Chapter 6 Rural Development and its Energy, Environment and Climate Change Adaptation

6.1 Preface

China is a huge agricultural country, with a rural population of over 700 million. The challenges entailed in ensuring the well-being of agriculture, countryside, and farmers—the "three rural issues"—have always been critical to the healthy development of the nation's economy and society. A stable and sustainable rural energy supply, in turn, is a prerequisite for ensuring rural economic development, raising farmers' living standards, and preserving the rural environment. That is, a sound rural energy supply is an essential foundation for both achieving sustainable development in China's countryside and building a well-off society in an all-around way.

With the continuous development of the rural economy, ecological and environmental problems are becoming more obvious. In fact, China is entering an important historical period, facing the dual challenge of building an ecologically friendly new socialist countryside amid a global financial crisis while also tackling climate change. Research on rural energy, environment, and adaptation to climate change has therefore become vitally important. That research shows that a stable and sustainable energy supply can raise farmers' living standards while also enabling rural areas to both mitigate and adapt to climate change.

6.2 An Overview of Rural Energy, Environment, and Ada-ptation to Climate Change

As an inextricable part of the national energy system, rural energy can be defined in two ways: narrow and broad (Luo Guoliang et al. 2008). In its narrow sense, rural energy refers to commercial energy transported from other places and used in rural areas, as well as local forms of energy, usually renewable. In its broad sense, it refers to the notion that rural areas of many developing countries must rely on local sources of renewable energy because commercial supplies are limited at their current state of development. In its essence, rural energy refers to the overall challenge of providing energy to rural areas (Wang Xiaohua et al. 2003).

The rural energy supply includes all commercial and noncommercial sources, both renewable and nonrenewable. Rural energy demand refers to energy used by both households and producers. Household energy consumption includes energy used for cooking, heating, cooling, hot water, lighting, and home appliances. Energy consumed for production includes that used for agriculture, forestry, husbandry, fishing, and the transport and initial processing of the resulting goods, as well as for farmer-owned township enterprises.

Aspects of rural energy explored in this report include supply and demand, energy management in rural areas, and the development and use of renewable energy resources.

6.2.1 The Environmental Impact of Rural Energy Use

China's rural energy and environmental issues have always been closely linked. On the one hand, energy use puts great pressure on the rural environment and ecology (Chen Jiabin 2003). On the other hand, the development of new and renewable energy sources in rural regions could promote more effective use of agricultural wastes, such as livestock manure and crop straw, play a pivotal role in improving the rural environment, and ensure rural sustainable development.

Chinese farmers have long relied on traditional cookers with a thermal efficiency of less than 10 percent, wasting a great deal of straw, wood, and coal. The traditional use of these energy sources—which entails direct burning—has also brought energy shortages and greenhouse gas (GHG) emissions in rural areas (Wang Gehua et al. 2002).

The transformation of rural society and higher living standards will spur much higher rural energy use, and thus even more GHG emissions (Zhao Xingshu 2005, 2006). Fortunately, new and renewable energy resources that replace conventional sources can improve the efficiency of rural energy use while reducing GHG emissions.

6.2.2 Controlling GHG Emissions and Adapting to Climate Change

Nearly every country has resolved to take active steps to reduce GHG emissions while strengthening the ability of social and economic systems to adapt to climate change. China has long been an active participant in formulating and executing international policies related to global climate change. In 2007 the Chinese government issued a national action plan to respond to global warming. This plan proposed that, by 2010: 1) Energy consumption per unit of GDP will fall by 20 percent from 2005 levels. 2)The discharge of major pollutant will decline by 10 percent. 3) Renewable energy, including large hydropower, will account for more than 10 percent of the nation's primary energy supply. 4) Forests will cover 20 percent of the nation's area, storing some 50 million additional tons of carbon-dioxide.

To achieve those goals, the nation must pursue large-scale changes in its economic structure, energy system, and consumption patterns. Those shifts, in turn, will create opportunities for rural economic development and revolutionize agricultural production, the development and use of rural energy, waste disposal, and rural environmental protection. To achieve those goals, the nation will need to vigorously develop renewable energy, strengthen the comprehensive processing and use of agricultural and other rural waste, and continue to pursue carbon sequestration, such as by planting forests.

Of course, global climate change means that extreme weather events such as floods and droughts are becoming more frequent and ferocious, undermining the stability of agricultural production and threatening rural sustainable development. China must therefore strengthen the ability of its agriculture and countryside to adapt to climate change, to ensure steady development of agricultural production and a sound rural ecology. Toward that end, the nation must provide economic rewards to encourage farmers to adopt agricultural practices and technologies that can both mitigate and withstand climate change.

6.2.3 Tackling the Global Financial Crisis while Building a New Socialist Countryside

The global financial crisis directly affects China's countryside and farmers. Because of a sharp drop in exports, some domestic industries have too much capacity, and some enterprises have had trouble remaining in operation. As a result, millions of migrant workers have flocked back to rural regions, undermining farmers' income and rural stability.

In 2008, under dual pressure from the global financial crisis and serious natural disasters at home, the Chinese government adopted positive coping strategies, such as expanding investment in "agriculture, countryside, and farmers" and constructing an ecological civilization. For example, in the Report of the 17^{th} National Party Congress, President Hu Jintao pointed out that one way to realize the goal of constructing a well-off society in an all-around way by 2020 is by building an ecological civilization.

That goal is spawning new development ideas. These emphasize the use of market pricing and regulatory structures to comprehensively address energy construction and environmental protection, and to build the capacity of the Chinese countryside to mitigate and adapt to climate change.

These policies have proven effective in stimulating domestic demand and sustaining economic development. However, the financial crisis may slow the growth of government revenues at all levels and curb agriculture-related expenditures, rural infrastructure construction, and supplies of rural public goods.

6.3 Trends and Challenges in Rural Energy Use

Since the reform and opening-up, under the nation's diversified development policy and in light of local conditions, China has begun to develop renewable rural energy resources. These include biogas systems, which rely on anaerobic digestion of animal and human waste to produce methane; straw briquettes, produced by compressing straw; small hydropower stations; wind energy; and solar energy.

For example, from 1990 to 2000, China promoted the development and use of more than 10 renewable energy technologies in rural areas, including biogas and wind. The use of these technologies prevented the release of 159 Mt of carbon dioxide (CO_2) and 231,000 tons of methane (CH_4) emissions (Wang Gehua et al. 2002). The nation has also reformed rural power grids, brought power to 30 million people in far-flung areas, and improved the energy efficiency of rural production and everyday life (Luo Guoliang 2008).

However, overall planning and investment in the rural energy system continue to lag behind those efforts in urbanized regions. These longstanding problems also mean that energy demand will grow more strongly in rural areas than in urban regions for quite some time, and that relying on conventional sources to supply enough energy for rural economic and social development will be difficult. The rural energy deficit will become more and more obvious.

6.3.1 The Current Situation

In 2007, rural energy consumption totaled 727 Mt of coal equivalent (Mtce), with commercial and non-commercial supplies accounting for 58.7 percent (427 Mtce) and 41.3 percent (300 Mtce) of that amount, respectively.

6.3.1.1 *Rural Energy Consumption for Household Needs*

Energy end-use by rural households totaled almost 346 Mtce in 2007, with commercial supplies accounting for 23.2 percent and non-commercial supplies providing 76.8 percent of that amount. Straw and firewood are the main non-commercial energy sources, accounting for 60 percent and 35 percent, respectively. Coal and electricity are the main commercial energy sources, accounting for 62.6 percent and 22.4 percent, respectively (Table 6-1).

Table 6-1 Energy end-use by rural households, 2007

Type	Amount		Reference quantity (10,000 tce)	Per capita consumption		Percent
Commercial energy sources			8 015	110	kg ce	23.2
Coal	7 173	10 000 tons	5 014	69	kg	14.5
Electricity	1 459	100 million kWh	1 793	201	kWh	5.2
Petroleum products	363	10 000 tons	533	5.0	kg	1.5
LPG	379	10 000 tons	649	5.2	kg	1.9
Natural gas	1.61	100 million cubic meters	21.57	0.2	cubic meter	0.1
Coal gas	1.73	100 million cubic meters	4.98	0.2	cubic meter	0.0
Non-commercial energy sources			26 561	365	kg ce	76.8
Straw	33 998	10 000 tons	15 979	467	kg	46.2
Firewood	18 217	10 000 tons	9 291	250	kg	26.9
Methane	1 023 963	10 000 cubic meters	731	14.1	cubic meter	2.1
Solar energy	5 810	10 000 cubic meters	560	0.08	cubic meter	1.6
Total			34 576	475	kg ce	100

Source: Department of Science and Technology Education of the Ministry of Agriculture.

Note: tce = tons of coal equivalent. "Other" includes liquid petroleum gas, coal gas, and other sources such as solar water heaters. ce = coal equivalent.

In 2007, per capita rural household energy use reached 475 kilograms of coal equivalent—1.7 times that in urban areas. Rural energy use is inefficient because rural residents rely on few high-quality energy sources. For example, per capita household use of non-commercial energy totaled 365 kilograms of coal equivalent, while per capita household use of commercial energy totaled just 110 kilograms of coal equivalent—less than 40 percent that in urban areas. Per capita household use of electricity, natural gas, coal gas, and liquefied petroleum gas (LPG) is also lower than national levels. This suggests that demand for high-quality energy sources has great potential for growth in the countryside.

The level and structure of rural household energy use vary regionally. Both total household consumption and per capita household consumption are higher in western areas of China, for example, than in central and eastern areas.

Household energy use has become more diversified and commercialized in more developed rural areas. The use of straw and firewood is higher—and the use of electricity, petroleum products, and liquefied petroleum gas far lower—in the West than in central and eastern areas, and domestic biogas is relatively well-developed in the West (Figure 6-1). In eastern areas, in contrast, higher-quality energy sources such as electricity and LPG account for a larger proportion of household energy use, dramatically improving energy efficiency (Figure 6-1).

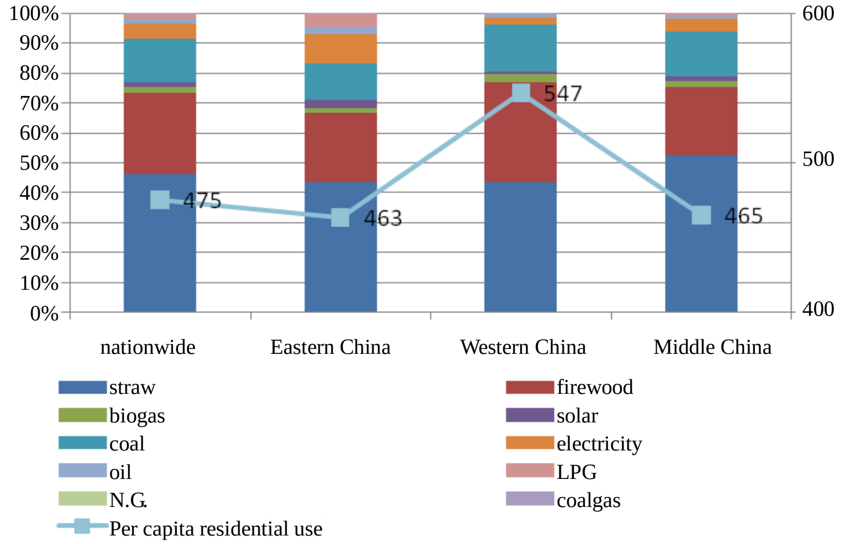


Figure 6-1 Per capita consumption of various types of energy for household use, by region, 2007

6.3.1.2 *Rural Energy Consumption for Production*

End-use energy consumption for rural production reached 380 Mtce in 2007. Commercial sources provided most of this energy, including coal (62.4 percent), petroleum products (17.3 percent), coke (5.9 percent), and electricity (5.4 percent). Firewood is the main non-commercial energy source, contributing 9.1 percent of all energy used for production (Table 6-2).

Township enterprises are major energy users, accounting for 84.5 percent of total energy used for rural production in 2007, while agriculture, forestry, animal husbandry, and fisheries accounted for only 15.5 percent.

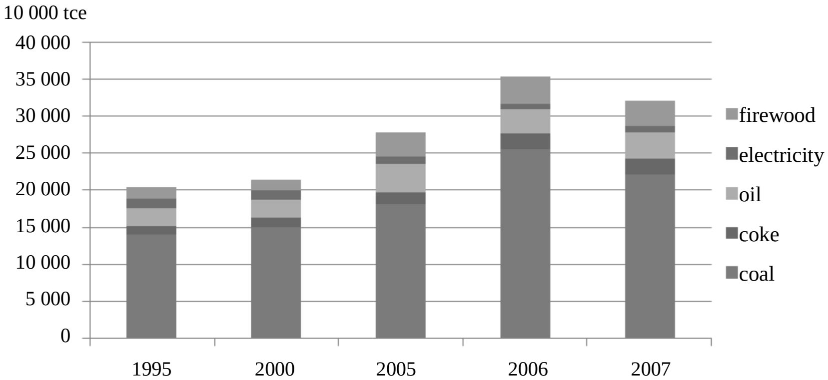
Commercial sources supply most of the energy used by township enterprises, with coal providing 68.8 percent, and petroleum products supplying 11.0 percent. Agriculture, forestry, animal husbandry, and fisheries rely completely on commercial energy sources, including petroleum products (51.1 percent), coal (27.8 percent), and electricity (19.8 percent).

Table 6-2 Energy used for rural production, 2007

	Total energy used for production (in 10 000 tce)	Percent of total	Amount used by agriculture, forestry, animal husbandry, and fisheries (in 10 000 tce)	Percent	Amount used by township enterprises (in 10 000 tce)	Percent of total
Coal	23 788	62.4	1 688	27.8	22 145	68.8
Coke	2 230	5.9	79.4	1.3	2 153	6.7
Petroleum products	6 581	17.3	3 109	51.1	3 555	11.0
Electricity	2 047	5.4	1 203	19.8	876	2.7
Straw	3 452	9.1		0	3 452	10.7
Total	38 098	100	6 080	100	32 181	100

Source: Calculated by the authors from National Rural Renewable Energy Statistics, 2008, and China Energy Statistics Yearbook, 2008.

Note: tce = tons of coal equivalent.



Note: tce = tons of coal equivalent.

Figure 6-2 End-use energy consumption by township enterprises, 1995–2007

Although township enterprises are considered an integral part of rural economies, the nation does not collect or report information on their energy use—particularly of enterprises in suburban areas—as energy used for rural production. Information on end-use energy consumption by township enterprises are therefore probably greatly underestimated (Figure 6-2). For example, current statistics show that from 1995 to 2007, township enterprises accounted for only 12.7 percent of the nation's energy use, even though they contributed about 30 percent of GDP.

6.3.2 Problems with Rural Energy Consumption

As rural energy use has risen and its structure has changed, problems have become more evident.

First, a great deal of rural energy ends up as waste, because the traditional use of biomass—direct burning—is very inefficient. Second, the use of commercial energy sources, especially coal, has caused severe environmental problems. Burning coal produces huge amounts of waste, and most residents simply discard coal residues along with household garbage in open inner yards or nearby areas, without any treatment. And rural residents usually burn coal indoors, so they face serious indoor air problems from total suspended particles (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), and other pollutants (Li Zhiwen et al. 2006).

The development of cleaner sources of rural energy has suffered from a dearth of long-term financial support. Development of renewable energy sources for the countryside, in particular, relies heavily on government funding. The gap between government funding and the need for new sources of rural energy is widening day by day.

Farmers' difficulty in obtaining loans is another significant brake on the construction of rural renewable energy supplies. Under collective land ownership, peasants cannot get adequate credit, because they cannot put land or homes into market circulation or pledge them as collateral assets. Because peasants cannot find a guarantor or have no proper mortgage, most cannot get financial support for expanding their supply of clean energy.

6.3.3 Future Rural Energy Demand

As China's rural economy continues to grow, a rapid increase in rural energy consumption seems inevitable over the next 10 years (Zhao Xingshu 2003).

Rural energy demand reflects the size of the rural population, the level of a region's economic development, income levels and living standards, the price of energy, and levels of energy efficiency. China's current economic development strategies and rural energy policies suggest that these factors will undergo significant changes.

6.3.3.1 *Rural Population*

The major contributors to the size of the rural population are its natural growth rate and the rate of urbanization. In China, urbanization occurs at a higher rate than natural population growth. That means the rural population is shrinking. In 2010, China expects to have a rural population of 700 million, accounting for 51 percent of the total population. By 2020, those numbers will fall to 610 million and 42 percent, respectively. By 2030, the rural population will decline by another 5.3 million, while still accounting for 36 percent of the total.

6.3.3.2 *Income Levels and Living Standards*

Energy consumption interacts closely with income levels. The higher rural residents' incomes, the higher their requirements for energy that provides "comfort, convenience, and cleanliness" (Lu Hui et al. 2006). Under the national goal of building a well-off society in an all-around way, per capita net income of China's farmers will keep growing at an annual rate of 5–6 percent over the next two decades. A moderately prosperous society in all respects means not only higher living standards but could also lead to a potentially cleaner environment, because these changes will spur demand for high-quality commercialized energy.

6.3.3.3 *Changes in Rural Energy Demand*

The Task Force analyzed China's rural energy demand and carbon emissions for 2010, 2020, and 2030, taking 2005 as the base year. In so doing, we relied on a qualitative and quantitative analysis of historical trends in population, income levels, grain yields, and the added value of agriculture, forestry, animal husbandry, and fisheries.

In our analysis, we considered industry restructuring and energy technology that may emerge in the next two or three decades, based on China's Long-Term Energy Alternative Plan (LEAP), as well as the impact of social, economic, and environmental uncertainties on rural energy demand and greenhouse gas emissions.

Our research revealed that end-use energy consumption by agriculture, forestry, husbandry and fishery production will reach 120 Mtce in 2030. As rural production modernizes and industrializes, the use of petroleum products and electricity will grow rapidly, while the proportion of coal in the consumption mix will drop to about 10 percent.

With new rural construction and rising living standards, farmers will gradually increase their demand for energy for heating, cooling, boiling water, electrical appliances, and transportation, even while the number of people per rural household drops.

To understand the impact of those changes on energy use, we examined two scenarios. In the conventional scenario, both the absolute use of traditional biomass resources and their proportion in the household energy mix continue to decline over the next 20 years. Households rely on modern technologies for using straw and wood resources to obtain clean energy. By 2030, the ratio of modern to traditional use of straw will reach 1:1, in this scenario.

The proportion of other modern renewable energy sources such as small hydro, small wind, methane, and solar energy in the rural energy mix will also expand gradually. Rural household demand for high-quality commercial energy—particularly electricity, oil products, and LPG—will also rise. The household use of coal will continue to decline slowly, as it has over the past three years.

In the intensive renewable energy scenario, rural areas develop small hydro, small wind, marsh gas, and solar power resources more quickly than in the conventional scenario. As the government accelerates the modern use of biomass, the ratio of modern to traditional use of straw will reach 2:1 in 2030, reducing not only direct combustion of those resources but also coal consumption.

In this scenario, per capita household energy use continues to increase in the next 20 years, and reaches 0.7 tons of coal equivalent by 2030. However, because of the declining rural population, total household energy use then begins to fall. Commercial energy supplies from other regions meet most of the incremental rural demand for household energy, but non-commercial supplies remain the major sources. By 2030, the ratio of commercial to non-commercial energy sources for household use reaches 1:2.

6.3.4 Renewable Energy Resources in Rural Areas

Fortunately, renewable energy resources—such as biomass, hydropower, wind power, solar power, and geothermal—are widely available in China's countryside.

Annual gains in grain yields and grain-to-straw ratios suggest that annual crop straw resources can total 600 Mt. If half of those resources are used as soil fertilizer, livestock feed, and raw materials for making paper, the remaining 300 Mt can be used to produce 150 Mtce of energy each year.

Twigs and other waste from the lumber industry can total 900 Mt annually. Transforming just 300 Mt of that waste into energy would yield about 200 Mtce. The yield of biogas produced through anaerobic digestion of animal waste, meanwhile, could be 70 billion cubic meters. And farmers could plant energy crops on over 20 million hectares, which could provide 50 Mt of organic liquid fuel equivalent to 70 Mtce. Together these annual biomass resources total about 600 Mtce.

The economically exploitable installed capacity of small hydropower resources—single stations with 100 to 50,000 kW of capacity—is about 128 million kW. Some 90 percent of these resources occur in Hubei, Hunan, Guangdong, Guangxi, Henan, Zhejiang, Fujian, Jiangxi, Yunnan, Sichuan, Xinjiang, and Tibet.

China also has considerable wind energy resources, as it is favored by prevailing monsoons. In particular, Southeastern coast and islands, Inner Mongolia, the Northwest, and some areas in the Northeast have abundant wind resources, with wind speeds above 3 meters per second for as many as 5 000 hours each year.

Finally, most of China lies below north latitude 45°, so the nation enjoys abundant solar resources. Sunshine tops 2200 hours annually in Xinjiang, Tibet, Qinghai, Gansu, Inner Mongolia, Shanxi, and Hebei. In fact, solar energy is already reasonably well-developed in those areas especially for solar water heating, especially in the Northwest and Qinghai-Tibet.

6.3.5 The Evolution of Policies on Rural Energy Use

Since 2000, given continuous econ-omic growth and the accumulation of national wealth, China has underwritten the construction and management of the energy industry. The national government has also emphasized the exploration of renewable resources to supply rural energy, especially biomass and small hydropower plants. Efforts such as renovating the electricity grid in rural areas, constructing new electricity facilities, and exploring new forms of energy such as biogas systems have boosted the rural energy industry.

Under the goal of balancing urban and rural development and constructing a new socialist countryside, the rural energy system can finally become an integral part of the national energy system, and rural areas will have equal opportunities to enjoy commercial energy services. Making good use of their natural renewable energy resources, in turn, will help rural areas ensure food security, protect the environment, and mitigate global climate change. New energy and environmental pricing policies that encourage the development of clean renewable energy and reward cuts in pollutants, including greenhouse gas emissions, are essential to achieving these results.

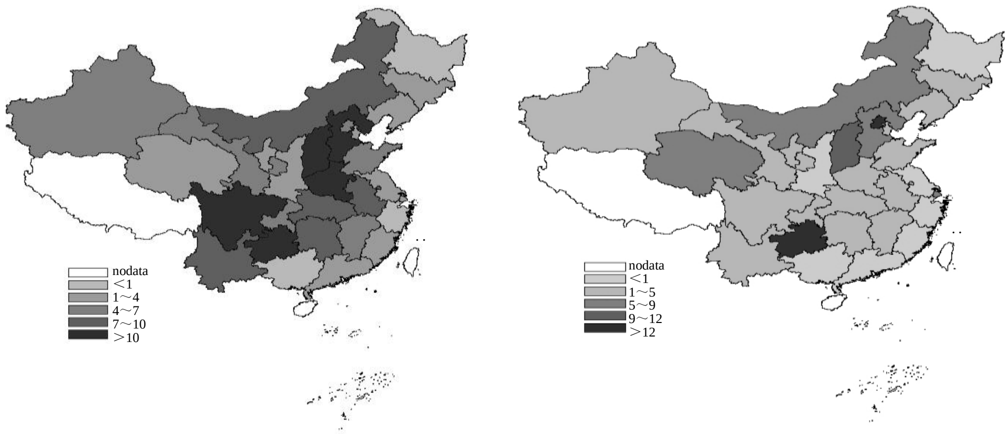
6.4 The Environmental Effects of Rural Energy Use

6.4.1 The Impact of Rural Coal Combustion

Unlike traditional biomass resources, waste from the large-scale rural use of commercial energy—mainly fossil fuels, including coal and petroleum products—cannot be readily recycled.

Since the reform and opening-up, coal has become the primary commercial energy source in rural China. The pollutants emitted from coal combustion include sulfur dioxide (SO_2), nitrous oxide (NO_x), and solid waste. The volume of these wastes is large because rural areas have not implemented the needed control technology, especially compared with urban areas.

SO_2 emissions from rural coal use have grown 7.3 percent annually, from 2.01 Mt in 1980 to 10.91 Mt in 2004. These emissions vary by region. The highest total emissions occur in Hebei, Shanxi, Henan, Sichuan, and Guizhou provinces, while the highest per capita emissions occur in Beijing, Shanxi, and Guizhou (Figure 6-3).



(a) SO_2 emissions per province (10,000 tons) (b) SO_2 emissions per capita (kg)

Figure 6-3 SO_2 emissions from rural coal consumption, 2004

Like SO_2 emissions, NO_x and TSP emissions from rural coal consumption are rising, with emissions from agricultural use of coal growing more quickly than those from household use of coal.

The amount of solid waste from household use of coal is also growing. Rural residents rely on honeycomb briquettes and coal balls, which produce much more waste than the direct use of coal.

Coal combustion also emits pollutants such as carbon monoxide (CO) and benzopyrene (BaP). People exposed to these substances for long periods may suffer from respiratory diseases and cancer, and their children often have birth defects. Coal combustion also causes fluorosis, a disease affecting teeth and bones, in many areas, especially Southwest China.

6.4.2 The Environmental Impact of Traditional Energy Use

Traditional non-commercial energy sources consist mainly of straw and firewood, which can be burned directly. The pollutants from such energy sources include TSP, SO_2, methane (CH_4), and NO_x (Yu Jiangping el al. 2008; Wang Xiaohua el al. 2004; Cao Guoliang el al. 2005).

Straw and firewood contribute 98 percent of all emissions from biomass burning (Table 6-3). Other sources, such as forest fires and grassland fires, contribute a tiny share.

Table 6-3 Pollutants from Biomass (percent)

Pollutants	Straw	Firewood	Forest fire	Grassland fire
SO_2	97.98	0.78	1.08	0.16
NO_x	75.29	23.65	0.86	0.19
NH_3	75.20	24.08	0.61	0.11
CH_4	84.78	14.62	0.47	0.12
EC	83.21	15.00	1.53	0.25
OC	91.18	6.67	1.76	0.39
VOC	46.93	51.66	1.31	0.11
CO	76.08	23.10	0.65	0.17

Source: Cao Guoliang el al. 2005.

6.4.3 The Environmental Impact of Renewable Energy

As noted, China is developing renewable energy sources as an important approach to meeting rural energy needs, reducing pollution, and promoting economic development. If the nation reaches its goal for 2010, the use of renewable energy could reduce annual SO_2 emissions by 4 Mt, NO_x emissions by 1.5 Mt, dust emissions by 2 Mt, and CO_2 emissions by 600 Mt, while also saving 1 500 Mt of water and protecting 150 million mu of woodland.

If the nation reaches its 2020 goal, the use of renewable energy could reduce annual SO_2 emissions by 8 Mt, NO_x emissions 3 Mt, dust emissions by 4 Mt, and CO_2 emissions by 1 200 Mt, while saving 2,000 cubic meters of water and protecting 300 million mu of woodland.

6.4.4 Rural Energy Use and Climate Change

The rapid development of the rural economy and swift rise in the quality of rural life are bringing continuous changes to rural energy use. These changes are clarifying the relationship between the development and use of rural energy, reductions in GHG emissions, and global climate change.

6.4.4.1 *Rural Energy Use and Greenhouse Gas Emissions*

Rural coal combustion is the main source of CO_2 from energy use in the Chinese countryside. CO_2 emissions from rural coal consumption have been rising. In 1980, those emissions totaled 190.96 Mt, but by 2004 that figure had quintupled, with an average annual increase of 7.3 percent.

According to the LEAP model, direct rural CO_2 emissions from both production and household energy use will rise in the coming 20 years—whether or not the nation expands its reliance on renewable energy sources. Under normal circumstances, China's carbon emissions in rural areas will total 78.7 Mt, 91.56 Mt, and 103.31 Mt in 2010, 2020 and 2030, respectively, representing an increase of 8.1 percent, 25.7 percent, and 41.9 percent over 2005 levels. Greater reliance on renewable energy sources will reduce those emissions (Table 6-4).

Table 6-4 Direct Carbon Emissions from Rural Production and Household Energy Use under Two Scenarios (in 10,000 tons)

Year	2005	2010	2020	2030
Normal circumstances	7,283	7,870	9,156	10,331
Mid-level household energy use under normal circumstances	4,289	4,572	4,777	4,722
Strengthened reliance on renewable energy	7,283	7,695	8,739	9,272
Mid-level household use, given strengthened reliance on renewables	4,289	4,396	4,361	3,663

In fact, renewable energy sources can help China cope with climate change in three key ways. The first is by improving energy efficiency and controlling increases in energy use. The second is by replacing conventional energy sources while meeting rising energy demand. And the third is by relying on energy use to achieve multiple goals, including strengthening the rural economy and reducing rural GHG emissions and other pollution. Research has shown, for example, that biogas can reduce average net GHG emissions by 1.88 kilograms per cubic meter (with a range of 1.76–2.11 kilograms per cubic meter).

6.4.4.2 *Strengthening the Capacity of Rural Areas to Adapt to Climate Change*

Climate change has already adversely affected rural production in China, and that impact will continue and even worsen. In the past 100 years, the nation's average annual temperature has risen 1.1℃, with warmer temperatures especially obvious in the most recent 50 years. The location and timing of precipitation and extreme weather events have also changed, significantly affecting agriculture and the development of the rural economy.

According to Xiong Wei et al. (2007), the per-unit yield of the three main food crops could remain steady in the face of a 2.5–3° rise in average temperatures, if farmers adjust their planting structures (leaving out the fertilizer effect of CO_2 and adaptive measures). However, if average temperatures rise further, per-unit yields will fall.

Because of continuous climate change, droughts now common in northern China will occur more frequently, so crop yields will be more dependent on irrigation. Rising temperatures and accelerating decomposition of soil organic matter will shorten the release cycle of chemical fertilizers.

To safeguard its food supply, China may respond to these changes by increasing its energy consumption and use of chemical fertilizers. However, those responses will pose more obstacles to rural energy efficiency and managing GHGs and other emissions. Given this dilemma and uncertainty, China's food security will largely depend on the effectiveness of adaptive measures, such as low-carbon agriculture and progress in agricultural technology.

6.5 International Experiences in Rural Energy, Environment, and Adaptation to Climate Change

Many countries have sought to develop modern energy sources in rural areas to enhance productivity, improve farmers' living standards, and accelerate economic development. Their experiences can help China identify the obstacles and find the best solutions to establishing a new socialist countryside.

6.5.1 Lessons from Developing Countries

In many African and Asian countries, progress on rural electrification lags population growth because of limited resources. However, in Thailand, more than 80 percent of the rural population has access to electricity, while in Costa Rica, cooperatives provide electricity to almost 95 percent of the rural population, and in Tunisia, 75 percent of rural residents have access to electricity.

These experiences show that successful rural electrification programs must meet the following conditions:

(1) They must have effective institutional structures, such as rural electrification authorities and cooperatives.

(2) They must keep the arbitrary use of policies and funds to a minimum, to ensure fairness and transparency in all decisions.

(3) They must establish baseline criteria for rural electrification, as it can make a significant contribution to sustainable development only in areas with existing demand for services such as lighting, television, refrigeration, and transportation, and where farmers' income has reached a certain level.

(4) The price of rural electricity should be realistic. The initial connection charges demanded by a utility are often a far greater barrier to rural families than monthly electricity bills. Lowering the initial connection charges increases the number of users.

(5) Cost recovery is probably the single most important factor determining the long-term effectiveness of rural electrification programs. In most successful programs,

developers receive a substantial proportion of capital at concessionary rates or in the form of grants.

(6) The involvement of local communities in the development of rural electrification programs is essential.

(7) Optimized system design can reduce construction costs by up to 30 percent, and accelerate the pace and scope of the rural electrification program.

(8) Remote areas, where connections to the electricity grid would be prohibitively expensive, should consider alternatives such as photovoltaic systems.

6.5.2 Lessons from the United States

6.5.2.1 *Encouraging Rural Electrification*

Before World War II, U.S. President Franklin D. Roosevelt offered low-interest loans to utilities that would extend electricity lines into the countryside. However, because the number of farms was too small, utilities did not find it profitable to invest in rural transmission and distribution, even with the loans.

Farmers therefore set up cooperatives to purchase electricity in bulk and distribute the power. The cooperative movement became a key feature of the U.S. energy system, and cooperatives continue to provide farmers with relatively inexpensive power today.

6.5.2.2 *Encouraging Renewables*

The 2008 Farm Bill includes a number of provisions that encourage the development of renewable energy and empower rural communities to increase their energy self-sufficiency. For example, funds will help companies and rural regions build refineries to produce biofuels, pursue R&D on advanced biofuels, and improve the efficiency of hydropower.

6.5.2.3 *Paying Farmers to Reduce Greenhouse Gas Emissions*

Major opportunities for rural economies and land managers are emerging with the global effort to control atmospheric concentrations of carbon dioxide. That is because existing practices and technologies offer many ways to reduce GHG emissions—both directly, by cutting emissions at the source, and indirectly, by storing more carbon in soil and biomass. In the United States and other countries with mandatory and voluntary carbon markets, farmers and land managers can sell GHG reductions as GHG credits, or offsets, bringing them extra income.

Under business as usual, U.S. GHG emissions are expected to reach some 8,700 million metric tons of CO_2 equivalent by 2025. An often-suggested target is to lower U.S. emissions from today's levels by 15 percent by 2025, which would require a reduction of about 2 600 million metric tons of CO_2e per year. Research shows that land management practices and technologies could contribute significantly to reaching that target.

The price of carbon is a key factor in the amount of GHG reductions and credits farmers and land managers will supply by changing their land-use practices. The higher the price, the more GHG reductions farmers and land managers will produce. At a price of $15 per ton of CO_2, land management projects could reduce GHG emissions by nearly 1,500 million metric tons of CO_2 per year by 2025—or around 60 percent of the reductions needed to meet the 15 percent target. At $50 per ton, land managers could reduce their GHG emissions by almost 2,000 million metric tons of CO_2 per year—providing nearly all the cuts in emissions to meet this prospective target.

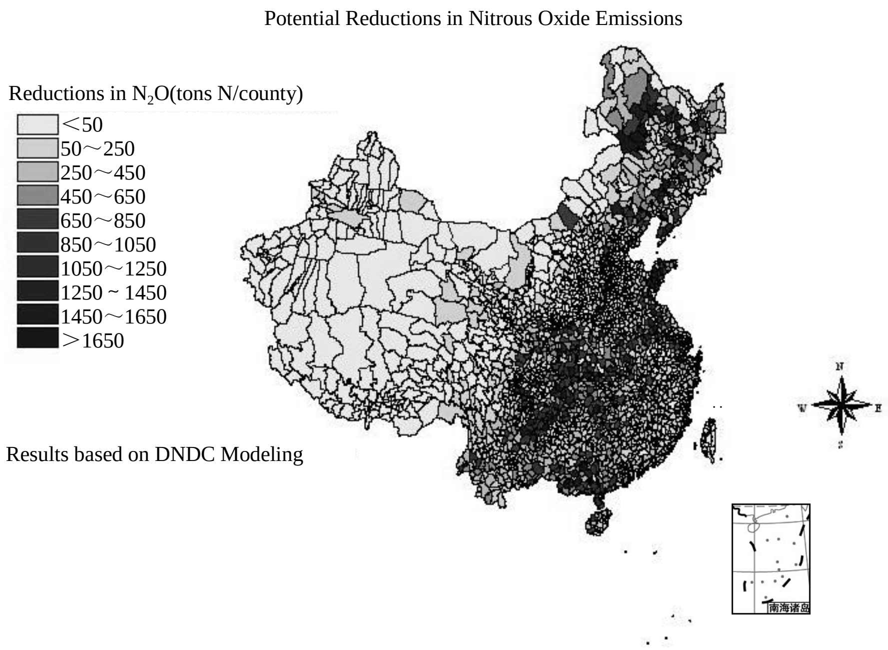


Figure 6-4 County based potential reduction in N_2O calculated based on difference between county based N_2O emissions from the baseline scenario and an optimal use scenario. Pattern of reduction opportunities reflect cropping intensity

The U.S. market for GHG credits is now based on voluntary transactions, so demand is relatively weak, resulting in prices of $1–10 per ton of reductions in CO_2 emissions. In the European Union, which has adopted a mandatory cap on GHG emissions under the Kyoto Protocol, prices have risen well above $35 per ton of GHG reductions in recent years. If the United States enacts a mandatory cap on

GHG emissions, as several bills now before Congress would do, the price of CO_2 will be high enough to spur the land sector to become a major producer of GHG offsets.

In a recent study of the potential GHG effect of improving nitrogen fertilizer management in China (Li and Salas, 2009), researchers found that applying nitrogen optimally to meet the needs of China's soils and crops would result in more than 300 million metric tons of CO_2e reductions annually.

6.6 Policy and Funding Options for Mitigating and Adapting to Climate Change in Rural Areas

6.6.1 Policies Promoting Energy-Efficient Rural Buildings

The Energy Saving Regulation for Civil Constructions, implemented in October 2008, stipulates that the state will encourage and support the use of solar, geothermal, and other forms of renewable energy in both new and existing buildings, and that local governments should allocate special funds to the initiative.

A team from the School of Architecture at Tsinghua University is pursuing the first large-scale domestic attempt to optimize and evaluate an integrated energy-saving system for rural buildings. The team has just completed a pilot project in a village in the Fangshan district of Beijing. The team has also cooperated with the Council for Promoting Sustainable Development in Beijing, and completed "green" renovation for more than 500 rural residences in Pinggu, Shijingshan, Huairou, and Miyun disfricts. If China's entire northern region adopted this approach, it could eliminate the need to burn about 5 Mt of coal equivalent (Mtce) for heat each year—worth about 50 billion RMB.

6.6.2 Policies Promoting Rural Renewable Energy

China's Energy Conservation Law stipulates that the government will encourage the development and use of new and renewable energy sources through various incentives, and allocate special funds to support that initiative. For example, regardless of their size, new power plants that rely on gasified straw can enjoy government subsidies of 0.25 RMB per kWh for 15 years. Operators of electricity grids must guarantee that they will buy all the power that such plants produce, and operators of the plants do not need to pay tariffs or value-added taxes on imported equipment.

6.6.3 Funding Mechanisms for Mitigating and Adapting to Climate Change

Ensuring that agricultural regions mitigate and adapt to climate change will require a large-scale national investment beyond that normally devoted to food production. About half of China's expected climate change mitigation costs and almost all its adaptation costs will occur in economic sectors related to rural poverty. The nation should use those funds to spur afforestation (the planting of trees on nonforested lands) and reforestation, improve forest management, and avoid deforestation. China also needs to invest funds in managing agricultural lands, grasslands, and rangelands to reduce nitrous oxide and methane emissions from fertilizer and livestock.

6.6.4 Funding for Large National Projects

Several key projects aim to protect and reconstruct the ecology of the upper reaches of the Yangtze River, and the upper and middle reaches of the Yellow River:

Rural biogas program. During the 11th Five-Year Plan, the central government invested 3.4 billion RMB in marsh projects in these areas, benefiting 3.74 million rural households. Some 9,144 villages in 721 counties have also received government loans since 2003.

Rural irrigation program. The central government reformed the system for funding state-owned medium- and large-scale irrigation projects and pumping stations in 2002. Under the new policies, institutions managing medium- and large-scale state-owned irrigation areas and pumping stations are classified as public-welfare and quasi-public-welfare units, making them eligible for funds from local governments.

Returning Farmland to Forests Program. Under this program, which became fully operational in 2002, the central government established policies, funding mechanisms, and subsidies to encourage farmers to return farmland to forests. After their projects pass inspection, farmers can receive food subsidies and cash.

6.6.5 China's Clean Development Mechanism Fund

In November 2007, the State Council approved creation of the Clean Development Mechanism Fund, to be used to produce marketable credits for cuts in GHG emissions under the United Nations Clean Development Mechanism (CDM). This long-term, nonprofit state-owned fund will support efforts to mitigate climate change under the national strategy of sustainable development. The fund will encourage project construction, provide technical support, share and manage information, train personnel, and build institutional capacity and public awareness. This fund is an important innovation, because it will coordinate the efforts of domestic enterprises and governments and institutions abroad. It will also provide some of the experience and infrastructure necessary for full scale integration into the global carbon market.

6.6.6 Private Investment in New Energy Sources

China is actively building a sustainable energy system to spur the use of new and renewable energy sources. That effort will require investment from international financial institutions as well as domestic companies. In November 2008, the State Council unveiled 10 policies to encourage private capital to invest in research and development on new energy sources.

6.6.7 International Climate Change Funds

Several funds are investing in projects to produce marketable credits for reducing GHG emissions, with some specifically investing in China:

Global Environment Facility (GEF). By June 2002, China had received more than $300 million in grants from GEF—more than any other country. Those funds supported 55 projects targeting conservation of biodiversity, energy efficiency in industry, renewable energy, protection of international waters, control of land degradation, and related institutional capacity building.

The European Carbon Fund. A number of financial institutions in Europe created the European Carbon Fund (ECF) to invest in projects worldwide that reduce GHG emissions, and to market credits based on those reductions. According to a recent ECF study, the European Union's program for trading GHG emissions will create a market for reductions of some 2.2 billion tons of CO_2 emissions annually. The fund will try to find buyers for another 60 to 120 Mt of GHG reductions created through the Clean Development Mechanism.

The World Bank Fund. The World Bank manages nine carbon-related funds that use public and private financing to buy credits for cuts in GHG emissions from lower-income countries and communities. China's Umbrella Carbon Facility is one of the nine funds, which together handle more than $1.9 billion. The Umbrella Carbon Facility can produce double dividends, because the Chinese government has promised to invest 65 percent of the revenues from that facility in its Clean Development Mechanism Fund.

6.6.8 Voluntary Financial Mechanisms

In October 2007, American International Group announced that it would purchase GHG credits from projects in Xinjiang and Sichuan provinces that aim to conserve energy and provide more renewable energy. Transaction payments of roughly $2 million will help farmers obtain credits for about 310 000 tons of CO_2 reductions—offsetting half the GHG emissions from the company's global business segments in 2006.

These projects will reduce the use of water, fossil fuel, and nitrogen fertilizer in agriculture, and produce methane from anaerobic digestion of solid waste from human and animals for use for cooking and lighting. The projects will also plant trees in desert areas to conserve soil, block winds, fix sand, and reduce soil erosion.

6.7 Case Studies: How Rural China is Conserving Energy, Improving the Environment, and Tackling Climate Change while Addressing Rural Poverty

6.7.1 Cases on the Use of Biomass Energy

Rural sustainable development requires breakthroughs in the development and use of biomass energy. Fortunately, although this transformation is still in its early stages, the use of modern forms of biomass energy in rural China is growing rapidly.

6.7.1.1 *Biogas Projects in Xinjiang and Sichuan*

China has tried various methods of relieving energy shortages in rural areas, such as producing marsh gas, installing energy-saving stoves, and building small hydropower, solar energy, wind energy, and geothermal plants. Marsh gas has achieved the most widespread use.

For example, from 2004 to 2006 the government supported a marsh gas project in Xichong and Yilong counties in Sichuan province. According to information gathered during a door-to-door survey by researchers from Peking University, a minority of farm households had used government subsidies to build marsh gas tanks before the project began, with a few having installed the tanks as early as 1980.

Today nearly half of all peasant households in the project villages have now installed the tanks. Nearly a third of households have also updated their livestock facilities, and 14 percent have updated their toilets.

The government also promoted a family-use marsh gas project in a village in Manas County in Xinjiang prefecture from 2003 to 2005. The project was designed to integrate construction of the tanks with updated livestock beds, toilets, and kitchen stoves. Marsh gas generated through the project is mainly used for cooking and for heating water.

Several factors have affected the output of the tanks. The first is location: winter temperatures in North Xinjiang slow the production of the gas. Building the tank in a big-arch shelter or around warm livestock beds could raise gas production. Survey results show that only one-third of farm households chose to build their tank near warm pigsties or big-arch shelters, while the other two-thirds build the tanks in open courtyards.

The second factor is construction materials and quality: because marsh gas is produced under anaerobic conditions, the tank must be tightly sealed and well insulated. A survey revealed that 60 percent of marsh gas tanks in Manas County are made of brick and concrete, which are relatively low cost. Glass-reinforced plastics are good materials for such tanks, but only 11.43 percent of tanks in the project area are made of such materials because of high costs and low quality.

The third factor is capacity: family-use marsh gas tanks should not be too large, because the amount of material available for fermentation is limited. Most peasant households build 8 – 10-cubic-meter tanks, to ensure energy efficiency.

Because the tanks require a big up-front investment and pose other challenges, just 13 percent of households in Manas County are participating in the project. And even households that do participate often use marsh gas for cooking just two to three months a year.

However, despite these barriers, the marsh gas program has had a significant impact on coal consumption among peasant households in both Xinjiang and Sichuan. In Sichuan districts, for example, marsh gas now accounts for about 16 percent of household energy use, mainly replacing direct burning of straw and coal. Much of the straw formerly used as fuel is now returned to the soil, increasing its organic content and improving its quality. These benefits have reduced the cost of farming and improved farmers' net income.

6.7.1.2 *A Cost-Accounting for Electricity from Biomass*

The use of straw rather than coal to produce electricity could provide significant economic as well as environmental benefits. An analysis of the use of agricultural straw to produce electricity in Ningbo, in Zhejiang province, can shed light on the cost of biomass energy, and the income it could provide to rural communities.

Ningbo has abundant straw resources, with annual output averaging 1.85 Mt. The use of 50 percent of those resources to produce electricity could provide energy amounting to 462,500 tons of coal equivalent. The details follow:

Land: A 25,000-kW plant that can produce electricity from straw would require about 10 hectares of land to grow the straw. Buying enough wasteland for industrial purposes in Ningbo would cost 22.50 million RMB.

Fixed assets: Generating electricity from straw requires a place to store the biomass, factories, offices, subsidiary facilities, and equipment, which together cost 110.50 million RMB.

Raw materials: Dry straw purchased from peasants costs 100 Yuan per ton, and companies that buy and transport the raw material to the power plant charge 130 per ton. The 25,000 kW plant would need about 450,000 tons of straw each year. Thus the annual cost of raw materials would be 58.50 million RMB.

Salaries and other operating costs: Such a plant would require 150 employees. At an average salary of 3,500 RMB, annual employee costs would total 6.30 million Yuan. Other operating costs would total about 5 million RMB, and interest would cost 3 million RMB. Thus the plant would spend 14.30 million RMB on operating costs each year.

Income: If the 25,000 kW plant ran 8,000 hours a year, it would generate 200 million kWh. The plant would receive 0.35 RMB for each kWh it fed into the power grid for the first 15 years. The power plant itself would use 6 percent of the electricity it produced. Annual income from the sale of electricity would therefore total 112.80 million RMB.

Subsidies: Because electricity produced from straw provides social and environmental benefits, a plant can receive a one-time government subsidy of 8 million RMB, as well as tax relief for 15 years.

Bottom line: If the annual depreciation rate is 7 percent, yearly fixed costs of land, buildings, and equipment would total 8.75 million RMB, while variable costs such as materials, salaries, and operating costs would total 72.80 million RMB.

Pre-tax income would therefore total 31.25 million RMB, with a four-year payback on the initial investment. Thus rural communities could see substantial economic benefits from building such plants. Turning biomass into a high-value commodity, in turn, would raise peasants' incomes while producing clean energy, protecting the environment, and creating a recycling economy.

6.7.1.3 *Challenges to Producing More Electricity from Biomass*

Given the striking environmental advantages of producing electricity from biomass, national and local governments should create policies to encourage its development. Such policies are especially important because bottlenecks and unfavorable operating conditions are inhibiting its long-term development:

(1) An unstable supply of raw materials means higher costs.

(2) Collecting, storing, and processing biomass into solid fuel requires specialized agricultural machinery.

(3) The technology is immature: producing electricity from straw is still in the R&D stage.

(4) Costs are higher than those of producing power from coal and other fossil fuels, partly because biomass power plants themselves use a lot of energy.

6.7.1.4 *Recommendations on Expanding Rural Biomass-Based Electricity*

Government and power plant operators can take the following actions to expand rural biomass-based electricity:

(1) To help guarantee a stable supply of biomass resources, the government can help coordinate their production and use for

power plants.

(2) To stimulate the market for straw as an energy resource, the government needs to bring prices and costs in line with those of other fuels. Local governments can do that by setting the purchase price of biomass. This could also be accomplished by establishing a market price for GHG reductions through a trading system.

(3) Power plant operators, institutes of higher learning, and vocational schools need to cooperate on training, research, and technical support for the industry.

6.7.2 Cases on Using Energy Efficiency to Clean Up Pollution and Raise Income from Animal Husbandry

Since the reform and opening-up, animal husbandry in China has attracted global attention for its achievements. In 2007, national output of meat and poultry ranked first in the world, with an output of 69 Mt and 25 Mt, accounting for 25 percent and 38 percent of world output, respectively. China also ranked third worldwide in milk output in 2007, producing 36 Mt, or 5.4 percent of global output. Animal husbandry has become a pillar industry for China's rural development.

6.7.2.1 *The Impact of Animal Husbandry on Energy Use and the Environment*

China's expanding animal husbandry industry is raising peasants' income and improving the living standards of both urban and rural residents. However, the industry is also posing growing challenges to rural society.

In modern animal husbandry, farmers must provide daily ventilation for indoor areas, and cool them in summer and heat them in winter. The development of animal husbandry in China and a continuous increase in its scale has therefore meant growing energy demand. Global climate change and rising average temperatures will only make the situation worse.

Animal husbandry also accounts for a significant portion of agricultural GHG emissions. Livestock and poultry continuously discharge carbon dioxide created during metabolism, as well as methane produced by fermentation in their intestinal tracts. Ruminants such as cattle and sheep release methane at much higher rates than poultry and other animals. Animal waste also releases large amounts of methane and nitrous oxide during storage and treatment.

The huge volume of wastes from animal husbandry greatly pollutes the rural environment. In 2007, excrement from beasts and birds reached 2.7 billion tons, while cultivation sewage reached 11 billion tons. Because of the lack of waste treatment facilities, most of the wastes and sewage are discharged directly into the environment, seriously polluting the air, land, and underground water. Animal waste also contains numerous pathogenic microorganisms, parasitic ovum, and mosquito and fly larvae, which can harm both people and animals.

6.7.2.2 *Managing Animal Wastes More Effectively*

Two projects in rural China are aiming to raise the income of rural residents engaged in animal husbandry while reducing energy use, improving the local environment, and cutting greenhouse gas emissions.

(1) Oversize Marsh Gas Project of Shandong Minhe Animal Husbandry Co.

Shandong Minhe Animal Husbandry Co., Ltd., is Asia's biggest manufacturer of breeding chickens. The company uses an oversize marsh gas project, which costs over 60 million RMB, to produce combined heat and power. The project includes eight efficient, 3 000-cubic-meter anaerobic digesters, which produce 10.95 million cubic meters of biogas annually. The biogas is sent to a power plant with 3 megawatts of installed capacity. The power plant, connected to the grid, uses the biogas to produce 60,000 kWh of electricity daily, and 21,900 MWh annually. At a per-unit price of 0.35, the plant's annual income from the sale of electricity is about 7.60 million RMB.

After anaerobic fermentation, the digesters produce 47 tons of sludge each year (with a water ratio of 70 percent), which converts to 17.5 tons of organic fertilizer (with a water ratio of 20 percent), as well as about 850 tons of slurry (with a solid content of 1.3 percent). These substances retain most of the nutrient content of the chicken manure, including nitrogen, phosphate, and calcium, making them efficient green fertilizers.

The sludge is applied to crops and fruit trees and used in aquaculture and floriculture, while the slurries are used to irrigate neighboring farmland, replacing 310,000 cubic meters of fresh water every year. At a price of 500 RMB per ton, the sale of solid fertilizer brings in 3.20 million RMB each year, and annual income from the sale of both sludge and slurries totals 3.51 million RMB.

Total annual income from the project is therefore 11.11 million RMB, and net income is 5.61 million RMB, after operating costs. Given that the project required an investment of 60 million RMB, its static payback time is 10.7 years. However, because the project reduces GHG emissions by 86 000 tons of CO_2 equivalent, the company has agreed to transfer credits for those reductions to the World Bank—the first agricultural project approved under the United Nations Clean Development Mechanism (CDM). At $10 per ton of CO_2 equivalent, the company will receive nearly 58 million RMB for its GHG credits over a 10-year period.

That income, combined with revenue from the sale of fertilizer, brings the company's annual gross income from the biogas project to 16.91 million RMB. After deducting operating costs, the company will see total net earnings of 11.41 million RMB per year, enabling it to recover its investment in 5.3 years.

(2) Small Marsh Gas Project in Enshi Prefecture, Hubei Province.

In 2003, the Party Committee and government of Enshi proposed creating a model ecological prefecture and villages, with construction of marsh gas tanks as the core strategy. The government saw this approach as the key to resolving the “three rural issues” while also protecting the environment.

Local leaders planned to construct 700,000 marsh gas tanks in appropriate rural areas over five years. The cost of facilities was around 3,000–5,000 RMB each, of which 1,000 RMB was subsidized by the government. Farmers themselves paid the remaining 2,000–4,000 RMB. As of 2006, Enshi had built 410,000 marsh gas tanks for home use, accounting for 44 percent of farm households in the chosen areas.

On February 19, 2009, the project was approved by the CDM Executive Board and successfully registered as a CDM project. Around 33 000 farmers from eight counties and cities are involved in the project. By replacing coal use and the traditional approach to managing swine excrement, the project could reduce GHG emissions by 59 153 tons of CO_2 equivalent while providing income of 330 million RMB to local residents over 10 years.

6.7.3 Cases on Reducing Greenhouse Gas Emissions from Agriculture and Forestry

Rural China has huge potential to save energy and reduce GHG emissions. Annual straw output totals more than 600 Mt, and nearly 150 million households are suitable for producing marsh gas from animal and human excrement. Large areas of barren mountains and salt lick farmlands are suitable for growing energy crops.

Using these resources to reduce agricultural GHG emissions would help increase grain yield, improve the environment, and bring economic benefits, especially if farmers can receive payments for producing marketable GHG credits. Projects to reduce agricultural GHG emissions are therefore becoming very popular in rural areas.

6.7.3.1 *Xinjiang Chinese Tamarisk Greenhouse Gas Reduction Project*

The Chinese Tamarisk Forestation Project aims to reduce GHG emissions by growing more Chinese tamarisk trees, which store carbon as biomass while they grow, and also increase the amount of carbon stored in soil. The project is occurring mainly in Hotan prefecture, Xinjiang, a multiethnic region with 250 000 square kilometers of land and a population of 1.8 million. Hotan prefecture includes seven counties and one city—all of which are high-poverty areas, and thus receive key state support. Mountains cover 44 percent of the prefecture, deserts 42 percent, and oases 4 percent. Agriculture is the mainstay of the economy, so farmland accounts for 18 percent of the oasis area, where local peasants plant mainly cotton, wheat, and fruit trees.

The prefecture planted 100 000 mu with Chinese tamarisk and inoculated 60 000 mu with herba cistanche (a valuable traditional medicine) in 2008, and plans to expand reforestation by another 265 000 mu within 10 years. In addition, Manas, Hutubi, and Qitai counties would then have artificial Chinese tamarisk forests covering 365 000 mu, with a biologic carbon fixation of 288 000 tons of CO_2 equivalent. Carbon fixation includes the amount of carbon stored in biomass and soil, minus carbon dioxide and nitrous oxide emissions from the use of fossil fuel and any chemical fertilizers used to establish the trees.

Benefits of the Project

If artificial forestation of Chinese tamarisk carbon fixation at Manas, Hutubi and Qitai County reaches 365 000 mu and stores 288 000 tons of carbon dioxide equivalent by 2010, and credits for reducing GHG emissions earn $5 per ton of carbon dioxide emissions avoided, the project could earn a total of $1.44 million. If forestation in Hotan reaches 300 000 mu and biological carbon fixation reaches 400 000 tons of carbon dioxide equivalent, the project could earn $2 million.

Farmers could also earn $1.60–4 million annually from the sale of 20–40 tons of herba cistanches. If the area planted in Chinese tamarisk expands to 365 000 mu and the area inoculated with herba cistanches reaches 200 000 mu, total income from the project could reach $5.4–13.4 million.

The project is already providing more than economic benefits. The trees have clothed the bare desert in green, and form a windbreak and sand-fixing forest belt more than 300 kilometers long and 10–15 kilometers wide from the oasis margin in North Manas to the oasis margin of Hutubi County and Qitai County. Vegetation now covers 54 percent of this land, and the number of species of vegetation has increased from 4 to 46, because the forest allows a three-layer structure of trees, shrubs, and grass. These rising levels of biological diversity are expanding the area's productive potential, preventing the desert from encroaching on the oasis, and gradually improving the environment on which human survival depends.

6.7.3.2 *Soil Testing and Formulated Fertilization Project in Sichuan*

Jian'ge County is one of more than 200 counties that have encouraged farmers to test their soils and then apply fertilizer specially formulated to provide the precise amount of nitrogen, phosphate, calcium, and trace elements that the soil and crops need. The goal is to increase the percentage of the fertilizer that plants absorb while reducing the overall need for fertilizer.

Crops covered by the project include wheat, rice, corn, and rapeseed. A survey showed that crops absorb formulated fertilizer much more easily than regular fertilizer, so farmers can apply less. That helps reduce labor costs while increasing yield, with no significant change in unit cost. About 72.2 percent farmers in the demonstration villages therefore prefer to use formulated fertilizers, covering 77.3 percent of the demonstration farmland.

6.8 Policy Recommendations

China is an agricultural country, with rural residents accounting for 60 percent of the national population. The large, scattered rural population—and different natural conditions and level of economic development—make energy issues even more complicated in the countryside than in urban areas.

An accurate understanding of rural energy demand, supply, and use is important in tackling the “three rural issues—agriculture, countryside, and farmers—and in ensuring the effectiveness of national energy polices. Since the reform and opening-up, China’s rural economy has been developing rapidly, and that development has brought significant changes in energy use. First, total rural energy use has nearly tripled, from 328 Mt of coal equivalent (Mtce) in 1980 to 956.5 Mtce in 2006.

Second, the use of noncommercial energy sources such as biomass has been relatively stable, fluctuating only slightly from year to year. The use of commercially produced energy, in contrast, has risen steadily—from 30 percent of all rural energy use in 1980 to 67.3 percent in 2006. That means that biomass no longer occupies a leading position in rural energy consumption. Although that energy source accounted for 70 percent of rural consumption in 1980, by 2006 it had dropped to about 30 percent.

Third, commercial supplies are becoming a major energy source for rural production, rising from 20.4 percent in 1980 to 47.6 percent in 2006. Coal, petroleum products, coke, and electric power are the main commercial energy sources, contributing 62.4 percent, 17.3 percent, 5.9 percent, and 5.4 percent, respectively.

Household users continue to rely mainly on noncommercial energy sources, which supply 76.8 percent of those needs, with straw and firewood contributing 60 percent and 35 percent, respectively. Coal is the largest source of commercial energy for rural residential use, contributing about 62.6 percent of the household commercial total, and electricity contributing 22.4 percent.

Our research shows that as farmers’ income rises, they prefer high-quality, clean, commercial forms of energy for household use. We expect per capita energy use for rural household needs will rise to 0.7 tons of coal equivalent by 2030. With rural use of commercial energy growing at an annual rate of 8 percent, commercial sources will meet a growing share of rural energy demand, although traditional and modern noncommercial forms will remain basic energy sources. By 2030, the ratio of commercial to non-commercial energy sources for household use will be about 1:2.

To develop the rural economy and address the challenges of energy, environment, and climate change, the Task Force offers six policy recommendations to the government:

(1) Spur the rural use of biogas by integrating the construction of biogas facilities into efforts to rebuild the rural infrastructure.

The government should promote the development and use of clean, renewable, and low-carbon technologies to meet farmers' demand for high-quality energy for household use and production. However, today's rural energy policies—which rely on subsidies as a key tool—are no longer adequate to respond to changes in rural energy demand.

We suggest that the government build large and medium-sized biogas facilities as part of the national effort to rebuild the agricultural infrastructure, and set up market mechanisms to support that development. The government should also comprehensively address rural energy and environmental needs by fully enlisting government entities, enterprises, and farmers.

(2) Enhance the statistical analysis of rural energy use.

The Ministry of Agriculture has historically tracked and managed rural energy supply, demand, and use in China. The result is that information and action on rural energy use have remained separate from the national energy management system. However, this approach can no longer keep up with fast-growing and changing rural energy demand.

For example, data on rural energy now appear in the Energy Statistic Yearbook of China, produced by the State Statistics Bureau, and the Yearbook for Rural Energy of China and Statistics for National Rural Renewable Energy Sources, from the Ministry of Agriculture. These two sets of statistics rely on different measures, and data on energy use, structure, and efficiency among township enterprises are insufficient.

These statistics show that rural use of commercial energy accounted for 16.4 percent of the national total in 2007, and that use is rising steadily. If the nation included energy use by township enterprises in information on rural energy use, that proportion would be even higher. To ensure that rural energy becomes an integral part of

China's energy system, authorities need to strengthen their statistical analysis of rural energy end-use by both households and producers.

First, authorities need to unify the definition of rural production, to ensure that statistics reflect actual energy use of township enterprises. Second, national officials need to bolster the ability of county governments to organize and manage energy statistics. As our survey revealed, county-level accounting is a weak link in the creation of national energy statistics, as county statistical departments are unable to present systematic and accurate data on rural energy use.

Agricultural Bureaus, Forestry Bureaus, and other industry bureaus should then calculate and report statistics on local energy consumption under the guidance and organization of local statistics bureaus. The National Statistics Bureau can collect, check, and issue the overall results, to ensure the authority and authenticity of the nation's energy statistics.

(3) Adopt integrated measures to spur the development of clean and renewable energy sources.

Growing rural use of commercial energy sources such as coal, petroleum products, and electricity results in significant pollution and GHG emissions. Unlike urban regions, rural China lacks the infrastructure and technology to clean up these pollutants. For example, most pollutants from coal combustion are released directly into the environment, without any treatment.

Fossil fuels, especially coal, are the major source of CO_2 emissions from rural energy use. In 2004, rural coal burning poured some 1.04 billion tons of carbon dioxide into the air, of which 561.09 Mt came from agricultural use, and 477.63 Mt came from household use.

Rural CO_2 emissions have been rising continuously. In 1980, rural areas produced 191 Mt of carbon dioxide. By 2004, that amount had quintupled, after rising at an annual rate of 7.3 percent.

In 2004, the rural burning of coal also released 10.91 Mt of SO_2, of which 5.89 Mt stemmed from rural production and 5.02 Mt from household use. Rural coal burning further released 932 000 of NO_x and 644 500 of total suspended particles (TSP) that year, with agricultural production accounting for 503 400 of NO_x and 348 100 of TSP, and household use accounting for 428 600 and 296 300, respectively.

Rural coal use also produced 180 Mt of solid waste that year, with agricultural production contributing 100 Mt and everyday rural life contributing 80 Mt. The amounts of all these pollutants are rising rapidly.

Developing renewable energy sources could help relieve gaps between energy supply and demand, curb pollution, increase farmers' income, and control GHG emissions. Research has shown that the use of a cubic meter of biogas rather than coal reduces GHG emissions by 1.88 kilograms. From 1991 to 2005, biogas provided some 28.4 Mt of coal equivalent for heating. That energy source therefore reduced GHG emissions by about 73.16 Mt of CO_2 equivalent, with an average annual reduction of 4.88 Mt—or 0.07–0.16 percent of total national GHG emissions.

In 2005, China used some 166 MTCE of renewable energy (excluding traditional direct burning of straw and firewood)—accounting for about 7.5 percent of national primary energy use. The use of renewable sources reduced annual SO_2 emissions by 3 Mt.

Existing technologies provide several options for converting biomass into an efficient energy source: producing biogas (also known as marsh gas), solidifying or gasifying crop straw, and using biomass to generate electricity. Of those technologies, biogas is the most highly developed in China.

However, high up-front costs are restraining further development. The initial investment needed to build a straw gasification station averages 1.2 million RMB, for example. If each such station serves 200 rural households, each household must contribute 6,000 RMB in construction expenses. Stations that press straw into blocks are also difficult to organize and operate, and profits are limited, so private capital is not very interested in investing in the straw gasification industry.

The governments will therefore need to promote these technologies to bring them into widespread use. The government could do so by expanding its own investment in modern biomass facilities, and by providing subsidies and tax incentives to encourage private capital to invest in R&D on rural renewable energy technology. Only with government guidance can China fulfill the goal of fully commercializing its extensive renewable energy resources.

We recommend that the government also use favorable pricing to promote the use of clean commercial energy sources, particularly electricity, in rural regions. For example, a Rural Energy Construction Fund could promote sustainable energy development, while “transfer payments” could subsidize electricity use among farmers.

A rural renewable energy strategy and related laws and regulations are essential to both improving the rural environment and tackling climate change.

(4) Support the development of low-carbon, high-quality agriculture.

Rural regions suffer from extensive pollution from overuse of pesticides, fertilizers, and plastic sheeting; low energy efficiency and high emissions from agricultural machinery; air pollution from the direct burning of straw and firewood; and a lack of options for disposing of animal wastes.

Developing a low-carbon agricultural economy is the only way to fundamentally solve all those problems. A low-emission, high-efficiency, recycling agricultural industry will reduce both pollutants and rural GHG emissions. Recommended low-carbon practices include reducing the use of fertilizers, pesticides, and plastic sheeting; replacing fertilizers with farm manure; replacing chemical pesticides with biological pesticides; and replacing plastic sheeting with biodegradable sheeting. Other practices include phasing out old irrigation application technology while promoting more efficient irrigation methods, increasing the recycling of agricultural wastes, and promoting other technologies and practices that reduce energy use.

China should rely on a comprehensive, long-term strategy based on local circumstances to develop low-carbon agriculture, including long-term subsidies to encourage investment in new technology. National voluntary carbon-trading mechanisms, and payments to impoverished farmers for reducing pollutants and GHG emissions, are a cost-effective way to promote low-carbon practices while also contributing to the nation's goal of alleviating poverty.

(5) Spur the use of renewable energy sources to provide heat and electricity for rural buildings.

Rural buildings already account for a large proportion of energy use in China, and the amount of energy they consume is rising fast. Meanwhile fossil fuels such as coal are replacing the traditional direct burning of straw and firewood.

Greater reliance on renewable technologies to heat rural buildings can help conserve energy. To promote that goal, the central government has created programs demonstrating the use of solar and shallow geothermal technologies in rural buildings. These programs include a thorough assessment of the results, timely readjustment of policies based on those results, and replication of lessons learned on a wider scale. The programs also encourage researchers, manufacturers, designers, architects, and builders to learn from the problems encountered in the projects and improve their facilities and technologies before applying them nationwide.

(6) Improve the capacity of farmers and rural regions to adapt to climate change.

China's average temperature rose 1.1℃ in the past 100 years. The frequency and intensity of extreme events, such as high temperatures, drought, and rainstorms—the predicted result of climate change—are also rising. These changes have brought higher average precipitation levels in West and South China but lower levels in North and Northeast China in the past 50 years.

Research reveals a close relation between climate change and food security. If China's average temperature rises by

2.5–3℃, the per-unit yield of the nation's three major crops could either rise or fall depending upon assumptions about technical change and other climate-related yield impacts, and farmers can maintain total grain output by readjusting planting patterns. However, if the rise in the average temperature exceeds 2.5–3℃, the per-unit yield of all three major crops will decline continuously, inevitably affecting total output.

Given this uncertainty, and the growing incidence of extreme weather, enhancing farmers' ability to adapt to climate change is essential, to sustain the rural economy, improve rural living standards, and ensure food security. Toward that end, the nation needs to evaluate the speed and scale of disasters that climate change could cause. China also needs to develop systems for monitoring regional climate change, and providing early warning of disasters. And authorities at all levels need to consider adaptation to climate change when creating development strategies, and bolster community-based disaster prevention and training.

Both facts and models convince us that climate change will have a profound impact on China's food security. To respond to this threat, the government will need to adjust the structure of the nation's agricultural production and consumption. Funding and technology are the two pillars supporting the rural campaign against climate change. However, the nation should adopt flexible approaches that reflect the needs of each area.

China needs to introduce practices that sequester carbon in soil and biomass and reduce GHG emissions to a wider audience, including afforestation, low-till or no-till farming, better grassland management, alternative varieties of animals and fodder, and more efficient use of fertilizer. The government should establish consulting services at all levels to ensure that farmers have access to energy-saving technologies and information on low-carbon farming.

The government must provide subsidies, insurance, and credits to advance these goals, especially in areas with fragile ecosystems and large numbers of farmers. A program that enables farmers to obtain credits for reducing GHG emissions through changes in production practices, and that markets and trades those credits, could achieve the dual goal of removing CO_2 from the atmosphere and providing new income to farmers and land managers.

To ensure a self-sufficient food supply and relieve pressure on domestic resources and the environment, the government should import agricultural products with high resource costs, such as soybeans and corn. A map matching biodiversity with climate change patterns will also be a fundamental tool for planning to protect the nation's agriculture and food supply. China should also preserve information on biodiversity in national and international gene pools.