willingness to participate in biofuel development will mainly be determined by government programs and incentives designed to overcome market barriers and reduce investor risk, which is discussed in Chapter 5. Biofuel producers, in general, are greatly concerned about two risks: (i) price floating between their particular biofuel and its competitive substitutes; and (ii) availability of energy crops, which is closely related to farmer incentives to plant and the economic arrangements with intermediaries and rural households on cultivation, collection, storage, and transportation of raw materials. A biofuel producer needs a contractual arrangement with the scattered small farmers to ensure a regular supply of energy crop for their production facility.

Industry development is complicated by the fact that small farmers dominate energy crop production in the biofuel industry. Farmers will grow energy crops only if they are assured a buyer and a reasonable profit. Government and biofuel

Industry development is complicated by the fact that small farmers dominate energy crop production in the biofuel industry.

To address these challenges, MOA and the National Development and Reform Commission (National Energy Bureau) should coordinate to guide farmers to grow energy crops in conjunction with the construction of biofuel production plants.

producers face several challenges: (i) assuring high farmer participation by guaranteeing a net income from energy crop cultivation that is not lower than that earned from competing crops; (ii) managing and arranging land rental and subcontracts for the kind of large-scale operations required for a cost-effective biofuel industry; and (iii) addressing farmer interests concerning energy crop prices, land rental rates and contracts, labor practices, salary standards, and regulations in light of the probable emergence of intermediaries who will help buy energy crops from farmers for biofuel producers.

To address these challenges, MOA and the National Development and Reform Commission (National Energy Bureau) should coordinate to guide farmers to grow energy crops in conjunction with the construction of biofuel production plants. The construction of biofuel plants will be in accordance with the commission's plans, industrial policies, and measures. There are many possible cooperative mechanisms that could ensure the long-term stable supply of energy crops. Early commercial projects using different possible mechanisms should be supported to test and evaluate their effectiveness.

To ensure consistent and long-term cooperation between industrial processors and farmers, the "company + household" contracts can be promoted. The arrangement is the same as for power generation, as explained above. Agricultural agencies can provide technical support and guidance on growing the crops.

Other possible measures to support development of the industry include:

(i) Working out procedures and regulations for land transfer, contracting and leasing, and democratic and transparent community decision-making processes on land leasing. The government should define the positions and roles of intermediaries and subcontractors, and restrict speculative acts;
(ii) Establishing industrial risk funds and encouraging financial institutions to offer microfinancing to enterprises and farmers;
(iii) Establishing support systems for promoting energy crop cultivation technology; and
(iv) Encouraging a support industry, such as middlemen and subcontractors that may be necessary to collect and transport feedstock.

Priority Technologies by Region

In selecting appropriate technologies, it is important to account for regional differences. Important regional variables include land use, agricultural products, use of agricultural residues, and level of economic development. Based on regional differences, Table 3.14 shows recommended technologies for each region in the PRC.

Table 3.14: Population Density, Income, Biomass Resources, and Priority Technologies by Region in the PRC

Region	Total Population (millions)	Rural Population in Millions (% of total)	Rural Income per Family (CNY)	Biomass Resources	Recommended Technology
Northeast	107.53	48.23 (45%)	3,416	High density of crop residues per farmer. Heating demand is high in winter, thus household biogas technology may have some drawbacks in this region due to short operation time.	Biomass pellet technology for rural cooking and heating applications. Direct combustion for electricity generation due to the high density of crop residues.
North	280.33	163.55 (58%)	4,642	Main agricultural production area with a high density of agricultural population. High density of crop residues per farmer.	Household biogas. Biomass pellets. Crop residue-based biogas production. Medium and large biogas plants for livestock farms.
Loess Plateau	96.62	60.88 (63%)	2,308	Low density of crop residues per farmer. Economically poor. Crop residues are limited, but demand for livestock feed is high.	High-efficiency stoves.
Middle and lower reaches of the Yangtze River	365.88	191.01 (52%)	4,596	Low density of crop residues per farmer. Climate conditions are suitable for household and medium-to-large biogas plants.	Biomass gasification technology, if the technical and institutional issues are properly addressed.
South	181.98	90.16 (50%)	3,660	Low density of crop residues per farmer.	Biogas technologies, including both household and medium-to-large scale, given climatic conditions.
Southwest	191.72	128.88 (67%)	2,383	Low density of crop residues per farmer. Farmers mostly live in mountain areas with poor transportation and economic development. Rural energy here is currently in shortage.	Household biogas. Biomass pellets. Biomass gasification technology, if technical and institutional issues are properly addressed.
Qinghai-Xizang Plateau	8.19	5.32 (65%)	2,115	A main pasturing area in the PRC and has the lowest density of crop residues per farmer. Ecological balance is particularly needed here between agriculture and livestock sectors.	Highly efficient stoves.
Inner Mongolia and Xinjiang	49.89	28.65 (57%)	2,660	A main pasturing area. Has the highest density of crop residues per farmer and a low density of farmers. Under the government's new policy to recover grassland, crop residues will be used mainly for livestock feed.	Biomass pellets, which could be integrated with household solar energy. Biomass gasification technology, if the technical and institutional issues are correctly addressed.

Section 2

Targets and Their Barriers

Chapter 4
Goals and the Technology Road Map

Some countries interested in developing biomass energy will follow a single development trajectory. For example, a snapshot of biomass energy production in many countries in Southeast Asia shows a generally limited picture—a predominance of household biogas digesters for turning animal waste into energy. A snapshot of the PRC, however, is a varied picture of numerous biomass energy technologies at various stages of development.

Compared with developed countries, the PRC still lacks pertinent experience in design, manufacturing, and operation of pretreatment equipment and boilers adopted for the straw combustion needed for electricity generation, which is preventing the country from effectively upscaling biomass energy production. Most usage of rural biomass energy has come from small-scale projects that use locally produced materials and equipment, such as stoves, furnaces, and small-scale biogas digesters. For some equipment, though, such as pellet and briquette machines and large-scale biogas digesters and steam boilers, locally developed technologies are outdated and inefficient. Other technologies are still immature, and to develop them creates significant risk for suppliers and users.

Until a better-developed biomass energy industry can be built, the PRC will have to import certain key technology and equipment. Historically, though, such technology transfer has not sufficiently considered the local conditions under which imported technologies will be operated and managed. Imported equipment is usually costly and prohibitively so. For instance, the unit cost of several early biomass power plants in the PRC was about 50% higher because of the imported boiler and auxiliary technology.

The development of the overall industry in the PRC is at a critical phase. Unlocking the full potential of the country's vast biomass resources will involve using a range of resources and technologies across a geographically large and diverse country, while simultaneously addressing the challenges discussed in Chapter 3. This massive undertaking will require consistent and focused support at every level, from the central government all the way down to village committees and individual households.

In this effort, ADB recommends that the PRC follow four main guidelines in promoting rural biomass energy.

(i) Promote modern technologies for cleaner rural energy services and higher living standard of farmers.
(ii) Design locally available, locally appropriate, and locally proven biomass resources, technology, and available skills.
(iii) Create more jobs in the field of biomass energy by developing more comprehensive services—ones that extend beyond the creation and distribution of biomass energy supplies to also cover environmental protection services and related socioeconomic development initiatives.
(iv) Use policy-based incentives and market mechanisms to create a dynamic, competitive field for biomass energy services.

Leadership should be driven by three clear but key objectives: cleaner energy, better environment and higher rural income. This section offers recommendations for meeting these objectives.

Strategic Goals

In July 2007, MOA issued the Development Plan on Agricultural Biomass Industry, 2007–2015, which lays out technology-specific goals for rural biomass energy development based on three priority areas. The TA study used the ministry's articulated strategic goals as basis for formulating a strategy for a cohesive, sustainable industry devoted to producing biomass-based energy in rural areas. The ministry's priorities are as follows:

Priority 1—household heating and cooking. The ministry places the highest priority on the technologies that provide high-quality cooking and heating fuel directly to rural households. The most promising technologies for this involve household biogas, crop straw digestion, pellets/briquettes, and medium and large biogas plants.

Priority 2—energy crops. The next highest priority is developing energy crops to help increase farmer income and to develop a substitute for oil in the transport sector. For fuel ethanol, the priority feedstocks are sweet sorghum, cassava, and sugarcane. Rapeseed is the main feedstock for biodiesel.

Priority 3—electricity. In regions with abundant crop straw and no competition for rural household fuel, power generation from crop straw can be developed. For this application, the main technologies are: co-generation of coal and straw combustion, direct straw combustion, co-generation from medium and large biodigesters, and straw gasification.

Box 4.1: Development Priorities for Rural Biomass Energy

Priority 1
Household biomass energy for high-quality cooking and heating fuel
Priority of technologies:
(i) Household biogas
(ii) Crop straw digestion
(iii) Pellet/briquette
(iv) Medium- and large-scale biogas plants and
(v) Village-scale crop straw gasification

Priority 2
Energy crops for increasing farm incomes and providing fuel substitutes
Priority of bio-ethanol technologies:
(i) Sweet sorghum
(ii) Cassava
(iii) Sugarcane

Energy crops for biodiesel oil from rapeseed

Priority 3
Electricity for households, in regions with abundant crop straw resources and no competition for rural household fuel
Priority of technologies:
(i) Co-generation of coal and crop straw combustion
(ii) Direct crop straw combustion
(iii) Co-generation from medium- and large-sized bio-digesters
(iv) Crop straw gasification

Table 4.1: Strategic Goals for Rural Biomass Energy Development

Priority Area for Development	Technologies	2010	2015	2020
Priority 1: Household heating and cooking	Household biogas digesters	40 million	60 million	80 million
	Straw biogas plants	100	500	1,000
	Straw briquette/pellet fuel	1 million tons	20 million tons	50 million tons
	Medium-to-large biogas plants (based on animal waste)	4,000	Not Available	10,000
Priority 2: Bioethanol/biodiesel	Energy crop planting area	1.66 million ha	Not Available	3.33 million ha
Priority 3: Biomass-powered electricity	Straw power generation	3 GW	Not Available	6 GW

GW = gigawatt, ha = hectare.

Note: Quanitified goals are based on the Ministry of Agriculture's 2015 goals (Development Plan on Agricultural Biomass Industry, 2007–2015) and the central government's overall goals for energy and biomass for 2020.

Priority 1: Technology goals for household usage rural household biogas systems. Household biogas has rapidly developed because of central and local government support, and will continue to be the main approach for improving the cleanliness of residential cooking fuel and sanitation. By 2020, household biogas digesters will be the principal technology used for producing rural biomass energy, increasing the proportion of clean and high quality household fuel by 20%.

If 80 million household biodigesters are installed by 2020, coverage will have reached 30% of rural homes and more than 50% of the total number of viable homes. Based on this coverage rate, annual biogas consumption will have reached 25 billion m^3, which averages out to more than 300 m^3 per household. This would meet more than 80% of the required biogas needs for cooking. Key geographic regions for developing household biogas are central, western, and part of eastern PRC.

Straw biogas plants. Straw biogas plants should be constructed as technologies mature and are proven successful by demonstration experience. By 2020, it is reasonable to estimate that 1,000 plants are supplying biogas for 200,000 rural households.

Straw briquette/pellet fuel. Straw briquette/pellet fuel is especially suitable in northern PRC for cooking, boiling water, and space heating. Prioritized as a modern, clean, residential fuel, straw briquette/pellet fuel can be used for many purposes and can supplement biogas for cooking uses. The production and distribution capacity of straw briquette/pellet fuel should reach 50 million tons by 2020, serving more than 10 million households (about 50,000 villages). Straw briquette/pellet fuel will increase the proportion of clean and high-quality household fuel by 10%.

Medium and large biogas plants. By 2020, manure from intensive livestock productions should be put to use at 10,000 new medium and large biogas plants, with an annual output of 5 billion m^3, supporting 5 million households for cooking and hot water. These plants will increase the proportion of clean and high-grade living fuel by 5%.

Priority 2: Technology goals for biofuels. The PRC is short on arable land, so the development of energy crops should not compete with growing strategic goods, such as food and cotton. The principle of "no competition with land for food, and no competition with food for humans" should be

Leadership should be driven by three clear but key objectives: cleaner energy, better environment and higher rural income.

The most suitable areas for growing energy crops are marginal lands, such as desolate hills and slopes, river basin flood areas, and idle winter lands.

followed in planning the development of bioethanol and biodiesel. The most suitable areas for growing energy crops are marginal lands, such as desolate hills and slopes, river basin flood areas, and idle winter lands.

To achieve the alternative liquid fuel goal of 10 million tons by 2020, 50 million mu (1 mu = 1/15 of a hectare) or 3.33 million ha should be planted with energy crops, of which 45 million mu are abandoned land and 5 million mu are winter idle land. The energy crops to be planted should be:

- (i) sweet sorghum—25 million mu (1.66 million ha),
- (ii) cassava—3 million mu (0.20 million ha),
- (iii) sugarcane—10 million mu (0.66 million ha),
- (iv) sweet potato—7 million mu (0.46 million ha) on abandoned land, and
- (v) cole—5 million mu (0.33 million ha) on winter idle land.

Priority 3: Technology goals for electricity generation. The technologies used in Priority 1 would meet about 35% of total energy demand[1] by rural households in 2020, which is equivalent to 100 million rural households. The remaining demand of 182 mtce would be met by a combination of commercial fossil fuel (coal and liquid petroleum) and traditional biomass (straw). Straw-powered electricity will consume about 164 million tons of straw via direct combustion (equivalent to 82 mtce), in addition to the 60 million tons to be used for biogas generators. That leaves 76 million tons needed for scale-up and/or power generation and combined heat and power systems, which are an efficient and clean approach for large-scale utilization of straw resources and an effective solution for unmanaged burning and piling of straw waste.

The total power generation capacity from straw is expected to reach 6 GW by 2020. The main obstacles confronting the straw-to-power strategy, however, include securing a stable and long-term supply of straw and managing the variations in the heat load demand for the combined heat and power systems. The location of power plants should be decided after a comprehensive study of the availability of straw.

Technology Road Map: Priorities and Stages

To help advance MOA's strategic goals, the TA study developed a ''technology road map'' for developing modern rural biomass energy in rural PRC.[2] The road map was prepared using a number of guiding principles (Box 4.2) and was based on the comprehensive assessment of technologies (Chapter 3).

Actions taken with any technology should be based on the general stage of development the technology is in. Figure 4.1 illustrates the current development stage for each technology and the expected changes in their development stage and priority between now and 2020. Research and

1 The total energy demand met by technologies of Priority 1 (of which the amount of straw used is about 60 million tons) was calculated as: 100 million households (HHs)/225 million HHs×80%; the remaining demand is calculated as: 65%×280 mtce=182mtce.

2 For developing this road map, the TA study team also closely consulted with the cross-agency steering committee and advisory committee.

development represents the most initial stage and dissemination replicates the most advanced.

The priority ranking listed in Box 4.1 is likely to change due to many factors, including the rate of technology development and changes in rural energy needs. Key observations are the following:

(i) Household biogas technology has been developed extensively. It has very good benefits from economic, environmental, and social impacts; and it is already at the dissemination stage, so research and development is a lower priority.
(ii) Medium and large biogas plants show fair environmental significance, but due to their poor financial performance, they can only be deployed with specific policy supports.
(iii) Pellet/briquette technology has good integrated performance, and while it still needs more research and development, the focus for the near future is pilot projects followed by demonstration projects. When the key technology issue has been solved, it will be disseminated gradually.
(iv) Co-combustion of straw and coal for power generation shows considerable potential in the future, but specific technology and management barriers confront its deployment in the PRC. Further development and policy adjustments are needed.

Significant research and development efforts should be put into village straw digestion systems and cellulosic production of ethanol, which show very high potential.

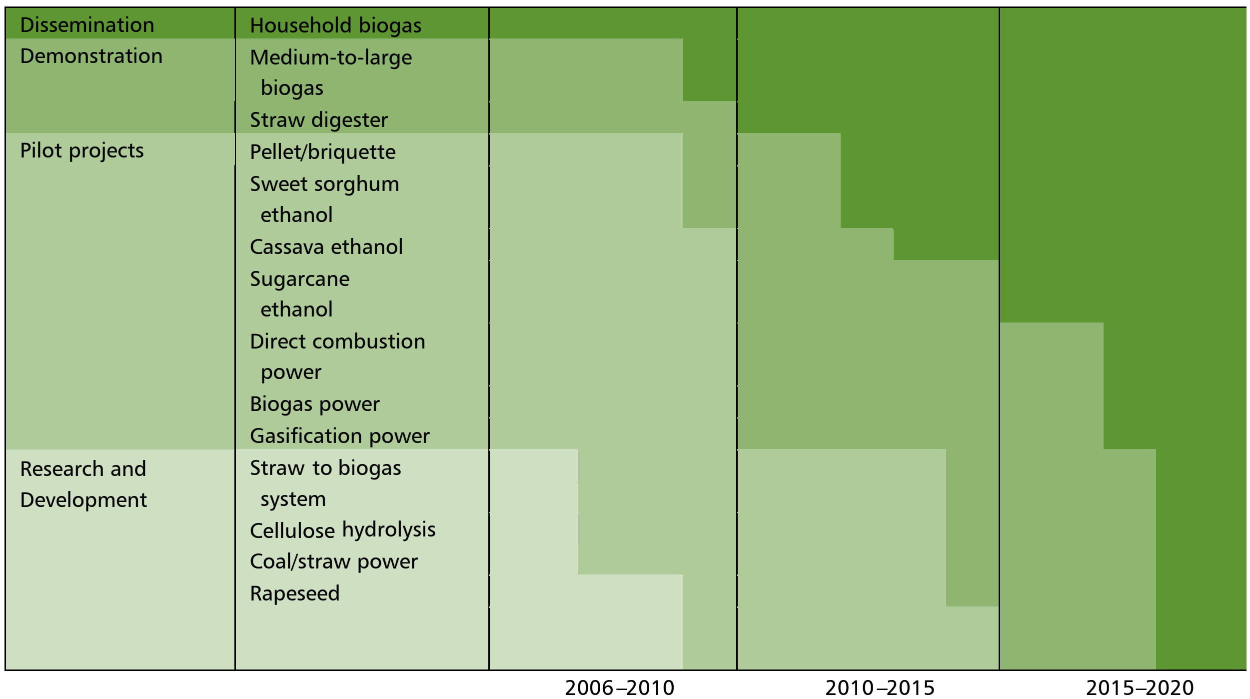
Table 4.2 presents the priority activities needed for each technology at different development stage. Advanced technologies and products should be continuously pursued, followed by pilot demonstration and deployment. To ensure a progressive sector, policies should include measures that call for increased government financing of research and development as well as incentives to attract prospective investors to the field.

Box 4.2: Guiding Principles for Developing Technology Road Map

(i) Using rural biomass to meet the energy needs of rural households should be the highest priority.
(ii) Fossil fuels should not replace biofuels in rural areas.
(iii) Current trends in rural PRC toward convenience and improved living standards should be supported and accelerated.
(iv) Technology industrialization that generates social and economic benefits in rural areas should be promoted.
(v) Energy crops must not compete with the production of food and biomass in terms of land use and water consumption.
(vi) The scale of enterprise operations should match the scale of the local communities being served.
(vii) Rural biomass energy enterprises should contribute to improving economic and social development, employment, and environmental protection.
(viii) Water consumption must be factored into the assessment of potential energy crops.
(ix) The government is responsible for implementing policy incentives and market mechanisms that support the utilization of modern biomass energy technologies.

Such measures will help ensure the development of advanced technologies and products and their timely piloting and deployment. In this regard, technologies should be developed in accordance with strategic goals, real-world demands during implementation, and strategies to develop rural biomass energy industries. One of the main objectives should be to secure investor confidence in the sector, thereby ensuring an increased pipeline of utility-scale projects.

Figure 4.1: Development Road by Stage



Box 4.3: Ongoing Research and Development for Bioethanol

The PRC has supported research and development of ethanol fuel that is based on nonfood products, including the breeding of high-yield sweet sorghum varieties and developing production equipment.

In 2001, a large sugarcane ethanol project began in the south. In Fujian, Guangxi, Hainan, and a few other southern provinces, a special kind of sugarcane was grown to make ethanol fuel. As of 2005, nine provinces were using ethanol fuel (ethanol gasoline), and domestic standards for fuel ethanol had been developed (for further information on the standards, see GB:18350-2001 Modified Fuel Ethanol and GB:18351-2001 Vehicle Use of Ethanol Gasoline).

To explore additional sources for biomass fuel, the PRC independently developed a fuel ethanol production technique using sweet sorghum stems. Regional plantations and pilot plants were developed in Heilongjiang, Inner Mongolia, Shandong Province, Xinjiang Autonomous Region, and the city of Tianjin. The plant in Heilongjiang Province has already reached an annual production of 5,000 tons of ethanol fuel. Ethanol fuel production is limited to designated factories in order to prevent the product from being diverted for distilling drinking alcohol.

Ethanol production from cellulose is under study in several universities and research centers across the PRC. Cellulosic ethanol technology is currently too costly to deploy, and large-scale development can only happen after significant technical breakthroughs and costcuts. In the near and medium term, infertile land should be used to grow cassava, sweet potato, and sweet sorghum for ethanol fermentation, which can also be developed by using corn and sugarcane. All these developments, though, should consider local conditions and have the objectives of strengthening research on cellulosic fermentation and industrial applications in the medium and long term.

Table 4.2: Priority Activities at Each Technology Development Stage

Technology	Research and Development	Demonstration	Early Deployment	Commercialization
Energy-efficient stoves	• Develop more efficient and robust stoves and furnaces	• Demonstrate furnace applications	• Education and promotion to expand deployment	• Promote poverty-based incentives
Pellets and briquettes	• Fund component development to create more efficient technologies applicable to more residue types	• Fund community-based technology demonstrations	• Promote incentives to suppliers and consumers for community-based pellet fuel systems	• Promote community-based incentives • Demonstrate market-based business models
Straw digesters	• Resolve issues of sodium contents in digested residues • Develop more effective pretreatment and explore co-digestion of straw with animal wastes	• Evaluate existing technical demonstrations • Fund new technology demonstrations	• Fund community-based commercial demonstrations	• Promote community-based incentives
Household biogas	• Explore co-digestion of animal wastes with crop straws • Explore the benefits of biofertilizers	• Fund technology service center demonstrations	• Expand successful national program to more counties	• Promote poverty-based incentives
Medium- to large-scale biogas	• Fund anaerobic digester technology improvement • Optimize design and performance requirements for eco-agricultural system	• Demonstrate improved digester technologies • Demonstrate optimal eco-agricultural systems	• Promote integrated eco-agricultural systems to promote optimal use of land and support strong rural communities	• Promote enterprise-based incentives to ensure environmental compliance and capture eco-agriculture benefits • Combine the energy and GHG reduction benefits by CDM
Power generation	• Assess performance and environmental impacts of biomass co-firing in existing coal plant • Fund improved combustion and gasification technologies • Develop the multiple fuel feedstock system	• Fund technical demonstration of biomass co-firing along with rigorous monitoring and verification techniques • Fund biofuels poly-generation demonstration	• Promote early commercial biomass co-firing plants if demonstrations are successful • Fund biofuels poly-generation systems if successful	• Monitor and verify co-firing • Promote market acceptance of biofuels
Bioethanol	• Develop new enzymes and processes for cellulosic fermentation	• Demonstrate advanced technologies on a regional basis	• Promote current technologies where most economically viable	• Promote agricultural-based incentives
Biodiesel	• Develop new bio-oil processing techniques	• Demonstrate advanced technologies on a regional basis	• Promote current technologies where most economically viable	• Promote agricultural-based incentives

CDM = Clean Development Mechanism, GHG = greenhouse gas.

Research, Development, and Demonstration Needs

The technology road map needs to be supported by targeted activities of research and development, pilot tests, and demonstration projects, which will be necessary to continue the technology development process and achieve the commercial potential of rural biomass energy in the PRC.

Research and Development

(i) Improvement of key equipment for straw pellet fuel production, including the development of molding machines and auxiliary equipment for different kinds of straws. The focus needs to be on increasing the equipment reliability and lifespan, and reducing investment and operating cost.
(ii) Development of a series of stoves and furnaces for straw pellet fuel to meet the requirements of different end users.
(iii) Development of key technologies for anaerobic digestion of straws, including enzyme cultivation and production, process optimization and special mechanical equipment.
(iv) Development of ethanol synthesis process from non-food crops, including selection and optimization of enzymes, and special mechanical equipment.
(v) Selection and cultivation of new energy crop species.

Pilot Tests and Demonstration

(i) Comprehensive test and demonstration for utilization of straw pellet fuel at the village level, including fuel manufacturing, delivery and end use, to explore compatible operation and management modes from feedstock collection and processing to fuel delivery and end use, and provide experience for large-scale deployment.
(ii) Demonstration of straw digestion engineering project, together with further development of pertinent technologies, to optimize the enzymatic process and improve the compatible technologies, explore operation mode from investment to management, and accumulate experience for further deployment.
(iii) Expanded demonstration of centralized gas plants using straw gasification to explore the viability of feedstock security, local capacity to operate the process technologies, and appropriate modes for investment and management.
(iv) Demonstration of cultivation and production of energy crops, including different demonstration bases for different species at different locations, to provide feedback for technology development and operating experience for further deployment.
(v) Policy incentive and monitoring methodology on co-firing technologies: co-firing of biomass and coal in power plant is one of the most economical technology solutions to make the biomass in mass and modern utilization for energy production. However, it has been difficult to verify "pure" renewable energy application, which could qualify for the green electricity price. Thus, development of monitoring methodology, which can enhance the application of this technology, is necessary.

The technology road map needs to be supported by targeted activities of research and development, pilot tests, and demonstration projects, which will be necessary to continue the technology development process and achieve the commercial potential of rural biomass energy in the PRC.

Chapter 5
Breaking Down the Sustainability Barriers

This report has explored the supply and demand side of biomass resources and the variety of technology options and combinations that could be developed with those resources, assuming their technical issues can be resolved through the research and development road map explained in the previous chapter. It would be a mistake, though, to assume that biomass energy can be developed without the initial strong, guiding hand of government.

Nowhere is government involvement needed more than in breaking the single greatest barrier: the financial barrier. Resources and technology are only a part of the development equation. Government has to create an enabling environment through policies, regulation, institutional arrangements and its own financing scheme to improve affordability at the household level and financial sustainability at the industry scale. Currently, household systems are out of reach for the poorest rural households and larger systems have not proven financially viable, which has stunted their growth.

If government is insufficiently present in the development of biomass energy, so will the benefits be to the rural poor and the environment—the two stakeholders who need these benefits the most. The benefits of rural biomass energy need to reach the poorer rural communities so they, too, can have an opportunity at increased farmer incomes and cleaner energy supply. At the industrial scale, the enabling policies must ensure ability of the biomass energy (either biogas or electricity) suppliers to show a reasonable return on investment. Environment needs to be spared of those organic pollutants that could be put to better use as biomass energy feedstocks and fertilizer.

This chapter discusses the major barriers confronting the overall development of rural biomass energy, with the financial barrier being a fundamental one. Solutions exist through the right policies and institutional arrangement. The United States, Europe, and Brazil have already proven how essential tax incentives and government regulations are to the development of biomass energy. The PRC must follow this path, and this chapter looks at recommended financial policies for some of the technologies discussed previously.

Removing the financial barrier alone, however, does not ensure sustainability. An industry is only as sustainable as the environment that it extracts resources from. In addition to needing a steady supply of agricultural waste, biomass conversion technology requires adequate water supply. And if the organic sludge that is generated from the biomass energy process is not appropriately managed (put to use as fertilizer), the environment could find itself again vulnerable to biomass.

Social acceptability and local relevance join the financial and environmental issues as being another key sustainability factors. Strong institutional coordination between agencies at all levels of government can ensure that local areas are being targeted with the right technologies and enough resources to make them sustainable. Knowledge about the availability of biomass resources and feasible technological options must be specific to the location where it is intended to be developed. By studying locations and their adaptability to biomass energy, the industry will learn about location-specific factors that could undermine the sustainability of biomass energy in that place. One size does not fit all. These factors—the barriers to sustainability—can be addressed through policy, institutional coordination, and financing.

Sustainability Barrier No. 1: Household-Level Affordability

The first step to owning and benefiting from biogas energy is not acquiring the cash for the system (although that is eventually necessary), but rather the required amount of biomass to feed the system. Poor farmers, however, typically do not raise enough livestock or crops to generate the appropriate amount of waste needed for producing enough biogas at levels which could significantly improve their situation both economically and socially.

If a household does have enough biomass resources, a second barrier may be the affordability to invest and sustain the system. The upfront investment cost for purchasing and installing a household biogas digester is more than just a stumbling block that poor farmers encounter—it is a solid brick wall, with few options for financing to help them overcome it. Not even a government subsidy of 50% is enough to remove the affordability barrier for farmers (Box 5.1).

Box 5.1: National Biogas Subsidy Program and the Efficient Utilization of Agriculture Waste Project Loan

The National Biogas Subsidy Program, begun in 2003, remains an important incentive for rural biomass energy development. From 2003 to 2007, the amount of national grants increased from CNY100 million to CNY2.5 billion. In 2008, as part of an economic stimulus package, the national subsidy was increased to CNY6 billion.

The subsidies allocated by the central government for the construction of biogas digesters in rural households are: CNY1,200 per household in the northwestern and northeastern regions, CNY1,000 in southwest region, and CNY800 in other regions. This program has significantly catalyzed the development of household biogas digesters nationwide.

Three weaknesses in the program need to be addressed: (i) the subsidy is still too low for many rural poor to afford the systems; (ii) the subsidy level is too low project-wide, leading to poor maintenance and shortened lifespan of systems; and (iii) weak linkages with the promotion of household farmer income and productivity.

Compared to the national subsidy program, ADB-financed Efficient Utilization of Agriculture Waste Project piloted a more comprehensive household biogas development scheme. It not only supported farmers with small loans for the construction of biogas digesters, but also provided support for purchasing enough livestock to get optimal usage from the biogas. The project also supported farmers in applying the organic sludge-fertilizer from the biodigester to backyard gardens, orchards, and fishponds to improve the productivity.

Cofinancing with the Global Environment Facility grant provided extensive technical support and training to the rural energy stations and household farmers, ensuring the sustainability of established household biogas systems. In 2006, when ADB and the government celebrated 20 years of cooperation, this project was highlighted as an "impact story."

For example, the typical cost of a household biogas system in the PRC is CNY2,000, while annual farm income per capita in the poor areas is only CNY2,500–3,000. This indicates just how poor some areas are, and how much this technology is out of reach. Yet the fact that ADB project households that received a biodigester increased their income by 86.4% should be the impetus for government to prioritize the deployment of digesters into these poorer households.

Once farmers can afford household systems (typically a biogas digester), they stand to gain from lower energy costs and a number of time and expenditure savings. For example, because biogas can be used for heating, cooking, and operating internal combustion engines, farmers need not spend time searching for fuel or purchasing energy.

For systems that use animal manure, farmers can sell the residue (bioslurry) to nearby agricultural enterprises, such as farms, fishponds, and orchards. If used onsite, the fertilizer can also increase agricultural yields and reduce expenses on chemical fertilizers. At the same time, these systems help farmers manage their animal waste, which will reduce pollution. For larger systems that generate electricity, excess electricity that is generated can also be sold to the public grid given the right conditions (e.g., workable distance to the grid, willingness of plant to purchase electricity).

Affording the system and keeping it running require more than cash—it requires technical knowledge and access to extension services. If households have been able to overcome the first two barriers of available resources and affordability, they face a third hurdle in maintaining and repairing systems. Extension services are often weak in general in rural areas and weaker in remote or severely poor areas, yet this is where biomass energy could sharply reduce poverty. Households and communities need skills training to ensure they know how to manage the systems and can access the market for replacements and special needs. When dealing with extremely low-income and remote areas, government support must be proportionate to needs.

Sustainability Barrier No. 2: Financial Viability of Centralized Conversion Technologies

Medium and large biogas plants, as well as most other centralized conversion technologies, have not enjoyed the same growth as household biogas digesters. Several factors contributing to their slow growth were revealed during ADB-financed Efficient Utilization of Agricultural Wastes Project, which constructed 12 medium and large biogas plants on livestock farms. These barriers need clearing, though, because household systems alone will not capture the waste or produce the energy needed to fuel rural development. Eventually, biomass energy production has to graduate to the next level—centralized systems.

The most significant barrier to medium and large biogas systems is their poor financial performance. But for other industrial-scale technologies, the greatest challenges involve designing the appropriate mechanism for a reasonable cost of transporting biomass from farms to plant. Currently, many centralized conversion schemes are simply not economically viable under current policy conditions and would require additional financing (Box 5.2).

The public sector in the PRC is already driving much of the spending on renewable energy in general to meet the goals set by the central government. This model, however, has mainly been applied to only hydro, solar, and wind. With the notable exception of biofuels (Box 5.3), there is still a shortage of public sector funding to develop biomass energy. Feasible investment plans and policies are altogether lacking. Meanwhile, because of profitability

Affording the system and keeping it running require more than cash—it requires technical knowledge and access to extension services.

Box 5.2: Barriers to Be Removed for Medium or Large Biogas System Development

For livestock farms that could take advantage of an onsite biogas digester system, several barriers are confronting them.

Financial barrier. No specific policy exists to promote commercial implementation of anaerobic digester systems on intensive livestock farms. While the Renewable Energy Law encourages the establishment of large-scale power generators, it only allows generators beyond 500 kilowatts (KW) to connect to the grid, yet most medium-sized biogas digesters can only generate 50–150 KW of electricity. In addition, inadequate national and provincial financial resources are failing to achieve the significant benefits of medium and large biogas systems, which improve the environment, expand rural biomass energy, and improve farm incomes.

Technical barrier. The inadequate system for providing technical support to existing medium and large biogas systems has led to poor maintenance and shortened lifespan of plants. Some biogas plants have stopped operating completely. The few engineers involved with medium-scale digester design typically come from working on the industrial wastewater treatment process, and do not have enough experience to deal with the complicated physical and chemical features of animal manure. Moreover, technical standards and procedures are not sufficient to ensure effective engineering design, construction, and operation of medium and large biogas systems.

Environmental enforcement and risk. Local officials and livestock owners believe direct discharge to anaerobic lagoons is the only economic solution. As a result, other options and benefits—such as developing on-farm biogas systems—are not being explored or encouraged, and environmental standards are not being sufficiently enforced. In addition, environments surrounding livestock farms are especially at risk, because there is usually not enough surrounding farmland to utilize the organic fertilizer produced from the biogas systems since many of these livestock operations are now in peri-urban areas. The transport and distribution of the sludge-fertilizer need testing to make the biogas plants attractive to farmers and livestock owners as well as make them environmentally safer.

Institutional barrier. Different agencies are promoting different technologies through different financial sources. This lack of cooperation between responsible agencies and lack of coordinated institutional arrangements have prevented medium and large biogas systems from getting the collective support they need to attract interest and commitment by the various stakeholders to really advance this technology's development.

challenges, private investment is more focused on specific areas within renewable energy technology, such as equipment manufacturing rather than energy production.

The current scenario makes it necessary to use existing funds as efficiently as possible and to investigate possible mechanisms for raising special funds and attracting foreign investment. Identifying low-interest loans, loan guarantees, mobilizing grants from the Global Environment Facility, and securing extra revenues through the Clean Development Mechanism become very important to removing the financial barrier.

The PRC government has recently issued a package of policies, including risk reserves, subsidies, and tax breaks, to encourage the development of the biomass energy and biochemical industries. First, under the Renewable Energy Law, the PRC now regulates the price of electricity generated by biomass power plants. For biomass-based power generation, the law specifies a tariff premium of CNY0.25/kWh higher than the base electricity generation cost in each province, usually between CNY0.3–0.45/kWh. The base electricity price is the average cost of generation from existing coal and hydropower plants in the province.

The PRC government has recently issued a package of policies, including risk reserves, subsidies, and tax breaks, to encourage the development of the biomass energy and biochemical industries.

Another new policy focuses on encouraging private sector financing by mitigating some of the risks. Under this policy, enterprises will set up risk reserves, which will be used to offset their losses when oil prices are low. If prices remain too low, a government subsidy regime would then be triggered to cover the losses of enterprises. The new policies were jointly issued by the National Development and Reform Commission, the ministries of finance and agriculture, the State Administration of Taxation, and the State Forestry Administration.[3]

These actions have resulted in some initial successes in promoting public–private partnerships for constructing and operating biomass power plants (Box 5.4). Overall, though, these new policy measures—particularly the tariff premium on biomass-based electricity—do not account for the various factors affecting the cost and development of biomass energy, and as a result, inherently undermine the adoption of modern biomass energy.

For instance, the TA study team found that the tariff level established under the Renewable Energy Law may be insufficient to make biomass power plants cost-effective. The study investigated the likely impact of the current renewable energy tariff and several possible tax incentives on the cost-effectiveness of several biomass power plants under construction in the PRC (some began operating in 2007). The economic analysis indicated that even with the most favorable tax treatment (0% value-added tax and 0% income tax), most of the planned plants do not appear cost-effective, mainly because of expensive imported technologies and the high price of biomass fuel (50% higher than the current price of coal). Given this assessment, the level of the current tariff premium under the Renewable Electricity Law may need to be revisited once actual

Box 5.3: Government Support for Biofuels

The PRC's Renewable Energy Law established the Renewable Energy Fund to assist with "biofuel technology research and development, standards development and demonstration projects and support biofuel investigation and assessment of raw material resources and information dissemination and domestic related equipment manufacturing." Biofuels are also included in the National Renewable Energy Industry Development Guide Directory so that discounted loans and tax incentives can be obtained for equipment manufacturing and cultivation of energy crops.

According to government data commissioned by the Global Subsidy Initiative, the PRC provided a total of CNY780 million ($115 million, about $0.40 a liter) in biofuel subsidies in 2006. This amount comprised support for bioethanol in the form of direct output-linked subsidies paid to the five licensed producers, as well as tax exemptions and low-interest loans for capital investment. Further support was provided through mandatory consumption of ethanol-blended fuel in 10 provinces (a 10% blend with E10 gasoline).

Total support for bioethanol and biodiesel is expected to reach approximately CNY8 billion ($1.2 billion) by 2020, according to official estimates. In addition, support is also given to farmers growing feedstock on marginal land, CNY3,000 ($437) per ha per year.

Source: Global Studies Initiative. 2008. *Biofuels – At What Cost? Government Support for Ethanol and Biodiesel in China.* Geneva. Available: www.globalsubsidies.org/files/assets/China_Biofuels_Subsidies.pdf

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3 Xinhua News Agency. 2006. China to Provide Subsidies to Bio-Energy Sector. Beijing Pioneer Technology Co. Ltd. 1 December. Available: http://210.51.191.165/show.php?contentid=20866

Renewable technologies would be treated unfairly under value-added taxes since these systems generally have higher capital costs and lower fuel costs than conventional technologies.

performance results are known from those plants that started operation in 2007.

In addition, several issues with actually implementing these new policies need to be resolved so that small-scale biomass facilities can access some of the government incentives. The PRC also lacks adequate incentives to overcome the current technical and administrative barriers that smaller biomass power plants face in connecting to the electricity grid. Most of the existing biogas power plants only possess an output capacity of about 100 KW, which falls short of a frequently reported 500 KW indicative target set by the government. Another prevailing constraint lies with local grid companies, which are often reluctant to connect the plants to the grid due to administrative complications, such as difficulty in obtaining licenses from the state and technical problems for both the plants and the local grid companies.

Biomass energy technologies also need favorable tax treatment. Tax exemptions should be provided for the sale of biomass energy products and for the investment in biomass energy processing equipment. Value-added tax is not recommended, because capital would be taxed, but not fuel. As a result, renewable technologies would be treated unfairly under value-added taxes since these systems generally have higher capital costs and lower fuel costs than conventional technologies.

Sustainability Barrier No. 3: Managing the Industry's Development

Biogas energy management is strongest in the area of household biogas digesters, and weakest among the centralized conversion technologies.

Box 5.4: Assisting Biomass Power Plant Development in Inner Mongolia

China Holdings, through its controlled subsidiary China Power, Inc., recently signed a contract with the Ongniute government in the Inner Mongolia province for the exclusive right to develop and construct a biomass electricity generation plant. The plant will have a power capacity of 50 MW, which brings the company's total power capacity from biomass energy projects to 200 MW. The total expected annual power generating capacity will be 400 million kWh.

Under the construction agreement, Ongniute agreed to provide China Power with the land rights for up to 200 mu of land to develop the plant, together with an additional 500,000 mu of land rich in straw resources to support the power plant. China Power committed to invest up to CNY580 million to develop the power plant.

Legally protected by the central government's biomass energy policies, Ongniute also guaranteed: (i) the financing for up to 65% of the total cost of the power plant—CNY580 million—through a local bank at a preferred interest rate, (ii) that 100% of the power generated shall be purchased by the China State Grid at a purchase price from CNY0.60 to CNY0.65 (or approximately \$0.08–\$0.09 per KW), and (iii) a payment of CNY13.2 million back to China Power once construction of the power plant is completed. Construction will take about two years.

Ongniute also guaranteed all necessary government approvals and ensured the supply of all required utilities, such as electricity, water, communications, and roadways, and China Power will be responsible for obtaining all required financing for the plant and operating the plant with the most advanced technology available. In addition, Ongniute agreed to ensure that the plant is not subject to income taxes for its first three years of operation, which will be followed by three years of no more than 12.5% tax rate.

Source: Energy Daily. 17 March 2008. China Holdings Announces Biomass Renewable Energy Development. www.energy-daily.com/reports/China_Holdings_Announces_Biomass_Renewable_Energy_Development_999.html

All government authorities in charge of agriculture at the provincial and municipal levels and more than 90% of all counties have a division for rural energy administration. Some of their business covers supervising construction of biogas digesters, delivering technical training, and disseminating new technology. These divisions employ more than 50,000 people. To date, MOA has certified more than 150,000 farmers as "biogas workers", and more than 50 factories are producing 5 million household digesters annually.

Such management, however, does not extend to other biomass energy applications. Poor maintenance and shortened projects are indicative of the limited capacity to design, build, operate, and maintain larger biomass energy systems, such as medium-sized biogas plants and biomass power systems. The necessity to locate the larger biomass energy systems in rural areas is an inherent challenge, which involves technical and market risks. Yet plants must be located in rural areas because that is where biomass is available. For the larger biomass energy systems, MOA and its provincial and local energy institutions will play an important role in identifying the resources and ensuring a sustainable supply. Also important is how MOA coordinates with other national agencies and these agencies' provincial and local counterparts, which is essential to ensuring wide dissemination and sustainability of these larger systems.

Also, technical standards and business procedures for engineering design, construction, and commercialized operation of these systems are undeveloped. Village-scale gasification technology in the PRC is an example of these shortcomings. After a number of centralized village biogas supply systems were developed in the 1990s, the technology quickly gained nationwide popularity. By the end of 2005, 537 straw gasification stations had been built in Beijing, Heilongjiang, Jiangsu, Shandong, and other provinces. Since then, though, many plants have shut down due to technical and management obstacles. Villages often lack experience in managing such infrastructure, and these plants face more challenges in operation and maintenance than biogas digester systems. Guidelines are needed for technical support and services, as well as improved project management.

One key step is developing and promoting standards and certification procedures that will allow interested developers to determine the best technologies and enterprises.

The single greatest intervention for more effective management of the development process is a stronger institutional framework between ministries and different levels of government. Sustainable utilization of biomass resources, especially agricultural residues, requires comprehensive planning of food production, rural development, and energy supply. Regional and local institutions must play an active role in this effort, since they are best able to coordinate and integrate resources in rural areas. Thus, the state government should work with provincial and local planning commissions in adopting integrated planning methods that will support the long-term management of local biomass resources.

To fully use local biomass resources, planning often extends across municipal boundaries but not as wide as a provincial scale. As a result, county institutions may often be the best suited to take up project management, which would minimize the unnecessary layers of bureaucratic procedures that drain financial capital.

At the central government level, planners and policy makers must adopt a comprehensive approach, not a piecemeal one, to the development of rural biomass energy. The implementation of policies and programs must involve several institutions. These can be classified either as those with a direct role in planning, implementing, and enforcing biomass energy development, or those having an indirect role, such as in studying the impacts of biomass development.

Sustainability Barrier No. 4: Environmental Risks

While biomass energy development promises rehabilitation of the local environment, there is also the potential for significant harm if resources are not managed properly. For example, harmful environmental impacts could stem from the misappropriation of a particular biomass resource, the over-extraction of water supply for processing, or the

If resources are not managed properly, biofuels development poses as much harm to the environment as it promises rehabilitation.

underutilization of the organic fertilizer by-product. Mismanagement of biomass development could also lead to detrimental changes in land use that would undermine food security and threaten biodiversity.

Tightening of emissions and discharge standards coupled with stronger enforcement using punitive measures can be a phenomenal catalyst for protecting the environment as well as actually accelerating the development of biomass energy. Greater environmental governance will encourage local governments, intensive livestock farms, and other environmentally harmful industries to incorporate biomass energy technologies, which allow them to reduce, reuse, and recycle their wastes.

Incorporating biomass energy technology into existing and future plant operations offers three major environmental and economic benefits. Firstly, it can reduce on-location costs by using the energy form it creates (whether that is heating or electricity) and avoiding costly wastewater treatment. Secondly, it can create new revenue streams through the sale of excess energy and the fertilizer by-product to surrounding communities. Thirdly, it can reduce their emissions and discharges into the environment, thus reducing the likelihood of environmental fines and penalties.

Environmental management and enforcement is particularly important for biomass energy. Unlike other renewable resources (such as wind, water, and solar), the potential of biomass is bound by its finite availability and dictated by developments in agriculture. These limitations have acute implications for the development of biofuels in the PRC, particularly the country's shrinking arable land, which could in turn affect food security.

Land availability. A 2006 survey by the Ministry of Land and Resources revealed that the country has lost 8 million ha, or 6.6%, of its arable land in the past decade.[4] The country's arable land area could fall below a "red line" of 1.8 billion mu needed to feed its people. With just 1.82 billion mu (121.7 million has) available at the end of 2008, the country is dangerously close to this line.[5]

Several factors are causing the land loss. In eastern PRC, a booming economy and urban sprawl have led to conversion of arable land into new home and commercial constructions. In western PRC, lower-quality arable lands have been appropriated for forest or grassland replanting to restore degraded or fragile ecosystems. The government, however, recently halted a program that lets marginal farmland return to woodland.

Food security. Recognizing the inherent conflict between first generation biofuels and food production, the government has set a biofuels policy that ensures that the technology moves forward in a way that does not compete with arable land and that grain is not used as feedstock for biofuels. The construction has halted on new maize-based ethanol plants.

Instead, new policies encourage the production of biofuels from non-grain feedstocks, grown on 35 million–75 million ha of marginal land that might be suitable for these crops. However, while some areas could benefit substantially from higher farm incomes and rehabilitation of degraded land, others may not yield enough feedstock to be profitable. Government subsidies would be wasted on such land.[6]

Sustainability and nature conservation. In addition to threatening food production, improper

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4 China Watch. 2006. *Worldwatch Institute*. 18 April. Available: www.worldwatch.org/node/3912

5 Graham-Harrison, Emma. 2009. China Arable Land Fears End Reforestation Drive. 23 June. Available: www.reuters.com/article/environmentNews/idUSTRE55M27F20090623

6 Global Subsidies Initiative. 2008. Biofuels – At What Cost? Government Support for Ethanol and Biodiesel in China. Geneva. Available: www.globalsubsidies.org/files/assets/China_Biofuels_Subsidies.pdf

Table 5.1: Environmental Benefits from the Development of Biomass Energy in 2005 in the PRC

	Emission Coefficient (t/tce)	Volume of Reduced Emissions (10,000 tons)	Benefit from the Reduced Emission (CNY/t)	Total Benefit from the Reduced Emission (CNY100 million)
CO_2	0.726	3,630	57	75.69
SO_2	0.022	110	1,260	13.86
NO_X	0.010	50	2,000	10.00
TSP	0.017	85	550	4.68
Total	**0.775**	**3,875**	**3,867**	**104.23**

CO_2 = carbon dioxide, NOx = nitrogen oxide, SO_2 = sulfur dioxide, t = ton, tce = ton of coal equivalent, TSP = total suspended particles.

Source: ADB. 2008. *Preparing National Strategy for Rural Biomass Renewable Energy Development.* Manila.

management of energy crop cultivation can damage the environment through erosion, biodiversity loss, and modified landscapes. These environmental losses could cancel out the local environmental gains that are supposed to have come from using more biomass energy. For instance, subsidies for growing biofuel feedstocks on marginal land are higher than subsidies for setting aside such land for environmental purposes, encouraging cultivation of conservation areas. The bottom line is biomass for generating biomass energy only makes sense if the whole process nets a positive eco-balance.

Climate change impacts. Rural biomass energy can help reduce the agricultural sector's greenhouse gas (GHG) emissions in the PRC. In 1994, the last year that the PRC officially released a GHG inventory, emissions from the agricultural sector accounted for 17% of the PRC's total GHG emissions. Further, agriculture was responsible for 50% of the country's total CH_4 emissions and 92% of the country's NO_2 emissions. More recent estimates made by the Pew Center on Global Climate Change estimated that, in 2003, emissions from agriculture accounted for 20% of the country's total emissions.[7]

Emission reductions can be achieved by improving on-farm agricultural practices in conjunction with rural biomass energy systems. These include improved manure management and crop management (e.g., land use and fertilizer use). Replacing fossil fuels with biomass energy—particularly biomass-based electricity and biofuels for transportation—can dent emissions even more.

Table 5.1 provides the results of the TA's environmental impact analysis, which attempted to calculate a monetary benefit for reduced pollutants. They are derived from recent developments in renewable energy in the PRC. For example, in 2005, the volume of renewable energy developed and utilized with modern technologies reached 50 mtce and the environmental benefits generated from the process are worth over CNY10.4 billion.[8]

Because the various forms of biomass energy all originate from solar energy (through photosynthesis) and extract carbon dioxide from the atmosphere (thereby reducing GHG), they also have good potential for generating extra revenues through the Kyoto Protocol's Clean Development Mechanism (CDM).[9] For instance, large biogas plants can gain a significant amount of certified emission reductions by removing the methane that is released from anaerobic lagoons,

7 Pew Center on Global Climate Change. 2007. Climate Change Mitigation Measures in the People's Republic of China.
8 In 2007, the volume of renewable energy developed and utilized with modern technologies reached 61 mtce (not including hydropower) and the environmental benefits generated are worth over CNY12.7 billion.
9 Projects that reduce GHG emissions (compared to the current baseline and are additional to what might be done under normal business practices) can qualify to receive Certified Emission Reduction Credits that can be sold to European and Japanese entities that have emission reduction commitments under the Kyoto Protocol.

the typical means of wastewater treatment. Financing from the CDM for these projects will: (i) improve the cost-effectiveness of biogas plants as a result of revenue raised from the sale of their certified emission reduction (carbon market); and (ii) introduce advanced technology, skills, and competencies.

Applying for certified emissions reductions under the CDM can involve high transaction costs, which disadvantage small-scale projects. As of 2008, only four of 1,630 CDM projects in the PRC were related to mitigating impacts from livestock. Transaction costs could be cut by bundling several similar projects (Box 5.5).

Box 5.5: Pilot Bundled Clean Development Mechanism Project for Medium and Large Biogas Plants in Henan

ADB-financed Efficient Utilization of Agricultural Wastes Project supported a Clean Development Mechanism (CDM) pilot project that bundled 11 medium-to-large pig farms, with sizes ranging from 5,000 to 20,000 pigs, and reduced methane emissions equivalent to 39,000 tons of CO_2. The CDM's project design document was developed and an institutional framework designed to facilitate the CDM transaction to keep costs reasonable relative to the potential value of the CDM revenues.

An institutional framework was also developed with company by-laws, powers of attorney, a biogas support organization, and service and compliance agreements.

The biogas support organization was created to assist the individual farms in developing and processing their data for the CDM Project Design Document, managing the application, validation, and registration process under the CDM, and training for quality control and assurance. The Biogas Support Organization is also the liaison with the carbon buyer. The organization coordinates the sale of the emission reduction credits and the distribution of the revenues to the project participants.

Section 3

The Way Forward for Developing the Industry

Chapter 6
A Policy, Institutional, and Financing Strategy

The PRC's rural biomass energy situation is characterized by a large number of geographically diversified resources and multiple, small-scale conversion technologies. Policy should be based on the need to alleviate the demand–supply stress, optimize the energy consumption structure, and ensure energy security in rural areas, all in accordance with the strategic aims of the government's "New Socialist Countryside"—to improve the rural living standard and increase farmers' incomes.

The potential of biomass energy in the PRC is gigantic, but the barriers to realizing this potential are also significant and complicated. Its development is now at a critical phase, needing government guidance to address energy security, environmental deterioration, and rural development, which are undermining the government's ability to achieve its social development objectives.

A holistic strategy covering policy instruments, institutional arrangements, and financial investment is essential to the furtherance of biomass energy in the PRC during the next 5–10 years. This chapter summarizes ADB-supported TA study's main recommendations, which have been discussed in more detail in previous chapters. To advance a sustainable industry, the country must coordinate market-oriented policies according to findings of its research and development programs, optimize its institutional capacity through proper coordination, and secure financing from development partners. This chapter looks at the major steps that need to be taken to lay the critical groundwork for a sustainable industry.

Policy Instruments

Technologies that provide commercial biomass energy will only be successful if they are developed after a rigorous research and testing stage and, only then, developed according to the proper industry scales and supply chains. To accomplish this, a long-term coordinated set of market-oriented policies and technology development programs are needed to stimulate commercialization and industrial development. Policies should be driven by four objectives: (i) ensure biomass resources are being utilized rather than wasted; (ii) stimulate research, development, and demonstration; (iii) support technology dissemination; and (iv) promote the industrialization of rural biomass energy development.

Policy Objective 1: Ensure Biomass Resources are Utilized Rather than Wasted

The potential of the three main forms of biomass—crop straw, animal waste, and energy crops—is thwarted by wasteful and environmentally harmful human behavior. However, policies are needed to harness the potential of these three resources to build secure, viable systems of alternative energy. In the PRC, we see how policy can act as a double-edged sword, attacking both environmental and economic inefficiencies at once. Following is a snapshot of policy in service of biomass materials:

(i) **Crop straw.** Much of this by-product of agricultural production is treated as waste and burned in fields, creating serious local environmental pollution. Better enforcement of policy to promote the conversion of agricultural straw to high-grade fuel would also enhance the effectiveness of the existing environmental protection policies.

(ii) **Animal waste.** Manure was traditionally used as fertilizer on farms, but the scaling of the breeding industry on the outskirts of cities has resulted in much of this manure being discarded unchecked. As a result, large amounts of manure are contaminating local water resources. Policy should call for medium- and large-scale biogas digester systems for livestock farms as an effective counter measure. Regulations related to wastewater pollution from livestock farms should be better enforced.

(iii) **Energy crops.** Following the principle of "no competition over land for food," policy is needed to remove investment barriers and risks associated with converting marginal lands into arable land for energy crops. Such policies should outline subsidies that are necessary for developing a sustainable supply of alternative fuels. These could involve a one-time subsidy to farmers or industries for bringing marginal lands into productivity as well as production subsidies, such as free seeds and fertilizers over a certain period of time until normal productivity is achieved.

Policy Objective 2: Stimulate Research, Development, and Demonstration

The achievement of the strategic goals for rural biomass energy development should be accompanied with the continued development of technologies in the road map, as described in Chapter 4. The development of advanced technologies and products and their timely pilot demonstration and deployment are important components of the national strategy, and significantly increased funding is needed to stimulate this.

A special program for research, development, and demonstration needs to be established with an annual funding source of no less than CNY100 million.

Policy Objective 3: Supporting Technology Dissemination

Biomass pellet fuel. The cost of producing pellet fuel is too high for rural PRC. To put the industry on sustainable development track, policy-based subsidies are needed in the interim. Three specific subsidies are recommended: (i) a one-time equipment subsidy to village-level pellet fuel producers for setting up facilities, (ii) a subsidy to farmers for purchasing stoves and furnaces that utilize pellet fuel, and (iii) a cost subsidy for producers or end users in the amount proportional to the price difference between pellet fuel and coal.

Industrial-scale biogas plants. While the overall strategy does not recommend financial subsidies for village-level biogas plants that would service households, such plants could help develop local enterprises, especially industrial-scale agro-processing, by producing hot water, steam, and hot

The potential of biomass energy in the PRC is gigantic, but the barriers to realizing this potential are also significant and complicated.

Box 6.1: Heating and Cooking Applications: Relevant International Experience

As the PRC further explores the energy possibilities bound in its agricultural wastes, several countries have experienced notable success in developing a biomass energy industry. These international experiences were identified as part of a TA study supported by ADB to assist the PRC in drafting a national strategy for biomass energy development.

Of the countries studied, India's policies on village-scale biogas production are especially relevant to the PRC, which has faced difficulty in upscaling any kind of biogas production beyond the household level. India does not promote village-scale gasification for cooking gas applications because of concerns about carbon monoxide poisoning. However, with more than 50% of rural households lacking access to grid electricity, India has focused its policies on small-scale biomass gasification for village electrification.

On heating applications, European Union policies are most relevant to the PRC. First, they promote biomass pellet fuels as providing a modern and convenient form of biomass fuels acceptable to consumers in industrialized settings. This could be relevant to the PRC, but the potentially high cost of pellet fuel is still a significant barrier. This implies that policies are needed to reduce the cost of pellet fuel for rural households. The following options are possible:

(i) Low-interest loans, loan guarantees, and tax incentives to pellet fuel producers;
(ii) Standards and criteria for biomass pellet fuels;
(iii) Equipment certification for stoves and furnaces using pellet fuels; and
(iv) Grants to low-income households to facilitate the purchase of pellet fuel and appliances.

air. Research and development should be carried out to enhance the potential for these types of plants and purposes.

Biomass-powered electricity. According to the Renewable Energy Law, the price of electricity generated by all biomass power plants should be CNY0.25/kWh more than the cost of electricity generated by local, desulfurized, coal-burning power plants (Box 6.2). Procedures to share fees have been established[1] but need to be strengthened and clearly extended to small-scale biomass power plants. Government should (i) accelerate implementing these rules; (ii) establish strict enforcement procedures; and (iii) consult with equipment suppliers, utilities, industry, and villages to establish acceptable lower limits to guarantee small-scale biomass power plants can get connected to the electric grid.

Biofuels from non-food crops. Financial support for producing biofuel from non-food crops should be established according to the Proposals for Implementation of Tax Support Policy on Development of Bioenergy and Biochemical Industry. Specific recommendations include near-term incentives to promote land reclamation, energy crop planting, and processing for bioethanol and biodiesel. Targets or requirements should be established based on the minimum amount of biofuel that traditional fuel must contain—ethanol in gasoline and biodiesel in diesel. Initially, the required level should be set about 5% and gradually increased. Midterm policies should include flexible subsidies to cover enterprise losses and to bring biofuels into the cost range of traditional oil (Box 6.3.)

Research and development should be carried out to enhance the potential for these types of plants and purposes.

[1] Renewable Energy Generated Electrical Pricing and Fee Sharing Management Rules and the Management Regulations for Electricity Generation from Renewable Energy.

Box 6.2: The PRC's Premium Tariff on Biomass-Generated Electricity

In February 2005, the PRC adopted a Renewable Electricity Law and began implementing it in January 2006. For biomass-powered generation, the law specifies a tariff premium of CNY0.25/kWh higher than the base electricity price in each province. The base electricity price is essentially the average cost of generation from existing coal and hydropower plants operating in the province. This base cost is generally from CNY0.3/kWh to CNY0.45/kWh, depending on the province. After about 18 months of implementation, the law has led to the construction of more than 50 biomass power plants by the National Development and Reform Commission and their local counterparts. The total planned capacity is 1,500 MW, and the total planned investment is about CNY10 billion.

Early cost-effectiveness research suggests that the PRC's tariff premium on biomass-powered electricity may need revising. A key principle of successful renewable energy policy is the ability to show a reasonable return on investment. Otherwise, financial institutions will not provide the capital required for investment. The PRC's price-setting polices, such as the Renewable Electricity Law, have generally been successful at developing renewable energy markets and domestic industries. Yet, several examples exist of initial tariffs needing to be revised as more information on actual implementation costs became known.

An ADB-financed technical assistance study to develop a national strategy for biomass energy development in the PRC investigated the cost-effectiveness of several biomass power plants under construction in the PRC under the renewable energy tariff and with several possible tax incentives. The economic analysis indicated that even with the most favorable tax treatment (0% value-added tax and 0% income tax), most of the planned plants do not appear cost-effective. The two principal reasons are (i) the use of imported boiler and auxiliary technology by several of these plants increased the unit investment by about 50%, and (ii) the price of biomass fuel is more than 50% higher than the current price of coal. Given this assessment, the level of the current tariff premium under the Renewable Electricity Law may need to be revised based on the actual results from a host of new plants that started operation in 2007.

Box 6.3: Biofuel Policy Lessons from the United States, European Union, and Brazil

Several common lessons emerge from experiences with biofuel policies in the United States, European Union, and Brazil.

(i) **Government support required.** Biofuel production of both ethanol and biodiesel can expand rapidly with government support. Credit guarantees and low-interest loans for producers are two common policy tools to promote rapid growth in supplies.
(ii) **Consistency counts.** Brazil's ethanol program has three decades of experience. The central requirement that ethanol make up a certain percentage of the fuel supply was important to sustaining the industry through hard times.
(iii) **Anticipate commodity price swings.** One essential way to prepare for price swings in fossil fuels relative to biofuels is with flex-fuel vehicles. Whether the price swing is due to a drop in world oil prices or to an increase in biomass feedstock prices, flex-fuel vehicles give consumers a short-term way to adjust and government time to adjust policy in relation to the price swing.
(iv) **Minimize changes in infrastructure.** Blending biofuels with conventional fuels is the easiest way to avoid costly investments in new infrastructure, especially early in the development of the biofuels industry.
(v) **Biofuel technologies improve steadily with time.** While this is true of almost any technology, the Brazilian experience over the past 30 years provides some compelling data on ethanol. From 1975 to 2000, production of ethanol per hectare in Brazil more than doubled. During the same period, harvesting costs fell 50%. To make these kinds of gains, policy should promote research and development for the biofuels industry.

Table 6.1: Policy Framework for Rural Biomass Energy

Policy Type	Policy
Policies to be better enforced	• Outlaw straw incineration • Subsidy for rural biogas
Policies to be enhanced	• Technical standard to prevent pollution from livestock and poultry breeding • Increased funding for biomass energy research and development
Policies pertinent to industry	• Subsidy for ethanol fuel • Pricing of biomass-powered electricity and access to small-scale generators
New policies for pellet fuel	• One-time equipment subsidy of CNY500,000/village plant • Stove subsidy of CNY750/household using pellet fuel • Flexible fuel subsidy for plants or end users in an amount proportional to the price difference between pellet fuel and coal
New policies for biogas projects in breeding operations	• Subsidy of CNY450,000 or 30% of project cost • Interest subsidy • Subsidy for end-user installment of CNY650/household
New policies for industrial biogas systems	• One-time subsidy of CNY500,000/plant, or a maximum of 50% of the total investment
New subsidy for planting energy crop	• One-time subsidy for soil reclamation, according to the type and situation of local soil (average is CNY500/mu) • Planting subsidy of seeds and fertilizer during certain time period and a product subsidy of CNY200/mu for three years to achieve normal productivity
New policies for research and devel-opment	• Establish special-purpose supporting program for rural biomass energy research, development and demonstration, and support it with CNY100 million annually
New policies for overall biomass energy industry	• Tax exemption for sale of biomass energy products • Tax exemption for processing machines related to biomass energy

Policy Objective 4: Promoting the Industrialization of Rural Biomass Energy

Before taxation is levied on the biomass industry as it is done on other industries, several factors need to be considered to prevent taxation from becoming another hurdle to cross. In general, the biomass energy industry produces clean energy from many materials that are currently considered waste, and their utilization produces significant environmental benefits in the form of avoided pollution. However, the cost of manufacturing equipment for biomass energy is relatively high since the technology has not been fully commercialized. Traditional taxation could narrow profit margins, which already suffer from high production cost and the loss of any sales tax credits since no input tax is levied on the biomass materials. Tax exemptions should be provided for the sale of biomass energy products and for the investment in biomass energy processing equipment.

Specifically for biogas projects in medium and large breeding farms, the environmental benefits from avoided pollution are significant and the levels of investment are high relative to the current capabilities of the industry. The government should provide either a grant subsidy of CNY450,000 (or up to 30% of the total investment) or a loan interest subsidy for biogas projects in breeding farms. In addition, the government should provide a subsidy of CNY650 per household for installing the piped distribution system and end-user equipment.

Institutional Framework

Key national institutions can be classified as those with a direct role in planning, implementing, and enforcing biomass energy development, or those having an indirect role, such as in studying the impacts of biomass development on poverty, especially health. Table 6.2 summarizes the recommended responsibilities for key national institutions playing direct roles.

The key ministries with direct responsibility for policy and planning should have the full cooperation of ministries and agencies having

In general, the biomass energy industry produces clean energy from many materials that are currently considered waste, and their utilization produces significant environmental benefits in the form of avoided pollution.

Table 6.2: Ministries with Direct Responsibilities

Institution	Role	Responsibilities
Ministry of Finance	Policy, planning	• Establish financial-incentive policies favorable to rural biomass energy development • Develop policy framework integrating financial investment, subsidy, price and taxation, and full support for pertinent technology research and development, pilot testing, demonstration, and commercialization
National Development and Reform Commission (National Energy Bureau[a])	Policy, planning, implementation, administration	• Integrate strategic goals and tasks for rural biomass energy development into the Long-Term Plan of National Renewable Energy Development • Publish guidelines for industrial development in rural biomass energy • Enforce pertinent industry development policies • Guide and monitor local government to implement tasks • Implement industrialization projects in areas of straw-to-power, bioethanol, biodiesel, etc.
Ministry of Agriculture	Implementation, administration (main agency)	• Manage large-scale deployment of household biogas systems in rural areas • Plan and implement intensive livestock farm biogas projects • Demonstrate and deploy centralized gas plants via straw gasification • Manage selection of seed species • Cultivate studies for energy crops and research, development, and pilot demonstration of straw pellet fuel production and straw biogas technology • As technology matures, manage construction of energy crop base, deploy straw pellet fuel production for distribution in rural areas, and demonstrate deployment of straw biogas projects
Ministry of Science and Technology	Implementation, administration (main technological support agency)	• Lead national research plan for rural biomass energy development • Implement research, development, and pilot projects with the Ministry of Agriculture
Ministry of Environment Protection (formerly State Environmental Protection Agency—better known as SEPA)	Enforcement, environmental protection policies	• Establish and monitor implementation and enforcement of environmental protection regulations and policies • Support rural biomass energy development from the aspect of environment-friendly and sustainable development
National Energy Leading Group	Coordinating	• Provide high-level communication and coordination between ministries regarding energy, including biomass energy use in rural areas

[a] The National Energy Bureau, under the National Development and Reform Commission, was established in 2008. There is a renewable energy department under this agency.

Coordination mechanisms between national agencies and their provincial and local counterparts are already quite strong in project implementation in the PRC.

indirect responsibility for rural biomass energy development, especially in identifying pilot projects, demonstration projects and extension bases, targeted beneficiary groups, and details for project implementation. Table 6.3 summarizes the roles and responsibilities of ministries and agencies with indirect responsibility for rural biomass energy development.

Table 6.3: Ministries with Indirect Responsibilities

Institution	Role	Responsibilities
Leading Group Office of Poverty Alleviation and Development	Design	• Plan participatory model for biomass energy development across the 148,000 poverty villages nationwide • Develop poverty alleviation projects that leverage off of central government's poverty initiatives and resources, such as the poverty alleviation special fund, food-for-work program, agricultural subsidized loans, etc. • Advise rural biomass energy programs on targeting rural household beneficiaries
Ministry of Civil Affairs	Design	• Establish minimum levels of social security for rural society
Ministry of Housing and Urban and Rural Construction	Accreditation	• Certify entities performing civil works under project implementation
Ministry of Health	Monitoring Implementation	• Monitor and control fluorosis and other respiratory diseases due to coal combustion in the countryside • Better coordination with the All China Women's Federation to reduce vulnerability of women to respiratory diseases caused by cooking and heating indoors with coal and firewood
All China's Women Federation	Coordination	• Coordinate among various stakeholders, particularly women, to participate in the demonstration and promotion of rural biomass energy (a strength of these federations are their mobility and rallying function for women) • Support national and local initiatives of household biogas system and energy crop plantation
Agricultural Bank of China and rural commercial banks	Financing	• Provide subsidized loans and microcredit to enterprises and rural households • Facilitate cooperation with and among banking institutions, especially between the Agricultural Bank of China and the State Development Bank, for preferential loans to enterprises with rural biomass energy projects. Only when investments are in place can the projects boost and provide employment opportunities. Cooperation with the rural commercial banks can help rural households to receive the financial service of microfinancing to support crop cultivation and livestock activities related to household biogas projects
National Statistics Bureau	Information support	• Monitor Xiaokang society and the PRC's rural poverty alleviation

Horizontal coordination. Strong coordination between national policy and planning is always needed to establish a comprehensive investment, taxation, and industrial policy framework and to establish goals for the development of rural biomass energy. In the case of the PRC, strong coordination is particularly important between (i) the Ministry of Science and Technology and the Ministry of Agriculture to ensure technological advancement of the research plan and the achievement of expected results in pilot testing, and (ii) the Ministry of Agriculture and the National Development and Reform Commission (National Energy Bureau) to strengthen coordination within the industrial sector. For example, straw-to-power projects should consider the situation and development of agriculture, and ensure the construction of the energy crop base is directly integrated with liquid fuel production plants.

Vertical coordination. Coordination mechanisms between national agencies and their provincial and local counterparts are already quite strong in project implementation in the PRC. What needs strengthening at the subnational level is technical capability. For example, design standards, training programs, and technical support for household biogas systems have been developed and refined over many years and are quite effective. But other biomass technologies and applications (such as large-scale biogas systems) are not as well developed and need to be developed at the national level and transferred to the provincial and local levels.

Financial Framework

Achieving the strategic goals identified in Table 6.4 will require policies and programs from government as well as investments by households, developers, manufacturers and many others, which will require financing. Possible programs for implementing each of the strategic goals are identified in Table 6.4, and the average project costs indicated there were used to calculate a total program cost for meeting each goal along

Table 6.4: Investment Required for Achieving Strategic Goals*

Activity	Unit Investment (CNY)	Scale	Investment Amount (CNY billion)
Household biogas	3,000/household	80 million (60 million new)	180.00
Mid-large biogas plants			
System installment	1.5 million/plant	5 million households (6,500 new)	9.75
End-user installment	650/household		3.25
Straw pellet fuel			
Fuel distribution stations	1 million/plant	10 million households	50.00
End users	1,500/household		15.00
Village straw gasification plants	500,000/plant	3,000 plants	1.50
Village straw biogas plant			
System installment	870,000/plant	1,000	0.87
End-user installment	650/household	200,000 households	0.13
Straw-to-power plant	7,000/KW	6 GW	42.00
Energy crop			
Base construction	800/mu	50 million mu	40.00
Farmer growing	300/mu	Subsidy 200/mu for 3 years	30.00
Fuel ethanol	3,500/ton (capacity)	10 million tons	35.00
Biodiesel	9,000/ton (capacity)	500,000 tons	4.50
Research, development, and demonstration			1.50
Total Investment			**413.50**

GW = gigawatt, KW = kilowatt, mu = $^{1}/_{15}$ hectare.
* The investment amounts in this table are cumulative through 2020.

Table 6.5: Investment Requirement Estimates by Regional Priorities in 2020

Region	Recommended Resources, Technologies, and Applications	Investment Share (CNY billion)
Northeast Region (Heilongjiang, Jilin, Liaoning)	Biomass pellet technology from crop residues for rural cooking and heating Direct combustion for power generation due to the high density of crop residues	32.8
North China (Beijing, Hebei, Henan, Shandong, Tianjin)	Household biogas Biomass pellets from crop residues for cooking and heating Biogas production based on crop residues Medium- and large-scale biogas plants for livestock farms	77.0
Loess Plateau (Gansu, Shaanxi, Shanxi)	High-efficiency stoves	29.8
Middle and lower reaches of the Yangtze River (Anhui, Hubei, Hunan, Jiangsu, Jiangxi, Shanghai, and Zhejiang)	Biomass gasification technology, if the technical and institutional issues are addressed	104.4
South China (Fujian, Guangdong, Guangxi, Hainan)	Biogas technologies, including both household and medium-to-large scale plants given climatic conditions	66.7
Southwest China (Chongqing, Guizhou, Sichuan, Yunnan)	Household biogas Biomass pellets Biomass gasification technology, if technical and institutional issues are addressed	82.9
Qinghai-Xizang Plateau	Highly efficient stoves	1.9
Inner Mongolia and Xinjiang	Biomass pellets, perhaps with household solar energy Biomass gasification technology, if technical and institutional issues are addressed	18.1
Total		**413.5**

with the total cost of this rural biomass energy development plan.

A total investment of CNY413.5 billion through 2020 is necessary to achieve all of the strategic goals of the rural biomass energy development plan. Of this total, about 76% (CNY314.3 billion) targets rural household beneficiaries in the forms of biogas, pellet fuel, and energy crops; about 4% (CNY16.5 billion) is for centralized gas plant projects; and the remaining 20% (CNY82.7 billion) is for power generation and liquid fuel production. An additional CNY1.5 billion is needed for research, development, demonstration, and pilot testing.

Sources of financing. Government and project financing are the two main sources of funding for the proposed plan to develop the PRC's rural biomass energy. While government investment is especially necessary for projects directly related to farmers, private financing is critical for securing self-sustaining financing cycles and maturing the biomass industries. The government should still subsidize other types of projects, but they should be largely cofinanced by farmers and both domestic and international financing institutions.

Government investment should come in the forms of

(i) grant subsidies for constructing household biogas digesters, deploying straw pellet fuel, and constructing an energy crop base;
(ii) grant subsidies and interest subsidies for mid-to-large biogas plants, centralized straw gasification plants, and straw biogas plants;

Table 6.6: Preliminary Investment Breakdown (CNY billion)

Item	Government Investments	Project Financing		Total
		Industry Owners	Other Sources	
Household biogas	60.00	60.00	60.00	180.00
Mid-to-large biogas plants				
System installment	2.95	2.90	3.90	9.75
End-user installment	3.25	0.00	0.00	3.25
Straw pellet fuel				
Fuel delivery system	25.00	12.50	12.50	50.00
End-user installment	7.50	7.50	0.00	15.00
Industrial straw gasification plants	0.75	0.38	0.38	1.50
Centralized straw biogas plants				
System installment	0.44	0.21	0.22	0.87
End-user installment	0.13	0.00	0.00	0.13
Straw-to-power plants		12.60	29.40	42.00
Energy crop				
Planting base	20.00	10.00	10.00	40.00
Farmer planting	30.00	0.00	0.00	30.00
Fuel ethanol		10.50	24.50	35.00
Biodiesel		1.40	3.10	4.50
Research, development, and demonstration	1.50	0.00	0.00	1.50
Total	**151.50**	**118.00**	**144.00**	**413.50**

(iii) grants for research and development (as the primary financier); and
(iv) cofinancing pilot and demonstration projects (at about 50%).

To ensure a more independent, sustainable, and competitive field for biomass industries, government should open the investment field to industry owners, domestic and international financing institutions, international organizations, and foreign governments and private sectors.

Table 6.6 presents a more detailed structure of the required financing and investments. The total government investment is CNY151.5 billion—36.6% of the total. The remaining CNY262 billion should be collected via project financing, in which CNY118 billion comes from industry owners and farmers and the remaining CNY144 billion (34.8% of the total) comes from financing agencies.

To ensure a more independent, sustainable, and competitive field for biomass industries, government should open investments to industry owners, domestic and international financing institutions, international organizations, and foreign governments and private sectors.

Chapter 7
A Framework for Partnership

As discussed in the previous chapter, developing rural biomass energy in the PRC will be costly and one that cannot and should not be shouldered by any one entity. A broad partnership is needed. International finance institutions, such as ADB, can be a catalyst in helping raise the necessary project financing, which will be a significant challenge. This chapter presents a framework for organizing a "Rural Biomass Energy Finance and Investment Partnership." It involves the PRC government and international financial institutions agreeing to support a national strategy to develop rural biomass energy.

There is a long history of cooperation between international and PRC agencies in the areas of renewable energy, energy efficiency, and climate change. However, only a few multilateral and bilateral development agencies have funded rural biomass energy development.

In addition to ADB's support for the Efficient Utilization of Agriculture Waste Project that has been highlighted in this publication, another ADB-funded biomass energy project has recently been approved, Promoting Medium- and Large-Scale Integrated Renewable Biomass Energy Systems. This project is also implemented by the Ministry of Agriculture, with cofinancing from the Global Environment Facility (GEF). It offers a good example of how various development partners collaborated for biomass energy development (Box 7.1).

Figure 7.1 illustrates a preliminary outline for the partnership framework. As shown, the success of the partnership rests on a solid policy and institutional foundation, as discussed in Chapter 6. It also assumes that international finance institutions will sign a "Partnership Framework Agreement" to fund portions of the national strategy that are consistent with their priorities and experiences.

Joint Implementation Plan

A joint implementation plan will coordinate the programs and funding levels of the government and each partner in the development of rural biomass energy. A major premise of the plan is that each partner will continue to support those areas it considers a priority based on expertise and funding history.

A broad partnership is needed. International finance institutions, such as ADB, can be a catalyst in helping raise the necessary project financing, which will be a significant challenge.

Box 7.1: New Biomass Energy Project Showcases Donor Cooperation

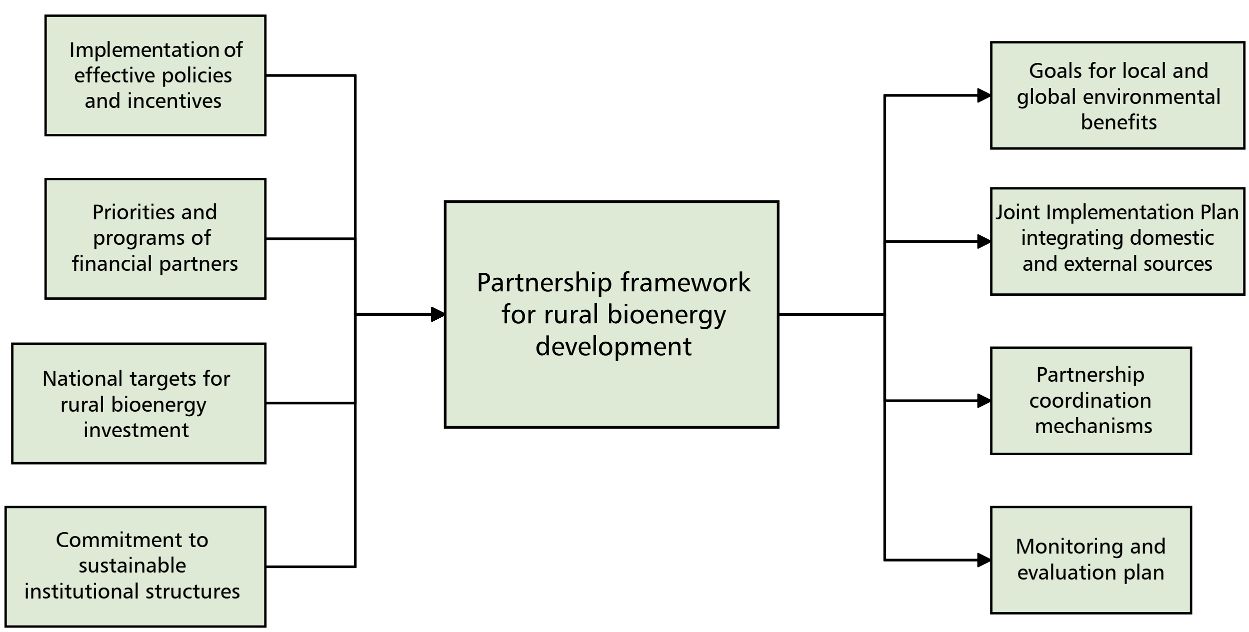
The $96.8 million Promoting Medium- and Large-Scale Integrated Renewable Biomass Energy Systems project pools funding from numerous bilateral and multilateral financing institutions. The project will assist medium- and large-scale livestock farms and agroenterprises in constructing "energy-ecological" types of biogas plants. It will be implemented by the Ministry of Agriculture with a $76.08 million loan from ADB, $3 million from the Multi-Donor Trust Fund under the Clean Energy Financing Partnership Facility administered by ADB, $9.2 million from the Global Environment Facility, and $4.6 million from the German Agency for Technical Cooperation.

The project will also demonstrate business models that aim to improve the cost-effectiveness and technical and environmental performances of centralized biogas plant systems. It will also support subprojects in manufacturing biofertilizers from biogas sludge and eco-farming to achieve a local, circular economy and improve livelihoods in four provinces: Heilongjiang, Henan, Jiangxi, and Shandong.

More specifically, the project will help about 130 livestock farms and agroenterprises improve their waste treatment to meet national standards. In addition, approximately 72,390 households, of which about 7% are poor, will benefit from improved environmental and health conditions. An estimated 7.44 million tons of waste will be treated, and about 102 million kWh of electricity and equivalent amount of heat energy will be produced each year, replacing nearly 84,440 tons of coal. About 1.0 million tons of methane gas will be reduced.

Roughly 5,450 temporary jobs will be created during biogas plant construction, and 1,545 permanent jobs for biogas plant operation. Also expected are 30,450 new contract farmers benefiting from the expanded production capacity of agroenterprises and 49,800 households benefiting from clean energy.

Figure 7.1: Outline Approach to Developing a Partnership Framework



As proposed, the joint implementation plan does not recommend an integrated fund or pooling available funding from any partner except for cooperative projects or programs. Each partner would continue to fund projects and programs as they typically do, such as through technical assistance grants, loans, loan guarantees, public–private partnerships, private sector loans, implementation of the Kyoto Protocol's Clean Development Mechanism (CDM) projects, etc. Rather, the objective of the joint implementation plan is to coordinate each partner's project and program funding so that all elements of the strategy receive the necessary funding.

The proposed joint implementation plan in Table 7.1 does not specify funding levels from potential partners but does provide a preliminary division of responsibilities based on an assessment of current priorities and programs of the potential partners and needs of the national strategy.

Carbon finance is treated as a supplement to the policies, programs, and incentives described in the national strategy. Without these fundamental supports, carbon finance will not make a significant difference to rural biomass energy development. However, carbon finance—either in the form of initial up-front investments or payments upon receiving emission reduction certificates—will play an important role in supporting the projects that may be developed by the Joint Implementation Plan. Larger projects will generally qualify for traditional CDM funds, while smaller activities may benefit from the mechanism's new programmatic approach.

The potential international partners include ADB, World Bank, GEF, United Nations Development Programme, European Union, bilateral agencies from Germany (GTZ and KfW), Netherlands, Italy, Canada (Canadian International Development Agency), Australia, Sweden (SIDA), and the United States (USAID). Government partners include Ministry of Agriculture, National Development and Reform Commission, Ministry of Finance, Ministry of Science and Technology, Ministry of Environmental Protection, and the State Council Leading Group Office of Poverty Alleviation and Development. The partnership framework should be open to other partners; the potential partners identified here are simply those with known activity in biomass energy development.

Opportunities for International Financing

With the success of ADB-financed pilot project on efficient utilization of agricultural wastes and the preparation for a national strategy for developing rural biomass energy, the government and ADB are now working together to upscale the experiences and apply them to medium and large biogas development projects and to prepare and implement the national strategy for energy crop development in the PRC.

During consultations to prepare the 12th Five-Year Plan (2011–2015), the PRC government requested ADB's support for (i) promoting eco-agriculture with biogas digestion liquids, (ii) extension services for community or centralized biomass renewable energy projects, (iii) demonstrating and replicating the community-based straw digestion systems, (iv) possible nonsovereign investments in energy crops development in selected provinces, and (v) coordinating a partnership for developing rural biomass renewable energy.

These expressed needs could form the basis for discussions on a strategic partnership between international financial institutions (IFIs) (led by ADB) and the PRC in rural biomass energy development. IFI support is needed in a number of areas.

Eco-agriculture development with biogas digestion liquids. In relation to the biogas system development (including rural household biogas, medium and large biogas systems in livestock operations, and straw digestion systems), the utilization of digestion liquids as fertilizers and the promotion of eco-farming needs to be further tested and developed. When there is a mismatch between the generation of slurry and sludge from biogas digesters and the availability of sufficient farmland nearby, which is supposed to use these by-products as fertilizers (particularly for livestock farms), a high risk of secondary pollution from biogas systems could occur. The PRC government needs analysis of existing practices, current problems and potential implications. Any technical assistance would need to focus on the mechanism for transporting and distributing the biogas sludge and residues to the fields for farming. For such mechanisms to be sustainable, they may need to be modified for the particular needs of a region.

Table 7.1: Preliminary Outline of a Joint Implementation Plan

		Potential Partners													
	Partnership Activities	Key Government Partners				Multilateral Development Partners					Bilateral Development Partners				
Priority Area	Biomass Resource/ Technology[a]	MOA	NDRC	MEP	LGOP	GEF	ADB	World Bank	UNDP	EU	Australia	Canada	Germany	Italy	US
1st Priority Area: Household biogas	Household biogas	X			X		X	X							
	Mid-to-large biogas plants	X		X		X	X			X			X		
	Straw pellet fuel	X		X		X	X		X		X			X	
	Centralized gas plants via straw gasification	X					X		X						
	Centralized straw biogas plant	X			X	X			X						
2nd Priority Area: Bioelectricity	Straw-to-power plant		X					X		X					X
3rd Priority Area: Biofuels	Energy crop	X					X			X					
	Fuel ethanol production		X	X											X
	Biodiesel production		X	X						X		X	X		
General partnership support	Technical Assistance	X	X	X		X	X	X	X	X		X	X		X
	Monitoring and evaluation	X		X	X	X	X	X	X	X	X			X	
	Capacity building	X	X	X	X	X	X	X	X	X		X			X

EU = European Union, GEF = Global Environment Facility, MEP = Ministry of Environmental Protection, MOA = Ministry of Agriculture, NDRC = National Development and Reform Commission (National Energy Bureau), LGOP = Leading Group Office of Poverty Alleviation and Development, UNDP = United Nations Development Programme, US = United States.

[a] Projects in this area may benefit from additional financing support through the Kyoto Protocol's Clean Development Mechanism.

Extension services. Current national and provincial financial sources and rural energy support services heavily emphasized the household biogas digesters development, and insufficient attention paid to other community-level or medium- and large-sized biogas systems, although the latter is widely recognized as the future direction for rural energy development.

Currently, technical support service systems for community-level gasification, straw digestion, or medium and large biogas systems are inadequate, which leads to poor maintenance and shortened life. In addition, there is a shortage of capable design engineers because most were involved with medium-scale digester design on industrial wastewater treatment process, and do not have adequate experience to deal with the complicated chemical features of animal manure. This limited technical capacity creates a bottleneck limiting the rapid development of community-level gasification systems, medium- and large-sized biogas digesters and other crop straw utilization technologies.

The PRC may consider loan-based projects from IFIs, including ADB, for a number of provinces to support extension services in infrastructure (information support, key equipment, laboratory and machinery facilities, etc.) and non-structure establishments (mechanism, technical standards and procedures, manual of construction and operation, guidelines and specifications for the economic characteristics, diversity and suitability of existing technology options, etc.).

Demonstrating straw digestion system. Crop straw digestion and co-digestion of animal waste with crop straw is promising in terms of effective use of abundant straw resources, enabling farmers who do not raise livestock to benefit from modern biogas technology. They also support eco-agriculture because the liquid fertilizers made from the biogas production can be easily used on farmland. The government has started this experiment in 12 provinces, and requested ADB to further pilot it in other areas.

The PRC should consider a loan from IFIs that focuses on piloting community-based, commercial demonstrations. Such a loan could combine grant money from the GEF with a CDM application. These demonstrations may evaluate the lessons from existing demonstrations and rectify the issues of costly bacteria strains, daily management requirements, raw material input and residue removal, and other related services.

Nonsovereign investment in biofuels.
The development of energy crops and the corresponding biofuel industry depends on the effective organization of farmers' production and coordination between farmers and the fuel production industry. Industry development is complicated by the fact that small farmers dominate energy crop production in the biofuel industry. Farmers will grow energy crops only if they are assured a buyer and reasonable profit.

ADB, as well as other IFIs, should explore nonsovereign loans to develop the supply chain for energy crops through contract farming, linking small farmers with selected state-owned biofuel enterprises. ADB-financed projects have already piloted particular forms of supply chain governance and contract farming. These projects have shown how enabled enterprises can help farmers obtain inputs and produce quality products at guaranteed prices.

Knowledge Sharing

Partnership is important not only to mobilize financial resources, but also to coordinate different agencies' approaches, establish networks, and share knowledge gained from each agency's experiences. Various initiatives are already underway for rural biomass energy.

ADB and other international development partners have been exploring ways to further support the

ADB-financed projects have already piloted particular forms of supply chain governance and contract farming.

Box 7.2: Energy for All (E4ALL) Working Group on Domestic Biogas

The objective of this working group is the innovative dissemination of 1 million domestic biogas plants in 15 ADB member countries by 2015, which would provide access to sustainable energy to about 5 million people. Support will also be extended to develop sustainable, commercial biogas sectors in these countries.

Specifically, the working group is undertaking the following activities: (i) participatory study on the feasibility of domestic biogas in 10 ADB member countries with no previous significant biogas programs; (ii) development of detailed implementation plans for national programs on domestic biogas in 15 countries; (iii) establishment of a development partner trust fund totaling about €300 million to cofinance the national programs; (iv) mobilization of about €180 million-worth of biogas credit to livestock farmers; and (v) networking and joint learning involving all stakeholders.

The working group will be chaired by the SNV Netherlands Development Organization, a non-profit organization that has been involved in domestic biogas production since 1989 around the world, and is comprised of two types of members:

(i) support-oriented members, which include representatives from the SNV, other international resource persons, ADB, and other development partners; and
(ii) implementation-oriented members, who are representatives from participating countries and reputable knowledge institutes in each country.

ADB and other international development partners have been exploring ways to further support the sustainable development of biomass energy.

sustainable development of biomass energy. For example, the Food and Agriculture Organization, International Fund for Agricultural Development, and ADB jointly launched a biofuel initiative in the Greater Mekong Subregion in 2007, which calls for concerted efforts to develop sustainable biofuel technologies, reduce the use of fossil fuels, effectively contribute to climate change mitigation, and help reduce rural poverty. The initiative aims to benefit everyone—biofuel producers, food buyers, and energy users.

ADB, together with MOA, also co-sponsored the International Conference on Rural Biomass Renewable Energy in Beijing in June 2008. This conference was chaired by the vice minister of MOA, and also served as the ASEAN-Plus Three Forum on Biomass Energy.

Another ambitious initiative is the Energy for All Partnership (E4ALL). It is a new regional partnership established by ADB in January 2009 to scale-up access to energy through better information sharing, resources, and financing targeted at appropriate technologies with a proven business case. The partnership aims to provide access to safe, clean, affordable modern energy to 100 million more people in the region by 2015. ADB is supporting the partnership and is hosting the secretariat for the first two years. Under this partnership, a working group on domestic biogas was created, which aims to create 1 million domestic biogas plants in 15 countries by 2015 (Box 7.2). It is led by the SNV Netherlands Development Organization, a non-profit organization that has been involved in domestic biogas production around the world since 1989.

Coordination Mechanisms

Coordination mechanisms define the structure and rules for the partnership. This section summarizes such essential elements of the partnership framework as the agreement between the various partners involved, the leadership structure of the partnership, the operational facets, performance tracking, and how the sustainability of the partnership should be addressed.

Partnership framework agreement. The proposed partnership would be initiated and operated through a partnership framework agreement, which should document the agreed form of the partnership elements and describe the role of each partner in terms of sharing of information, findings, lessons learned, etc., within the partnership. The agreement will also establish funding channels for management and implementation of the partnership's mission and vision.

The best way to formalize the agreement is through a formation workshop with the potential financial partners and the relevant government ministries. The workshop should present a draft of the agreement for review and discussion during the workshop, leading to formal signatures. If possible, this workshop should be scheduled alongside the International Bioenergy Symposium being organized by MOA with the support of ADB. In drafting the agreement, the implementation objectives of the national strategy should be translated into framework goals that reflect local and global environmental benefits, which can be measured and monitored.

Steering committee. A steering committee should be formed under the agreement to oversee and guide the partnership and maintain partners' interest and commitment. All parties to the agreement should be allowed a representative seat on the steering committee, and the initial members will be selected at the formation workshop. Committee members from government agencies should be vice ministers and members from international agencies should be vice directors. The committee should have annual coordination workshops to provide policy guidance, coordinate funding resources, and approve the proposed project pipeline.

Secretariat. A secretariat, under the steering committee, should be formed for periodic coordination, such as preparations for the annual coordination workshops, design and maintenance of a partnership website and information sharing database, scheduling quarterly information exchanges, and other activities as agreed to by the steering committee. The secretariat should primarily be staffed from the steering committee's lead government agency, but should include staff from all participating agencies. At the determination and funding of the steering committee, both short-term and long-term consultants can be hired to provide support.

An effective secretariat is critical to the partnership's success. As a standard baseline, the secretariat should be allocated 6%–8% of the total funding committed by the partners to the various partnership programs and projects. This level of funding should be split between government ministries and the international donors. An example breakdown of secretarial funding is provided in Table 7.2.

Annual partnership workshops. A formal partnership workshop should be held annually to review the status of the partnership, get reports from the ongoing programs and projects, assess progress towards achieving the partnership goals, and discuss lessons learned and approaches to improving partnership activities. The secretariat should organize the workshop. Agencies and individuals that could contribute to the workshop activities or benefit from the information presented should be invited.

Informal coordination meetings should be organized by the secretariat and attended by representatives of the parties to the partnership framework agreement. The meetings will allow the parties to coordinate activities of the partnership's ongoing programs and projects.

Monitoring and evaluation plan. A monitoring and evaluation plan would establish goals for the partnership and describe the approach and procedures for measuring and evaluating its effectiveness.

Table 7.2: Example Breakdown of Secretariat Funding

Project Management Secretariat Activities	Government (%)	International Donors (%)
Partnership management	1	0
Technical assistance	0	1.5
Monitoring and evaluation	1	1.5
Capacity building	1	1
Total	**3**	**4**

To the degree possible, quantitative measures should be used to determine the extent the partnership is achieving its local and global environmental goals. A preliminary set of evaluation categories are listed in Table 7.3, with several possible indicators for each category. As specific programs and projects are developed under the partnership, their contribution to achieving the goals of the national strategy can be quantified according to the identified indicators. The overall effectiveness of the partnership is the total contribution of all the individual programs and projects.

The impacts of the partnership's project activities should be measured consistently and accurately to maintain the integrity of analysis done on the impacts. The secretariat should hire qualified national and international experts to implement specific monitoring and evaluation tasks and to compile results for a national perspective.

Table 7.3: Measures of Partnership Effectiveness

Category	Indicators
Environmental improvement	• Reductions in greenhouse gases • Reductions in water pollution • Reductions in air pollution • Improvements in indoor air quality
Economic development	• Jobs created • Businesses and/or enterprises formed • Improvement in local standard of living • Increased community-level wealth
Social impacts	• Poverty reduction • Improvement to the welfare of vulnerable groups • Reduction of income gap between rural and urban
Energy generation	• New installed capacity for cooking, heating, and power generation • Energy generated from new projects
Investment effectiveness	• Funds disbursed • Projects and/or programs implemented • Partner satisfaction
Capacity building	• Training workshops • Study tours • Trade missions

Capacity Building to Improve Investment Effectiveness

Continual institutional strengthening, especially at the provincial and locals levels, will be important to improve project management and long-term sustainability of project impacts. Specific recommendations for capacity-building activities should be developed by the partners at the formation workshop. Potential activities include training workshops to

(i) improve the quality of feasibility studies, preparation of bid-request documents, and evaluation of proposals;
(ii) develop improved equipment design standards and certification procedures;
(iii) implement improved procedures and techniques for monitoring and evaluation; and
(iv) improve project management of large, multisite, multiparty projects and programs.

Other activities could include study tours to review policies, incentives, and programs implemented in other countries and training programs for the secretariat staff in the areas of project management, financial accounting, etc.

Continual institutional strengthening, especially at the provincial and locals levels, will be important to improve project management and long-term sustainability of project impacts.

This publication presents a road map, strategy and partnership for the PRC to achieve its ambitious 2020 goals of developing rural biomass energy. Through this process, new enabling policies, coordinated institutional capacity, and effective investments made today mean PRC's rural communities would enjoy cleaner energy, better environment, and higher rural income by 2020.

Rural Biomass Energy Book 2020

The developing world is looking for effective, creative ideas for upscaling clean, renewable energy. No place will gain more socially, economically, and environmentally from increased access to clean, reliable energy than poor, rural areas. Biomass energy, produced from animal and crop wastes, is a sensible renewable energy option for rural areas and it can be cost-effective at community and industry scales if guided effectively by governments.

This publication explores the potential of biomass energy to close the urban–rural energy gap, raise farmer incomes, and mend the environment in the People's Republic of China (PRC). Its findings are instructive for other developing and medium-income countries exploring energy-for-all strategies. The report examines the promises and limitations of leading biomass energy technologies and resources for various distribution scales, including but not limited to household biogas digesters. The information is based on lessons learned and experiences from the Asian Development Bank–financed Efficient Utilization of Agricultural Wastes Project in the PRC, as well as findings and conclusions from a technical assistance grant to assist the government draft a national strategy for developing rural biomass energy.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries substantially reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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