PARTNERSHIP FOR CLEAN INDOOR AIR
Household Energy, Indoor Air Pollution and Health: Overview of Experiences and Lessons in China

Prepared by

Center for Entrepreneurship in International Health and Development
School of Public Health
University of California, Berkeley

under the direction of

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The Partnership for Clean Indoor Air was launched at the World Summit on Sustainable Development in Johannesburg in September 2002 to address the increased environmental health risk faced by more than two billion people who burn traditional biomass fuels indoors for cooking and heating. The Partnership is led by the U.S. Environmental Protection Agency with support from the U.S. Agency for International Development. The mission of the Partnership is to improve health, livelihood and quality of life by reducing exposure to air pollution, primarily among women and children, from household energy use. For more information please visit www.PCIAonline.org

Principle author:

Shannon Graham, School of Public Health, University of California, Berkeley.

Contributing authors:

Rob Bailis, PhD candidate, Energy and Resources Group, University of California, Berkeley.
Dana Charron, School of Public Health, University of California, Berkeley.

Research and translation:

Tom Du, MBA candidate 2005, Haas School of Business, University of California, Berkeley
Nuyi Tao, MBA graduate 2003, Michigan School of Business

Special Thanks:

Prof. Kirk Smith, School of Public Health, University of California, Berkeley

Thanks

Doug Barnes, ESMAP, Energy and Water Department, World Bank

Sandra Dratler, PhD, Executive Director, Program for Research in International Health Management, School of Public Health, University of California, Berkeley

Majid Ezzati, School of Public Health, Harvard University

Susan Fischer, PhD Candidate, School of Public Health, University of California, Berkeley

David Fridley, China Energy Group, Lawrence Berkeley Laboratories

Dr. Nap Hosang, School of Public Health, University of California, Berkeley

Prof. Teh-wei Hu, School of Public Health, University of California, Berkeley

Jean Ku, National Renewable Energy Laboratories

Joanna Lewis, PhD candidate, Energy and Resources Group, University of California, Berkeley

Jonathan Sinton, PhD, China Energy Group, Lawrence Berkeley Laboratories

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List of Abbreviations

ARI	Acute respiratory infection
BEPE	Bureau of Environmental Protection and Energy
BOH	Bureau of Health
CAREI	China Association of Rural Energy Industry
CCDC	China Center for Disease Control
CNISP	China National Improved Stove Program
COPD	Chronic obstructed pulmonary disease
CSM	Cooperative Medical System
DALYs	Disability-adjusted life years
DFID	Department for International Development (UK)
ESMAP	Energy Sector Management Assistance Program
GDP	Gross domestic product
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HDI	Human Development Index
HRI	Health Risk Index
IAP	Indoor air pollution
IEA	International Energy Agency
IES	Integrated Environmental Strategies
LPG	Liquid petroleum gas
MDG	Millennium Development Goals
MOA	Ministry of Agriculture
MOH	Ministry of Health
NGO	Non-governmental organization
NREL	National Renewable Energy Lab
PAH	Polycyclic aromatic hydrocarbons
PIC	Products of incomplete combustion
PM	Particulate matter
PPM	Parts per million
PPP	Purchasing power parity
REO	Rural Energy Offices
RECO	Rural Energy Manufacturing and Service Companies
SDPC	State Development and Planning Commission
SETC	State Economic and Trade Commission
TNC	The Nature Conservancy
UNDP	United Nations Development Program
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WB	World Bank
WHO	World Health Organization
WRI	World Resources Institute

Note to Reader

1. In the authors' opinion, the information in this report is the "best available". It incorporates published and peer-reviewed articles from top experts, interviews with Chinese and foreign professionals active in the subject matter, current articles from the Chinese press, and statistical and literature databases that were translated from Chinese into English. The authors refer to the "best available" information with the understanding that the information obtained is some of the most accurate public information currently available, given the limited depth of and short timeframe for preparing this document. The authors faced several challenges in preparing this report, including that China is rapidly changing and information in some cases is not up to date; information about rural China is hard to find (some information, like household uses of energy, may simply not be studied); there are many players in this field, some of whom may have been missed in this analysis; and many public records and documents are not available electronically. The research for this project did not have the benefit of on-the-ground investigations in China.

2. Given the scope of the paper, the authors have integrated a variety of sources that range from highly quantified and highly peer-reviewed to qualitative and anecdotal. This range of source material affects not only the tone throughout the paper but also the degree to which the authors can claim something with 100% certainty. It is suggested that the reader leave some room for possible error where it is marked that the source is from a personal conversation or an interview. Given the timeframe of this paper it was not possible to interview a sufficient number of people so as to remove all uncertainty from certain claims.

Map of China


RUSSIA
Lake Baikal
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
INDIA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
VIETNAM
LAOS
THAILAND
CAMBODIA
PHILIPPINES
TAIWAN
Yellow Sea
East China Sea
South China Sea
Bay of Bengal
China
National Capital City
International Boundary
Provincial Boundary
Province Name
Disputed Boundary
500 km
0
500 Miles

Chapter 1 . Executive Summary

This chapter first provides a summary of the key facts for easy reference and comparison to other household energy and health country reports prepared for the Partnership for Clean Indoor Air. The second part contains chapter summaries to guide the reader through this complex document.

1.1 Summary of key facts

A "snap shot" of the current Chinese household energy and health situation and a review of past experiences is presented below.

1.1.1 Overview of household energy and health

Health and Indoor Air Pollution

- Aggregate indicators show that China's population has achieved a health status comparable to that of a middle-income nation. However, there are significant disparities between urban and rural areas.
- IAP-related diseases make a significant contribution to the burden of disease, estimated at 20% of deaths and 9% of disability adjusted life years (DALYs).
- Most IAP-related fatalities in China occur in adults as a result of COPD and other pulmonary diseases. The highest rates of lung cancer in the world are found in Yunnan province in southern China.
- The health effects from solid fuel use in China go beyond the diseases typically associated with chronic exposure to particulate matter and CO and include physiological symptoms associated with chronic exposure to toxic substances found in coal.
- Raw coal used in some part of China contains toxic compounds including arsenic and fluorine, as well as selenium, heavy metals like cadmium, mercury, antimony and chromium, and carcinogenic compounds. Coal use can result in exposure to these compounds, through direct and indirect pathways.

Household energy

- Approximately 80% of Chinese households depend on solid fuels, and virtually all rural home use solid fuels, primarily coal and biomass.
- Local availability is the primary factor in fuel choice, and many households use more than one fuel, at different time of the year and/or for different purposes within the home.
- Biomass (wood and crop residues) is estimated to accounts for more than 10% of the countries' total energy consumption. China is responsible for approximately 30% of the world's coal consumption. Residential coal use is much higher in China than in other developing countries. Over the last 20 years, biomass use has been relatively flat, while coal use in rural homes has increased three-fold. This shift represents progress up the energy ladder.
- The coal burned may be processed, washed, or most likely raw, with widely varying levels and types of impurities. Much of the residential coal is produced by a proliferating number of smaller coal mines.

1.1.2 Key entities/organizations working in the field of household energy and health

- Chinese government agencies: Ministry of Agriculture; Ministry of Forestry; Ministry of Health, Ministry of Science and Technology, National Development and Reform Commission; Offices of Western Development.
- NGOs: China Association of Rural Energy Industry (CAREI), The Nature Conservancy (TNC)
- Multi-lateral and bi-lateral agencies, including World Bank, Government of the Netherlands

1.1.3 Key household energy and health programs

- China National Improve Stove Program (CNISP): China is responsible for one of the most impressive rural biomass stove programs globally. From the early 1982-1992, 129 million rural households (65%) installed new stoves without significant subsidies and achieved modest gains in energy efficiency. Follow-on programs brought the total number of stove disseminated to almost 200 million. The national program has now concluded, and long-term results, in terms of number of systems still in use and the impacts on IAP, are currently being evaluated by a team led by Dr. Kirk Smith and funded by the Shell Foundation.
- Ministry of Forestry initiated a biomass stove program in the Yangtze River Valley to increase fuel efficiency. Goal is to slow hillside erosion and promote reforestation.
- Ministry of Health is running a small pilot study in 100 counties that targets human poisoning by emissions from coal with high levels of fluorine and arsenic.
- TNC is working in poor regions of Yunnan Province to protect biodiversity.
- Dutch Government is funding a renewable energy project with a household energy and health component in seven provinces.

1.1.4 Synthesis of lessons learned, categorized under EPA's four areas of focus

Market Development

- The wealth created during China's economic boom is unevenly distributed across rural areas; some areas are desperately poor while others have benefited from substantial improvements in quality of life. Similarly, the commercial market for improved stoves and fuels is well developed in some areas and not at all in others.
- There is a large coal stove market with evidence of customer willingness to pay for improved coal stoves that reduce their exposure to indoor air pollution.
- Factors in CNISP's success include: local regulations that accelerated the adoption of improved stoves: local citizens groups that checked progress on behalf of the government; and local energy business there were involved. By concentrating activities in the more affluent rural areas, directing them locally, and financing technical assistance, CNISP was able to disseminate stoves successfully through the marketplace almost entirely without consumer subsidies.
- Some rural areas and populations are still well beyond the reach of the commercial markets and may require more programmatic, donor-supported approach.

Technology Standardization

- China has very complex household energy patterns, with a large number of stove and fuel combinations in use. At the national level, this is not so surprising, as there are tremendous climatic, economic and cultural differences across regions. More interesting, perhaps, is the variety found within individual households, where different fuels are burned, depending on cost, availability and purpose (cooking, heating, hot water warming).

- The improved stoves disseminated through the CNISP included a variety of models, representing a range of production approaches, from mass manufacturing to smaller scale local production to individualized home-built devices.

Health Impact Monitoring

- The health care system in China is significantly better than in most developing countries so the background incidence of the diseases often associated with indoor air pollution are generally lower.
- Indoor air pollution is not officially on the national health agenda; however, an indoor air pollution standard was developed and instated in 2003. In addition, there is one government pilot project addressing toxins found in coal used in homes.
- Since each fuel/stove combination will result in a unique type and quantity of emissions in the home, developing a clear picture of emissions levels, even in a given region, and designing possible interventions is complex.

Social and Cultural Barriers

- Most rural individuals have limited health education, which makes it more difficult for them to understand the health effects of indoor air pollution. This in turn limits their ability to make good choices with regards to fuel selection, stove design and placement, and flue installation and ventilation.
- At the same time, it is critical that individuals understand these issues, so they can apply advances in technology to their local fuel situation. Because the variability of stove-fuel combinations is so great in rural China, there is unlikely to be a one-size-fits-all technical solution.
- Cooking and food preparation techniques and traditions are a vital part of cultural heritage in China as elsewhere. These also vary widely across the country.
- Public concern over elevated levels of indoor air pollution may be increasing but there is no evidence of organized awareness-building activities.

1.2 Summary of chapters

Chapter 2

While economic growth in China has propelled much of the country forward, many have been left behind. Inequity is growing not only between urban and rural, but also between the eastern coast and the western slopes of the country. Poor agricultural earnings, an excessive labor pool in rural areas, and land degradation is causing migration toward wealthier areas. In addition, while urban quality of life has improved tremendously for some, rural basic services have suffered from neglect since the economic reforms of the 1980s. Government leadership is facing challenging rural poverty issues in order to maintain social stability and environmental sustainability.

The heath status of China's populations shows the effects of the uneven economic growth. Mortality rates are falling in urban areas but rising in rural regions, and the Chinese health care system has to contend with health problems of both poverty and affluence. Despite degradation of the rural healthcare system and declines in rural health, aggregate indicators, such as infant and child mortality and life expectancy, are still well ahead of other developing nations due to earlier periods of excellent healthcare and education programs in rural areas. Public health statistics show that respiratory illnesses for which indoor air pollution is a known risk factor are common and account for as much as 20% of deaths.

Chapter 3
The indoor air pollution (IAP) and health situation in China is uniquely shaped by the legacy of a large stove program, the relatively high level of health care, the high incidence of smoking, and the high proportion of coal used in rural homes. On the one hand, the stove program probably produced unintended health benefits through the installation of improved biomass stoves. In addition, general improvements in the standard of living may have lowered the incidence of diseases often associated with IAP. On the other hand, the extensive use of coal in rural homes causes high levels of respiratory diseases in adults. Additionally, in some areas the use of coal laden with toxins leads to a range of disturbing health impacts.

Chapter 4
Along with China's booming economy, energy consumption has doubled over the last 20 years. While demand in the industrial sector is growing rapidly, 50% of primary energy is still used in the residential sector. Approximately 80% of residential energy is supplied by solid fuel (coal and biomass), even though only 65% of the population now lives in rural areas where solid-fuel use is the norm. This indicates that there is still significant use of solid fuel, mostly coal, in urban households.

In China, coal is abundant and relatively cheap, which explains why China is responsible for nearly 30% of global coal consumption. With the proliferation of small mines around the country-side, coal is easily available in many rural areas. While coal consumption is falling in urban areas where it is mainly used for space and water heating, increased incomes in rural areas are leading to increased coal use there.

China is one of the world's top five consumers of biomass, which is evenly split between crop residues and fuelwood. Primarily consumed in rural households, biomass accounts for about 20% of China's primary energy consumption. This tremendous demand for biomass and its consequences on the natural environment are what led to the efficiency-minded improved stove programs in the 1980s and 1990s. Biomass consumption increased in the 1980s, but by the late 1990s had returned to early 1980s levels.

From an aggregate standpoint, both rural and urban households are moving up the energy ladder. Urban households, never dependent on biomass, are now moving away from coal and relying on cleaner fuels like electricity, LPG and natural gas. Rural households are increasing coal use as income allows. One survey showed that only 10% of rural homes do not rely on any type of solid fuel. This indicates that significant increases in income will be necessary for rural homes to transition from solid fuels to cleaner liquid, gas and electric options.

Household energy use and demand varies widely across the country. Local fuel availability is a major factor in the fuel choices. At the rural level especially, fuel availability can be quite different across provinces. Climate is also an important factor in fuel use, especially with regard to the amount used for heating. Rural households are characterized by the variety of energy sources used in one household. While electrification in rural areas is over 80%, electricity accounts for only 2-3% of household energy use. Biomass is the most common rural household fuel, followed by coal. However, it is not uncommon to find all three in use.

Chapter 5
The complex array of fuel-stove combinations makes it even more challenging to measure and analyze solid-fuel emissions and exposure in the home.

Even within each fuel group the situation can be complex. Data show that coal use is increasing in rural areas. However, coal is not a uniform product and varies widely across the country in composition, caloric value, preparation, and price. Biomass likewise encompasses a wide variety of fuels.

Within one household it is common to find a number of stoves that are used for different tasks, such as cooking, warming tea water and space heating, and also to find that stoves are used differently throughout the year. The stove-fuel combinations ultimately affect the level of emissions and exposure in the household.

In addition to the fuels discussed up to this point, biogas development has been significant in China. In 2001, the Chinese government estimated that there were almost 10 million household biogas systems installed that produced gas for cooking and heating from between 8-10 months out of the year. In addition, there are over 300,000 biogas multi-purpose systems installed which provide gas for household use and also fertilizer and other benefits for agriculture.

Chapter 6

While China once had an exemplary health care system, it fell into decline after the economic reforms of the 1980s. The current situation in rural areas is very different from the 1970s when approximately 90% of rural inhabitants had some form of health insurance, and the rural medical system was the envy of the developing world. Today less than 10% of rural inhabitants have any type of medical insurance, there is a very low ability to pay for services out of pocket, and rural facilities are poorly staffed and stocked. The result is an underutilized rural health care systems and poverty induced by high medical costs. While healthcare in rural China is still probably better than in many developing countries, it is a national priority to reform the medical system in order to provide effective rural healthcare. So far, however, pilot interventions with a wide range of international agencies have not succeeded.

In March 2003, the Chinese government put into effect the first set of standards for indoor air quality in households. The standards were released jointly by the State Administration for Quality Supervision, Inspection and Quarantine, the Ministry of Health, and the State Environmental Protection Agency. There does not appear to be a clear enforcement mechanism.

Chapter 7

China is responsible for one of the most impressive rural biomass stove programs in history. From 1982 to 1992, over 100 million households adopted a new stove; this represented perhaps as many as 65% of rural homes. Follow-on programs resulted in another 70 million installations. The program has now concluded, and long-term results, including the number of stoves still in use, are currently being evaluated[1].

At this time, there are two relatively small government stove programs underway. The first addresses deforestation and flooding (Ministry of Forestry), and the other targets human poisoning by emissions from coal with high levels of fluorine and arsenic (Ministry of Health).

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[1] In 2002, a team of U.S. and Chinese researchers collaborated on an independent review of China's improved stove programs, funded by the Shell Foundation. At the time when the research for this report was underway, the results of the review were not yet available. They have since been published in *Energy for Sustainable Development*, Volume VIII No. 3.

There is one key government agency which looks at rural energy, National Development and Reform Commission, and other agencies involved in rural poverty alleviation (Offices of Western Development) and IAP (Ministry of Science and Technology). There is limited involvement from NGOs and multilateral agencies.

Chapter 8
In the coal stove market, approximately 10 million stoves are sold per year. While there are several large manufactures that distribute products over a multi- province area, the vast majority of stoves are produced and sold locally. The market tends to be very competitive as there are low barriers to entry. Customers have demonstrated interest in replacing their current coal stove with a model that minimized their exposure to emissions. The growing demand for commercial products in rural areas can be taken as an opportunity to more actively market improved coal stoves. Increased commercial activity in rural areas is due in some places to increased purchasing power, desire to emulate urban lifestyles, and improved distribution channels.

Note: This section focuses on the coal stove market. No comments are made on biomass stoves sales or the market for pre-manufactured stove components, as no information was available.

Chapter 9
The discussion is divided into three parts; findings, implications and suggested next steps.

Chapter 2 . Socio-Economic and Health Overview

Summary: While economic growth in China has propelled much of the country forward, many have been left behind. Inequity is growing not only between urban and rural, but also between the eastern coast and the western slopes of the country. Poor agricultural earnings, an excessive labor pool in rural areas, and land degradation is causing migration toward wealthier areas. In addition, while urban quality of life has improved tremendously for some, rural basic services have suffered from neglect since the economic reforms of the 1980s. Government leadership is facing challenging rural poverty issues in order to maintain social stability and environmental sustainability.

The heath status of China's populations shows the effects of the uneven economic growth. Mortality rates are falling in urban areas but rising in rural regions, and the Chinese health care system has to contend with health problems of both poverty and affluence. Despite degradation of the rural healthcare system and declines in rural health, aggregate indicators, such as infant and child mortality and life expectancy, are still well ahead of other developing nations due to earlier periods of excellent healthcare and education programs in rural areas. Public health statistics show that respiratory illnesses for which indoor air pollution is a known risk factor are common and account for as much as 20% of deaths.

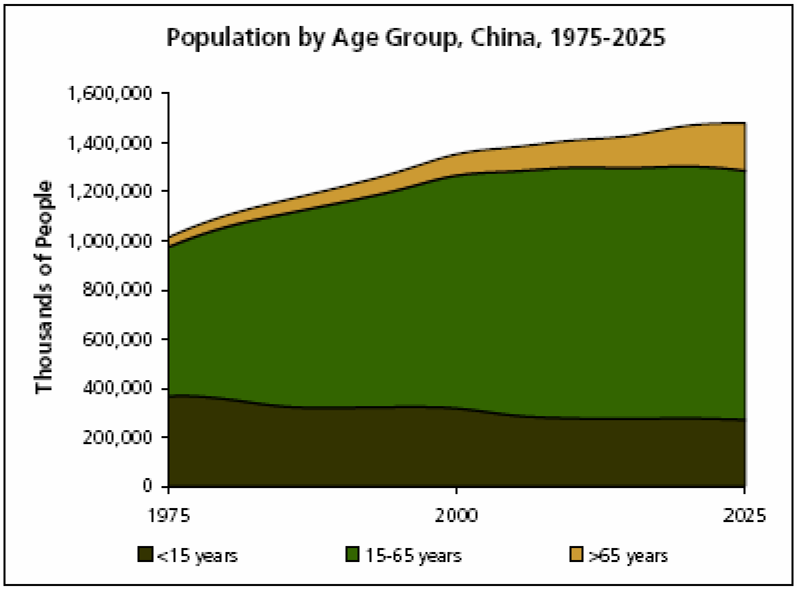
2.1 Population and demographic trends

China is still the world's most populous country, with a population of just over 1.3 billion (World Health Organization 2004). Growing at a rate of 0.9%, China's expansion is slow compared to the rest of Asia (1.6%) and to the world (1.6%), yet still significant. By 2025 the population could approach 1.5 billion as shown in Figure 2.1 below with age distribution. A recent report released by the World Health Organization, stated that the fertility rate was down to 1.8 in 2002, compared to 2.0 in 1992. This implies that the growth rate is lower now than it was at the beginning of the 1990s (World Health Organization 2004).

One of the challenges China faces is keeping its huge rural population stable and employed. With only 7 percent of China's land arable, every acre is already under cultivation (NOVA 2004). Some 80 to 120 million surplus rural workers are underemployed, and many migrate through the countryside subsisting on part-time, low-paying jobs (CIA website, 2004). In addition, there is rapid urban migration; the urban population grew from 19 to 30 percent between 1980 and 1998, and is now estimated at 35%. Another demographic trend is the movement of people from the poorer western slopes toward the wealthier eastern coast (UNDP 2002).

A growing population will placed additional demand on fuels for household use. The shifting demographics could affect the types of fuels demanded, the locations where they are needed, and the supply chain. Migrating populations, for example, may reduce pressure on biomass in some areas while adding to demand for fossil fuels in others.

Figure 2.1: Population by Age Group, China 1975-2025 ((World Resources Institute 2003))



2.2 Economic and political development

China's economic rise is unparalleled. Over the last 25 years, the economy has quadrupled, and 220 million people have been pulled up from poverty (Kuhn 2004). China now ranks as a lower-middle income country along with Russia, Brazil and Thailand, defined as countries with GDP per-capita over $1,000. China is one of the few countries performing well on the Millennium Development Goals (MDG). For example, China is "on track" to halve the number of people living in extreme poverty by 2015 (UNDP 2003).

While China has gone through a period where increased GDP took precedence over everything else, and citizens benefited with additional material goods, the government is beginning to realize that it "must meet demands for quality, public safety and sustainable development." (Kuhn 2004) This new stage of development could be painful for China, since it needs to continue to industrialize and modernize while avoiding economic gaps and social tensions. These types of problems have caused other rapidly developing country economies to stagnate (Kuhn 2004).

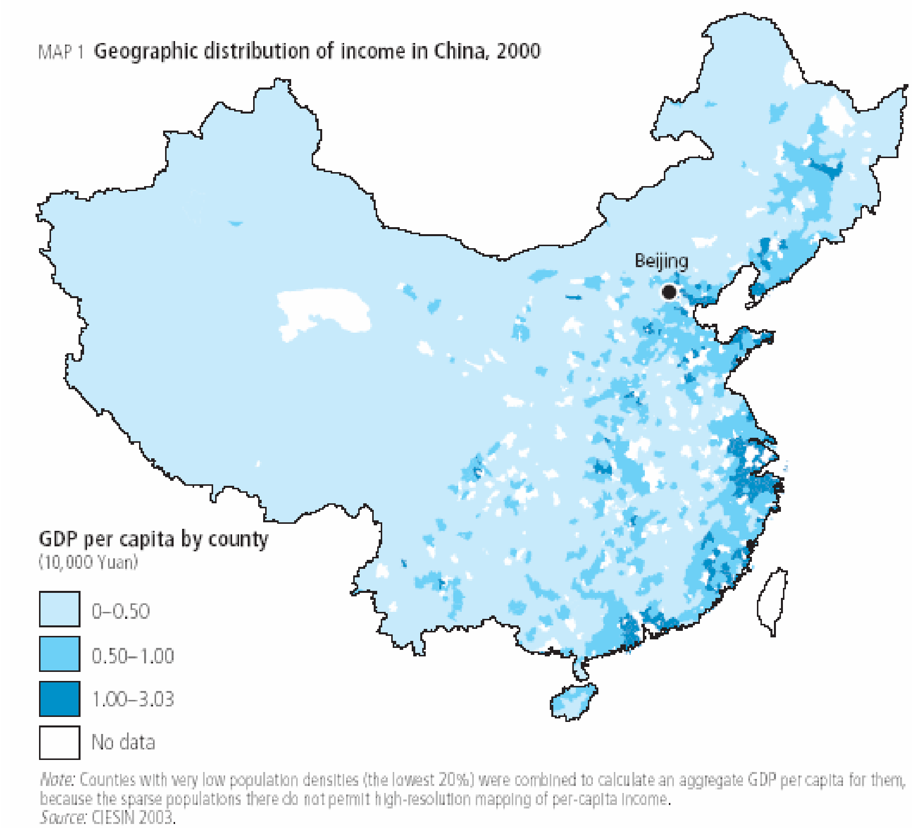
China's new leadership has signaled its intent to refocus government attention on development goals and ameliorate the circumstances of those who have been left behind in the economic boom. An indication of the new policy direction was Beijing's announcement in March of 2004 that GDP targets would be lowered to 7 percent from 9.1 percent, and lowered even further in some provinces (Kuhn 2004).

In the political landscape, the role and nature of government is changing in ways that will affect life in rural areas. First, the central government is devolving some of its power first to regional and local governments and then (to a lesser degree) to private players. Second, while the central government encouraged "self-sufficiency" at the rural level in the past, given the economic reforms in the last part of the 20th century, this type of approach is less appropriate and less feasible as rural areas become integrated into the market economy.

2.3 Widening divides

Indicators show that the inequities in Chinese society are widening: there is a divide between urban and rural areas, between East and West, and between costal and inland communities. The map below illustrates that the bulk of the national income is concentrated in urban areas and in the costal regions.

Figure 2.2: Geographic distribution of income in China, 2000 (World Development Report 2003)



Other evidence of inequities includes:

- National poverty rate is 4.6% but only 2.6% for urban areas (UNDP 2002).
- In coastal areas, ignoring inflation, economic growth translated to increased per-capita GDP from $100 in 1978 to $800 by 2000.
- Three of China's richest cities – Shanghai, Beijing and Tianjin – are at the top of the Human Development Index[2] (HDI), while overall China ranks 87th, in the middle of the index.

Approximately half of China's labor force is currently in the agriculture sector, which only produces 15 percent of GDP, down from 30 percent in 1980 (Energy Research Institute 2001). Cash income

[2] Human Development Index: A summary measure of three dimensions of human development—living a long and healthy life, being educated and having a decent standard of living. It is intended to provide additional depth to economic statistics, like per capita GDP, with regard to the development process.

for a farming family can be as little as $25 per month. More than 140 million people live in provinces which would fall to the low-end of the HDI if categorized as independent countries, and 50 million people still live in absolute poverty.

2.4 Health Statistics

China's rapid but uneven economic development is reflected in the health status of its population. For infant and child mortality, China's rates are lower than many developing nations in Africa and Asia, but still higher than mortality in Europe and North and South America. Life expectancy is just above the average for middle-income countries. Basic health statistics are listed below (World Health Organization 2004)

- Infant mortality rate is 31 deaths per 1,000 live births for children under one year of age.
- The under-5 mortality rate is 37 deaths for 1,000 live births.
- Life expectancy at birth is 71.1 years.

According to the World Health Organization, IAP-related diseases account for 20% of deaths and 9% of DALYs in the Western Pacific group[3], in which China is dominant and accounts for more than 90% of the population (Ezzati 2004). The most recent death and Daly's statistics are presented below.

Figure 2.3: Deaths for selected IAP related diseases in the Western Pacific Region, 2002 (World Health Organization 2004)

Deaths (units 000s)	**Total**	**10,794**
Disease	**Number**	**%**
Communicable		
Lower respiratory infection	374	3.5%
Upper respiratory infection	26	0.2%
Non-communicable		
Trachea/bronchus/lung cancers	361	3.34%
COPD	1,354	12.54%
Asthma	37	0.34%
	2,152	***19.92%***

[3] The World Health Organization does not aggregate data by country but rather by "mortality strata" per region. WHO uses a methodology similar to the one financial analysts use to categorize economies to group countries with comparable mortality statistics. China is grouped with other countries in the Western Pacific, but not with more developed nations like Japan, Australia, New Zealand and Singapore. Countries grouped with China in Asia Pacific mortality strata: Cambodia,** China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic,** Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea,** Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

Figure 2.4: DALYs for selected IAP related diseases in the Western Pacific Region, 2002 (World Health Organization 2004)

DALYs (units 000s)	Total	248,495
Disease	**Number**	**%**
Communicable		
Lower respiratory infection	7447	3.0%
Upper respiratory infection	552	0.2%
Non-communicable		
Trachea/bronchus/lung cancers	3,452	1.39%
COPD	9,820	3.95%
Asthma	3,007	1.21%
	24,278	***9.75%***

In general respiratory illnesses, for which air pollution is a potential cause or risk factor, figure significantly in China's public health burden. According to the preliminary results of a nation-wide study conducted in 2003 by the Ministry of Health, respiratory diseases ranked consistently among the top three reasons for death in both urban and rural China (see Appendix 1 .). In terms of percentage of hospital patients, respiratory disease was the primary disease in urban areas (11.23% of people admitted) and the second disease in rural areas (15.67% of people admitted), the primary being injury, poisoning and external causes. Incidence statistics showed that hepatitis, pulmonary tuberculosis, and diarrhea were the three most frequently contracted diseases (China Ministry of Health Website 2004, see Appendix 1 .).

2.5 Health in urban vs. rural areas

The growing economic divide in China is also reflected in the health statistics. Like other countries making the transition from a lower-income developing nation to middle-income or industrialized one, China is burdened with health problems from both types of societies. Accordingly, mortality rates in urban areas are falling, but rising in rural areas. Urban areas have a higher incidence of cancer than rural areas, which one report tied to significantly higher outdoor air pollution rates in urban areas. Mortality from other diseases is higher in rural areas, perhaps due to poorer access to medical facilities or lower socio-economic standards (World Health Organization 2001).

2.6 Health investment

The majority of health investment comes from private expenditure, as shown in below in Figure 2.5. Total government spending, as a percent of GDP is rising, while the percent of the total government budget allocated to health is actually falling significantly. The per-capita investment, in US dollars and dollars adjusted for purchasing power parity (PPP), is still relatively low, but rising rapidly, as seen in the Figure 2.6 below. Additional information on China's health system is presented in Chapter 6.

Figure 2.5: Health expenditure in China, 1997-2001 (percentage) (World Health Organization 2004)

	1997	1998	1999	2000	2001
Total expenditure on health as % of GDP	4.6	4.8	5.1	5.3	5.5
Total government expenditure on health as % of total health spending	40	39	38	36.6	37.2
Total private expenditure on health as % of total health spending	60	61	62	63.4	62.8
Total government spending on health as % of total government spending	14.2	13.3	11.8	10.8	10.2

Figure 2.6: Health expenditure in China, 1997-2002 (real spending) (World Health Organization 2004)

	1997	1998	1999	2000	2001
Per-capita total expenditure on health (US$)	33	36	40	45	49
Per-capita total expenditure on health (PPP)	135	155	176	200	224
Per-capita government expenditure on health (US$)	13	14	15	17	18
Per-capita government expenditure on health (PPP)	54	60	67	73	83

The following case offers a comparison of the public investment made into health and education in China and India.

Case 2.1: Social Investments in China and India compared

Social Investments in China and India Compared

"Social investments are required for sustained economic growth. In China public spending on education is 2.3% of GDP while that on health is 2.1% of GDP. The outcomes for human development are clear. Literacy stands at 84%, infant mortality rates at 32 per 1,000 live births and under five mortality rates at 40 per 1,000 live births.

"India, in contrast, has traditionally had lower spending levels. Health spending stands at 1.3% of GDP (central and state governments combined). Spending on education has increased significantly, from 0.8% of GDP in 1950 to 3.2% today, though it still falls short of the government target of 6% of GDP. Human development indicators for India remain much lower than for China. Literacy stands at 65%, infant mortality at 68 per 1,000 live births, and under-five mortality rates at 96 per 1,000 live births."

Source: Human Development Report, 2003, page 73.

Chapter 3 . Link between Indoor Air Pollution and Health in China

Summary: The indoor air pollution (IAP) and health situation in China is uniquely shaped by the legacy of a large stove program, the relatively high level of health care, the high incidence of smoking, and the high proportion of coal used in rural homes. On the one hand, the stove program probably produced unintended health benefits through the installation of improved biomass stoves. In addition, general improvements in the standard of living may have lowered the incidence of diseases often associated with IAP. On the other hand, the extensive use of coal in rural homes causes high levels of respiratory diseases in adults. Additionally, in some areas the use of coal laden with toxins leads to a range of disturbing health impacts.

3.1 Unique aspects of health impacts from solid-fuel use in China

There has been limited documentation of health impacts of indoor air pollution in China. In the 1980s, there were various studies performed in China to measure indoor air pollution levels and human exposures in homes using solid fuels. The methods and results are summarized in a database available through the WHO, but for the most part, these studies did not make the link to health impacts (Smith 1995). The notable exception is the connection between coal burning and lung cancer, which has been studied in China and around the world, and is discussed in section 3.2.

3.1.1 Effects on Adults vs. Children

The 2002 World Health Report estimates that 56% of global deaths attributed to household solid fuel use occurred in children under 5 (WHO 2002). Conventional wisdom holds that children are much more susceptible to the ill-health effects of solid-fuel-combustion emissions than adults. Children in India are thought to account for 68% of all solid fuel-related deaths, while, in sub-Saharan Africa and elsewhere, the fraction is even higher.

In contrast, in China, mortality in children under 5 only constitutes 12% of solid fuel-related fatalities. One reason for this difference in age-specific impacts is that children in rural China tend to have better access to medical care. Another reason that Chinese children may be affected less is that many of the biomass stoves in use have chimneys so that the bulk of the harmful emissions are vented outside. This is a result of China’s long effort to disseminate improved stoves.

Thus most combustion-related fatalities in China occur in adults as a result of COPD rather than in children as a result of ARI, as is the case in most of the developing world (Smith and Mehta 2003). The table below shows the WHO’s estimates of fatalities resulting from solid fuel use.

Figure 3.1: Deaths from household solid fuel use estimated by different methods (uncertainty bounds not shown) (adapted from (Smith and Mehta, 2003)).

Region	Under 5 deaths (% of total)	Total deaths	Reference
India	287,000 (68%)	424,000	(WHO 2002)
China	52,000 (12%)	423,000	(WHO 2002)
World	910,000 (57%)	1,600,000	(WHO 2002)

3.1.2 Health Implications of China's improved stove program

The Chinese National Improved Stove Program and related programs will be discussed in detail in Chapter 7 . ; here only the possible implications for public health are touched on. By the end of the 1990s, it is estimated that over 200 million improved stoves were disseminated in rural China (Edwards, Smith et al. 2004).

There may have been unintended health benefits that resulted from the improved stove programs, even though their primary purpose was to conserve biomass resources and delay the shift to fossil fuels that was expected to occur with rising rural incomes (Smith, Shuhua et al. 1993). Many of the stove models that were disseminated have flues or chimneys that remove pollutants from the indoor environment. Thus, it is possible that many rural Chinese households relying heavily on biomass fuels are using stoves with chimneys and are thus exposed to far lower levels of IAP than their rural counterparts in India or sub-Saharan Africa, where stoves with chimneys are still a rarity. Unfortunately, there is little up-to-date information on the number of stoves with chimneys *currently in use*, and therefore it is difficult to say to what extent benefits continue to be derived from reduced IAP levels.

At the same time, observations in the field indicate that many households using improved biomass stoves also rely on coal. Exposure to coal combustion emissions is associated with the same health implications as biomass combustion, however, coal tends to contain many more toxic substances than biomass and these lead to additional health impacts that are unique to coal (discussed in detail below). One account reported that 88 out of 112 households visited during a study tour had old unvented metal coal stoves in addition to their new improved biomass stoves (Smith, Shuhua et al. 1993). This was over ten years ago. It can safely be concluded, from the plot of rural household fuel consumption (see Figure 4.4: Residential energy consumption in rural China (Energy Research Institute 2001) that coal use is increasing in rural China, and that more individuals are exposed to coal emissions with each passing year.

3.1.3 High Incidence of Smoking

According to WHO, approximately 60% of Chinese men are regular or occasional smokers. Furthermore, second-hand smoke is common in homes, workplaces, and public buildings. These high rates of smoking make it difficult to accurately assess the health risks from solid-fuel use. Smoking acts as a statistical confounder, which researchers are not always able to address effectively (Personal communication with Kirk Smith, School of Public Health, University of California, Berkeley, May 2004).

3.2 Health impacts of residential coal combustion

3.2.1 Lung Cancer

Lung cancer plays a significant role in the burden of disease linked to household energy use in regions where coal is a common household fuel. Lung cancer is strongly associated with indoor coal combustion. It has been studied in China and in many places around the world. At least one study has demonstrated a reduced risk of cancer if coal is burned in stoves with chimneys rather than in stoves vented indoors (Lan, Chapman et al. 2002).

The coal that is used in China has both medium ash content (10-20%) and low to medium ash content (0.5-4%). The latter typically burns cleaner and is used primarily in industry. The coal with higher ash content burns with more smoke and is generally consumed in the residential sector. Incidentally, the size of particulate matter emitted from smoky coal burning is less than PM_{10}. Small particles remain in the air longer than larger ones and are easily inhaled and deposited in the lungs (World Health Organization 2001). In addition, epidemiological studies have associated such "smoky coal" with elevated risk of lung cancer in Chinese women (Bruce, Perez-Pedilla et al. 2000).

In Xuanwei county in Yunnan province, the highest incidence of lung cancer was reported not only for China, but for the entire world. Lung cancer comprised 49.5% of the total malignant neoplasms (tumors). Indoor air pollution concentrations throughout Yunnan province were found to be the highest of 12 locations selected in China. Women in Xuanwei were exposed to indoor air pollution concentrations more than 100 times the US-ambient-air 24-hour standard (World Health Organization 2001). Comparative mortality rates for lung cancers are shown in the table below between Xuanwei and the rest of China.

Figure 3.2: Age-adjusted mortality of lung cancer in Xuanwie, Yunnan province (World Health Organization 2001)

Table 2.5 Age-adjusted mortality of lung cancer in Xuanwei, Yunnan province

Xuanwei Incidence Areas	Mortality (per 100,000)	National lung cancer mortality/100,000
Low	5.98	Male – 6.28
Medium	20.90	Female – 3.20
High	126.06	

Source: He, 1990

3.2.1 Other Health Effects of Coal Combustion

In addition to particulate matter (PM) and carbon monoxide (CO), which are also common pollutants from biomass fuels, coal combustion releases contaminants that have been bound up in the coal during the long process of its formation. These compounds include arsenic and fluorine, as well as selenium, heavy metals like cadmium, mercury, antimony and chromium, and a host of carcinogenic compounds (Chuang, Wise et al. 1992; Liu, Zheng et al. 2002). The map in Figure 3.3: Map showing areas of China where health problems linked to coal burning have been observed (Finkelman, Belkin et al., 1999). Figure 3.3 indicates the provinces where some of the health impacts of exposure to these toxics have been observed (Finkelman, Belkin et al. 1999).

Exposure to these contaminants can occur through multiple pathways. When coal is burned in the household, toxic compounds become airborne, and individuals are exposed by breathing. In addition, it is common practice in rural China to dry food crops such as maize and chilies over the kitchen hearth. This practice leads to the absorption of toxic compounds in food and subsequent ingestion.

One study in Guizhou province of southwest China, where arsenic levels in raw coal are over 70 times the levels found in coal elsewhere, found that chilies dried over the kitchen hearth had nearly *2000 times the levels of arsenic* found in chilies not dried over high-arsenic coal. The contaminated chilies had an average of 70.5 ppm of arsenic as compared to the U.S. EPA maximum level for drinking water of 0.01 ppm. Other contaminants were also much higher than recommended safe levels, as shown in Figure 3.4.

Figure 3.3: Map showing areas of China where health problems linked to coal burning have been observed (Finkelman, Belkin et al., 1999).

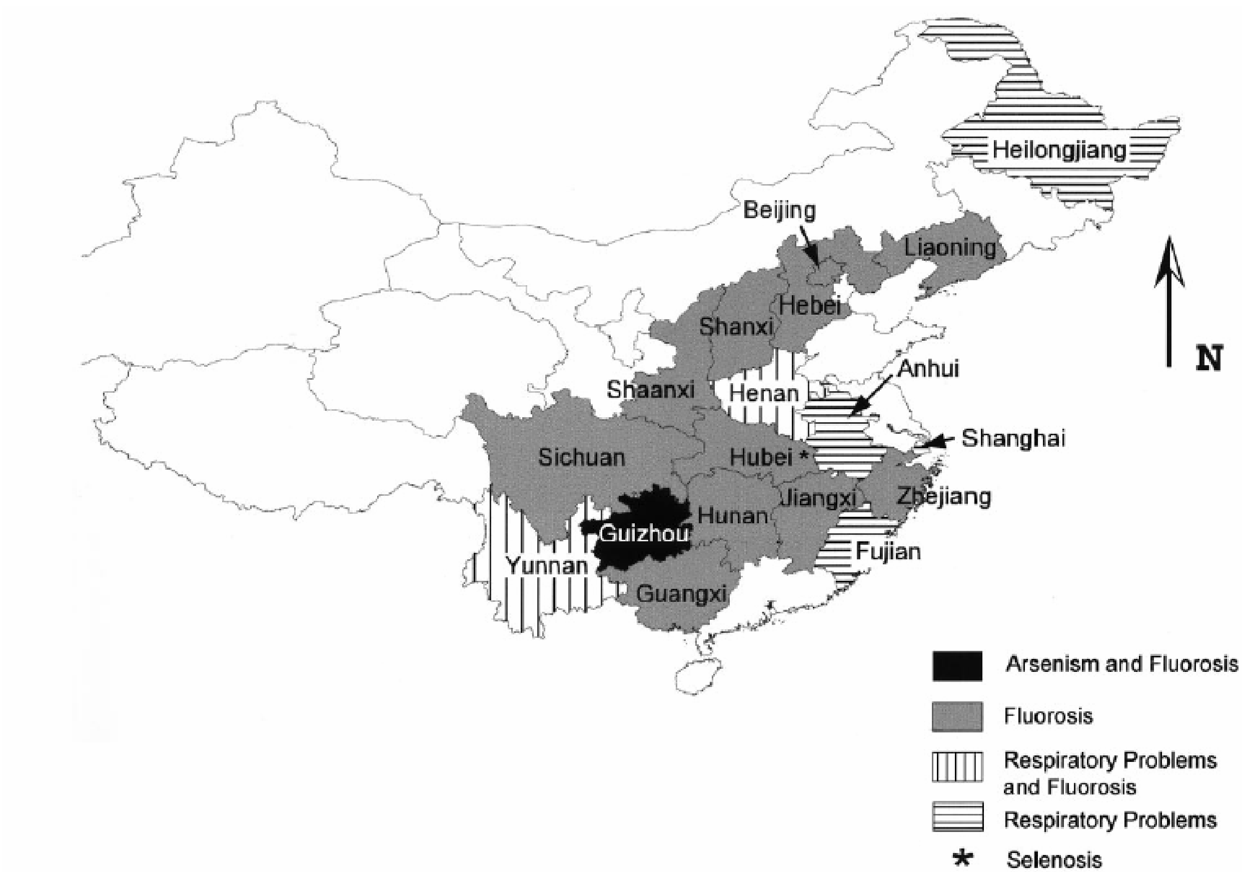


Figure 3.4: Concentrations of Arsenic and other toxics found in foods dried over contaminated coal (Liu, Zheng et al. 2002).

Foods	Arsenic (ppm)	Chromium (ppm)	Antimony (ppb)	Cadmium (ppb)
Chili peppers				
Normal (*n* = 3)	0.04 ± 0.01	0.77 ± 0.11	57.2 ± 5.1	48 ± 4.5
Dried over high-As coal (*n* = 6)	70.5 ± 40.3	6.18 ± 3.43	171 ± 20	230 ± 85
Corn				
Normal (*n* = 3)	0.01 ± 0.00	0.99 ± 0.05	19 ± 1.1	5.1 ± 0.01
Dried over high-As coal (*n* = 5)	3.40 ± 0.95	1.78 ± 0.21	26 ± 0.9	20 ± 1.11

3.3 Toxins found in coal

The primary health effects of burning coal with toxins are discussed in more detail below.

Fluorine: Fluorine probably has the largest impact of all of the toxic substances contained in Chinese coal. The health impacts of fluorine volatilized during household combustion affect more than 10 million people in Guizhou Province and surrounding areas. In addition to this region, 13 other provinces, autonomous regions, and municipalities in China have also seen the effects of fluorine exposure (Finkelman, Belkin et al. 1999). One source estimates that 31 million people are affected, primarily from eating contaminated food but also directly from combustion emissions (Ando, Tadano et al. 2001, and see map in Figure 3.3).

Fluorine enters the body through multiple pathways, though researchers estimate that the dominant vector is through contaminated food (>90%) while inhalation of vaporized fluorine resulting from combustion of fluorine-contaminated coal and ingestion through high-fluorine water account for ~3% and ~1% respectively (Ando, Tadano et al. 2001).

The physiologic response to fluorine exposure is manifest in a wide variety of symptoms all broadly defined as “fluorosis”. Typical symptoms include mottling of tooth enamel (dental fluorosis) and various forms of skeletal fluorosis, including osteosclerosis, joint immobility, and outward manifestations such as knock knees, bow legs, and spinal curvature. If exposure occurs in children already suffering from nutritional deficiencies, severe bone deformation can occur (Finkelman, Belkin et al. 1999).

Arsenic: Chronic arsenic poisoning affects at least 3,000 people in Guizhou Province (Finkelman, Belkin et al. 1999; Liu, Zheng et al. 2002). Coal containing arsenic is the most probable vector of exposure, though it can enter the body through multiple pathways. Researchers think that over half of the exposure can be accounted for through ingestion of contaminated food dried over hearths where high-arsenic coal is burned, as described in Figure 3.4. The second major pathway is through inhalation of airborne particles released by combustion of contaminated coal. Drinking water has been tested and shown to contain acceptable levels of the toxin, whereas coal samples in the affected region have levels as high as 35,000 ppm.[4]

Exposure to arsenic is associated with several different illnesses. Symptoms of arsenic poisoning include hyperpigmentation (flushed appearance and large freckles), hyperkeratosis (scaly lesions on the skin concentrated on the hands and feet), Bowen’s disease (dark, horny, precancerous lesions of the skin), and squamous cell carcinoma, a common skin cancer.

Selenium and Mercury: There is concern about both selenium and mercury in some Chinese coal. Approximately 500 cases of selenium poisoning have been reported in southwest China (Finkelman, Belkin et al. 1999). Human exposures are attributed to ingestion via food crops that are grown in soil treated with combustion ash. Similarly, mercury is a known toxin found in some Chinese coal in high concentrations. One test found concentrations as high as 55 ppm, or roughly 200 times the levels found in US coal. Nevertheless, there have not yet been any conclusive studies linking coal consumption to mercury poisoning (Finkelman, Belkin et al. 1999).

[4] This can be compared to a mean level of 22 ppm and a maximum level of 2,000 ppm found in 10,000 samples of US coal tested

Carcinogenic compounds: A range of carcinogenic compounds may be found in coal combustion emissions: some are generated by incomplete combustion while others are present as contaminants in the coal. The compounds generated by incomplete combustion are typically volatile organic compounds (VOC). Of particular concern are polycyclic aromatic hydrocarbons (PAH). Benzo(a)pyrene is often cited as an example of PAH, although tests show other compounds are equally relevant (Chen, Bi et al. 2004). In addition, research shows that processed coal briquettes have significantly lower emissions of PAH compounds than raw coal burned under similar conditions (Chen, Bi et al. 2004)[5].

3.4 Relative health risks of different solid fuels

3.4.1 Indoor Air Pollution Risk Index

The environmental Health Risk Index (HRI), introduced in Chapter 2, includes indoor air pollution risk calculations for China's provinces and three major cities. The map of the indoor air pollution index is presented below and shows three regions of concern: Tibet, and Guizhou and Qinghai provinces. However, the indoor air pollution risk assessment was based entirely on coal use. It may therefore underestimate the health risks in areas where biomass supplies most of the residential energy (World Health Organization 2001).

3.4.2 Comparative Risks

Given the limited available information, it is beyond the scope of this report to gauge the relative health risk to the population from burning coal or biomass. While coal is characterized in this report as a step up the energy ladder, this does not imply that it is less polluting or less threatening to the health of those who burn it in their homes. The commonly accepted model of the energy ladder puts coal above wood, solely because coal has a higher caloric density and is easier to use. The relative health impacts are not part of this model. Further, coal is likely preferred by end-users because it burns more slowly and requires less attention from the user than biomass fuels, and it is also available all year assuming the household can afford it. There is no evidence to suggest that consumers buy coal because they think it cleaner or healthier (More information on the Energy Ladder in Appendix 3 .).

From a programmatic perspective, it may be advantageous to prioritize risks associated with burning coal, especially raw coal containing toxins, over those related to burning biomass, even if the affected population is smaller. The health effects of fluorine and arsenic poisoning are severe and compelling, providing a clear baseline for an intervention. Several factors also indicate that the problem will persist and possibly worsen over time: 1) the demand for coal is increasing in rural areas; 2) the coal laden with toxins is found in areas of the country where population density is high; and 3) small less-regulated mines scatted throughout the country-side are proliferating.

More information on IAP and the link to health is found in Appendix 2 .

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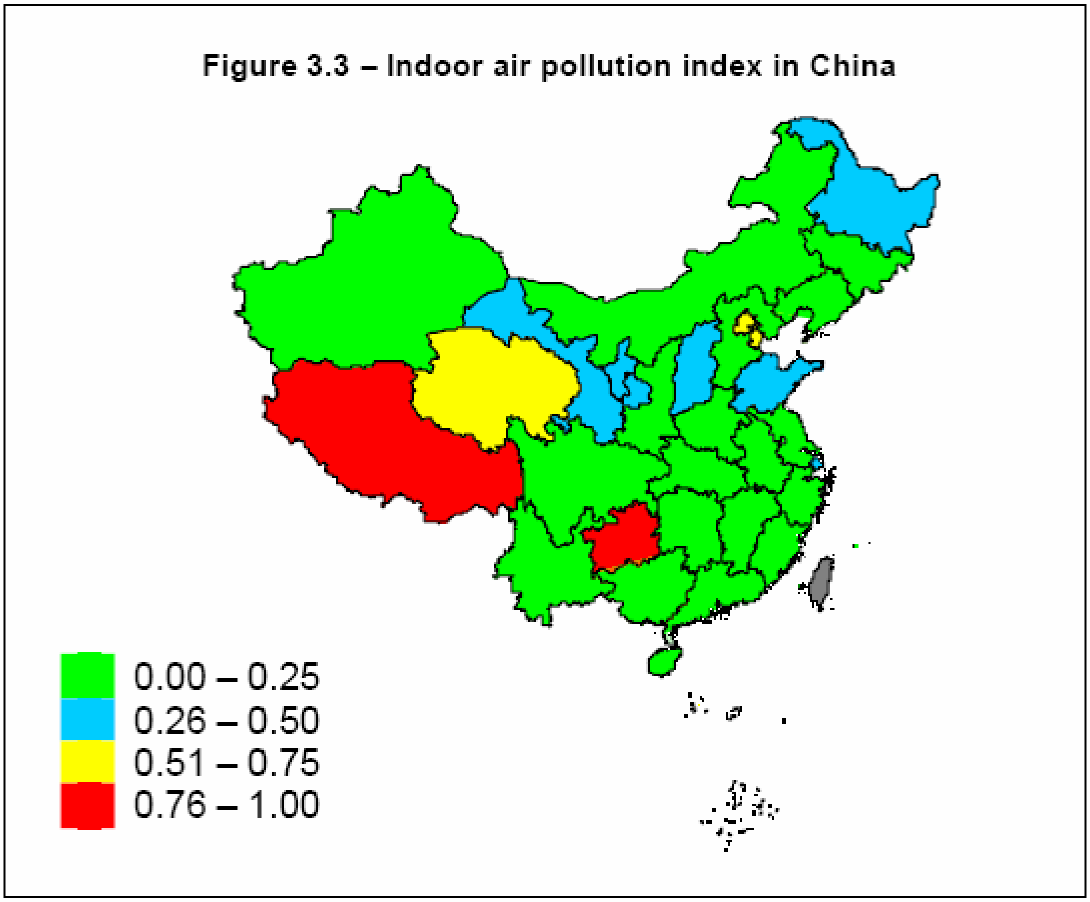
[5] Emission factors were given per unit weight of coal to account for the weight of the binder in the briquettes. The researchers found that emissions of total PAH from raw anthracite coal was 20 times greater than emissions from briquettes, and emissions of genotoxic PAH from raw anthracite coal was greater by nearly two orders of magnitude.

Figure 3.5: Indoor Air Pollution Index in China, 2001 (World Health Organization 2001)



Chapter 4 . Household Energy

Summary: Along with China's booming economy, energy consumption has doubled over the last 20 years. While demand in the industrial sector is growing rapidly, 50% of primary energy is still used in the residential sector. Approximately 80% of residential energy is supplied by solid fuel (coal and biomass), even though only 65% of the population now lives in rural areas where solid-fuel use is the norm. This indicates that there is still significant use of solid fuel, mostly coal, in urban households.

In China, coal is abundant and relatively cheap, which explains why China is responsible for nearly 30% of global coal consumption. With the proliferation of small mines around the country-side, coal is easily available in many rural areas. While coal consumption is falling in urban areas where it is mainly used for space and water heating, increased incomes in rural areas is leading to increased coal use there.

China is one of the world's top five consumers of biomass, which is evenly split between crop residues and fuelwood. Primarily consumed in rural households, biomass accounts for about 20% of China's primary energy consumption. This tremendous demand for biomass and its consequences on the natural environment are what led to the efficiency-minded improved stove programs in the 1980s and 1990s. Biomass consumption increased in the 1980s, but by the late 1990s had returned to early 1980s levels.

From an aggregate standpoint, both rural and urban households are moving up the energy ladder. Urban households, never dependent on biomass, are now moving away from coal and relying on cleaner fuels like electricity, LPG and natural gas. Rural households are increasing coal use as income allows. One survey showed that only 10% of rural homes do not rely on any type of solid fuel. This indicates that significant increases in income will be necessary for rural homes to transition from solid fuels to cleaner liquid, gas and electric options.

Household energy use and demand varies widely across the country. Local fuel availability is a major factor in the fuel choices. At the rural level especially, fuel availability can be quite different across provinces. Climate is also an important factor in fuel use, especially with regard to the amount used for heating. Rural households are characterized by the variety of energy sources used in one household. While electrification in rural areas is over 80%, electricity accounts for only 2-3% of household energy use. Biomass is the most common rural household fuel, followed by coal. However, it is not uncommon to find all three in use.

4.1 Energy consumption in China: putting the household level in perspective

China consumes almost 30% of the annual global coal output because coal is abundant and relatively cheap. Coal represents over 50% of the primary energy consumed in China. With the proliferation of small mines around the country-side, coal has become available in unprecedented amounts in rural communities (Stockholm Environmental Institute 2002). Unfortunately, most coal is fairly dirty with medium ash content (10-20%) and sulfur content of 0.5-4%, and is considered poor quality from an environmental and health perspective (World Health Organization 2001, more information on comparable country energy in Appendix 4 .).

China is also one of the top global consumers of biomass. Approximately 20%[6] of China's primary energy consumption is biomass; divided equally between fuelwood and crop residues. Although on a per-capita basis China's biomass consumption maybe lower than some developing countries, China's huge population creates an aggregate annual demand for biomass that puts China among the top five consumers of biomass globally, along with Brazil, India, Indonesia and Nigeria. These five countries together account for over half of the fuelwood and charcoal consumed globally (EarthTrends 2001, see Appendix 5 .). Due to the tremendous demand for biomass in China and the limited arable land, sustainable biomass use is of tremendous concern. For this reason, fuel-efficiency was one of the key motivators for the large biomass stove programs in the 1980s and 1990s (discussed in Chapter 7 .).

Another distinguishing characteristic of China's energy demand is the rate of growth. Over the last 20 years the demand for commercial fuels[7] has more than doubled (Figure 4.1). The rate of growth has implications for residential energy use, as availability and pricing are affected by increased demand.

Residential and commercial energy[8] consumption in China represents 50% of all primary energy consumed. In China most of this energy is used in the residential sector, and only a small percentage in for commercial activities. These patterns are similar to other developing countries. What is unique in China is the high percentage of coal consumption in the residential sector. In excess of 10% of residential energy consumption is coal; this is more than liquid fuels, gas, or electricity (see Appendix 4 .).

While coal consumption in China is high, especially in the residential sector, biomass use is also relatively high. Biomass represents over 60% of the energy consumed in the residential sector, and about 20% of the overall energy consumed in all sectors. Some studies suggest that biomass collection and use is under-reported at the local level.

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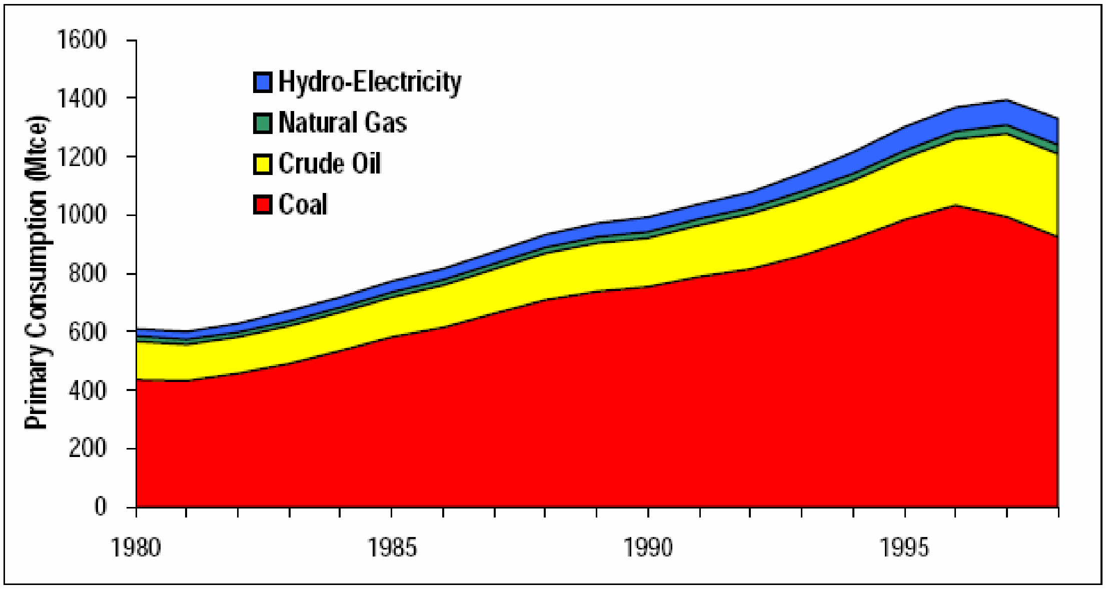
[6] While quantifying the exact biomass use is much more challenging than quantifying the consumption of fossil fuels, because the collection and use of biomass is difficult to track, official statistics serve as a solid estimate of the magnitude of actual consumption.

[7] Commercial fuel basically refers to all non-biomass fuels; fossil fuels and electric (like hydroelectric).

[8] Commercial energy consumption refers to any type of energy used in the commercial sector of the economy (as opposed to transportation, industrial, agricultural or residential). The commercial sector includes energy for businesses and services (non-industrial).

Figure 4.1: Primary Energy Consumption by Fuel Source, 1980-1998 (Energy Research Institute 2001)



What is striking, given the high rate of urbanization in China, is that 80% of the population burns solid fuel, even though only 65% live in rural areas (World Health Organization 2004). This means that a significant portion of the urban population is still burning solid fuel, most likely coal. Official government statistics and reports state that all biomass is consumed in rural areas.

One other notable difference in China's residential sector, as compared to other countries, is the relative lack of charcoal and kerosene consumed in the residential mix.

4.2 Household energy consumption

4.2.1 Findings from aggregate-level statistics

Rural and urban energy patterns at the residential level are distinct. An important energy trend can be identified by looking at the figure below. It illustrates an increase in the rate of urbanization, along with a decrease in the proportion of energy consumed in urban areas, compared to rural areas. It shows urban populations growing faster than their rural counterparts, while urban per-capita energy consumption is dropping. Rural energy consumption per-capita is growing.

Figure 4.3 shows aggregated (urban and rural) commercial fuel use (i.e. not including biomass). It illustrates that coal use declined around 30% from 1980, while new fuels like electricity and LPG picked up a considerable market share (see Figure 4.3).

Looking just at rural residential energy consumption, however, the picture looks somewhat different (see Figure 4.4). Here coal use rises sharply after the mid-1990s, while other commercial fuels have only modest gains.

Figure 4.2: Commercial energy consumption in urban and rural areas of China and urban population growth: 1985-1999 (Energy Research Institute 2001).

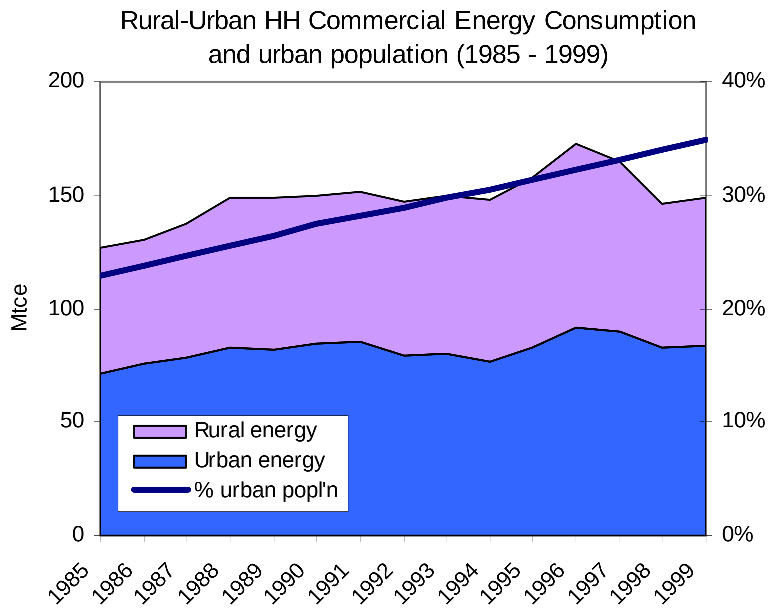
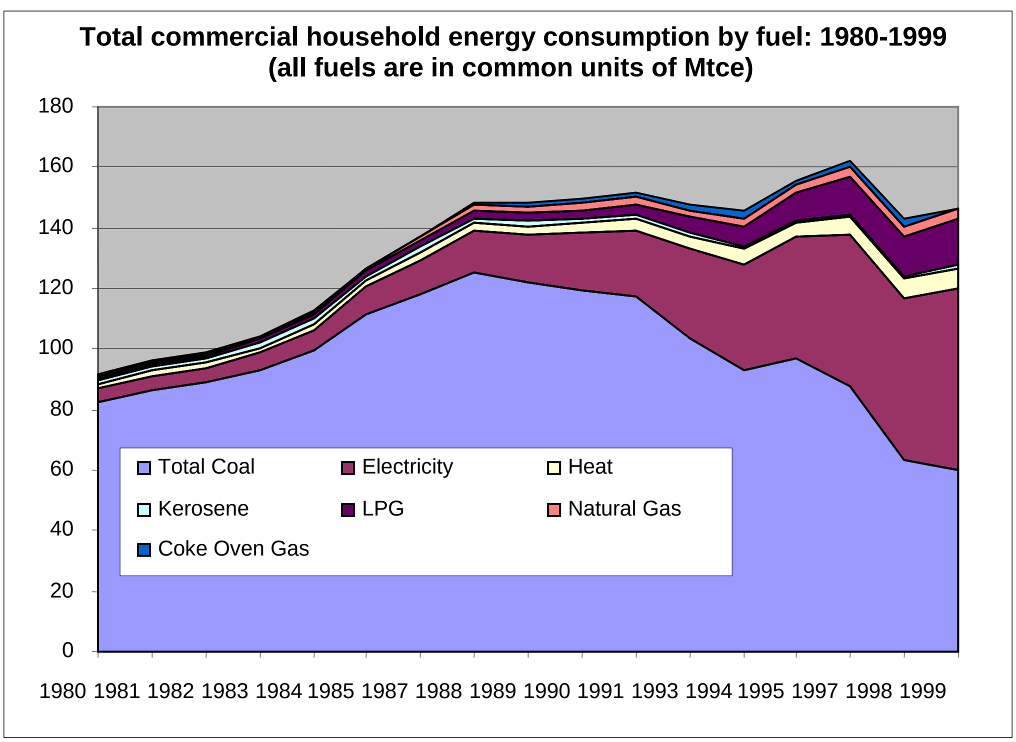
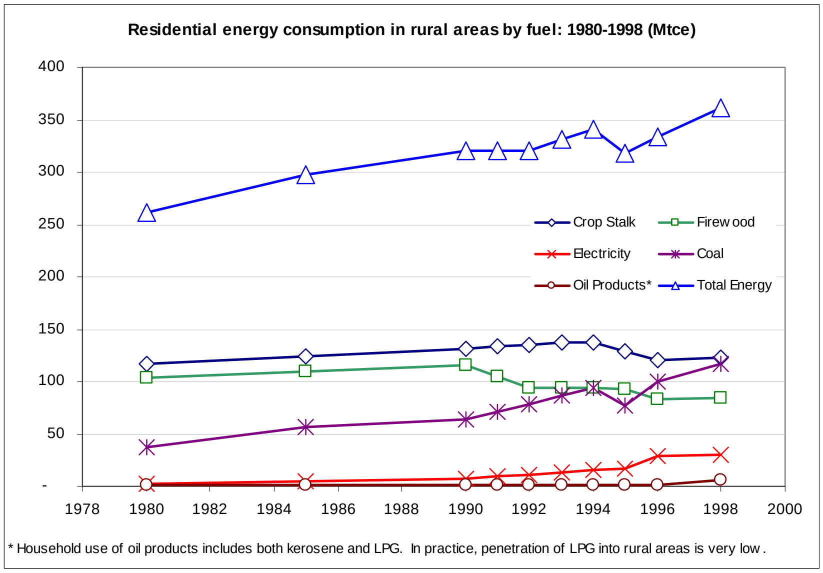


Figure 4.3: Commercial energy consumption in China's residential sector: 1980-1999 (Energy Research Institute 2001).



Note: Heat refers to district heating and is discussed in more detail in the following Chapter.

Figure 4.4: Residential energy consumption in rural China (Energy Research Institute 2001)



Both urban and rural populations appear to be moving up the energy ladder, but they are located on different parts of it. Urban areas are shifting toward more convenient and cleaner fuels, such as LPG, gas and electricity. Consumption of all these fuels is expanding due to increased availability and willingness to pay. In addition, central government mandates to improve urban air pollution have officially limited the use of coal in urban areas. Rural areas are increasing coal use and to a much lesser degree electricity and other oil-based products (see Appendix 3 .).

Nationwide access to electricity has increased dramatically in the past two decades. Currently, roughly 98% of Chinese households have access to electricity, including over 80% of rural households. However, residential electricity consumption remains low in rural areas where households typically continue to rely on solid fuels to cook (International Energy Agency (IEA) 2002).

By reviewing aggregate rural household energy statistics between 1980 and 1998, the additional following observations can be made about energy use in rural areas:

- Biomass is used almost exclusively in household, as opposed to in agriculture or township enterprises (97% in 1980 and 93% in 1998).
- Total household energy use in rural areas increased 38%.
- Total biomass use fell slightly, around 2%.
- Commercial energy (fossil fuels and electricity) use increased almost three fold.

(See Appendix 6 . Rural Energy Consumption)

While slightly outdated, data from both 1979 and 1987 (the most recent available) show that fuelwood is being used more rapidly than it is produced, while crop residue and dung cake are underutilized in terms of availability of resource.

The box at the end of the chapter includes an analysis of the energy transition occurring in rural areas taking into account economic changes as well as other socio-political factors.

4.2.2 Findings from household energy surveys

All of the data above is a reflection of aggregate statistics. There is very limited household-level data available in China. Even for urban areas, detailed studies of household consumption are almost non-existent. Recently, Lawrence Berkeley National Laboratories in conjunction with the Chinese National Bureau of Statistics performed the first 250-home detailed energy survey in urban areas (Fridley 2004). Such information for rural households is equally challenging to come by. Two rural household surveys, however, were found. The studies and their significant findings are described below.

The first analysis was based on data collected in the mid-1990s by a team from the World Bank's Energy Sector Management Assistance Program (ESMAP) and the Chinese government. The findings were published in 1996. The project covered many aspects of rural energy, not just household. Six counties were included in the survey. The report is called: "Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties." (ESMAP 1996)

The second analysis was based on data from the 1999 National Rural Household Survey in China. This is an annual survey conducted by the China Rural Socio-Economic Survey Division of the State Statistical Bureau. It includes approximately 50,000 households. In the 1990s, increasingly more energy data was collected. In 2000, however, total biomass consumption was no longer collected. It is for this reason that the authors of the second report chose the 1999 data-set for analysis. The report is called "The Energy Transition in China." (Leinwen 2003)

The major findings of both studies are summarized below:

<u>Type of Fuel Used</u>

A characteristic of Chinese rural households is the variety of fuels often available and used in one home. Findings from both surveys substantiated the complex energy mix:

- In excess of 97% of households use at least two types of energy.
- Biomass-electricity is the most popular combination, including 66% of homes. The homes may have other fuels. Biomass is always the dominant fuel and electricity plays a fairly small role, 3-5% of energy.
- If coal is used in a household, it accounts for 25-30% of total energy; if LPG is used, it accounts for only 2-3% of energy used.
- If biomass is not used, coal is the main energy source.
- Only 10% of homes do not use either coal or biomass and rely exclusively on "modern" energy sources.

"Average-use" figures often mask significant variations in energy use at the household level, even within one county. In fact, estimates done by the counties based on more limited information resulted in energy estimates that were quite low when compared to the detailed household surveys (ESMAP 1996).

Surprisingly, poor people were found not to be short of cooking fuels, just to be using lower quality fuels (Leinwen 2003). Also, noteworthy was the amount of fuel used to cook feed for pigs, which are a source of income in many rural areas (ESMAP 1996).

Geography and fuel use

Both surveys found that residential energy varied tremendously across geographic regions. Fuel availability was often one of the most important factors influencing the types of fuel being used. Geographic setting of the households was found to be important. For example, hilly areas used more biomass; plains more electricity, coal and LPG likely due to more easily accessible distribution networks. Climate was also found likely to play a role in household energy demand, with per capita energy use significantly higher in the North due to winter heating. In addition, fuel production costs varied significantly across counties, indicating that any policy or program should be tailored closely to the circumstances of each county.

Income and fuel use

As incomes increased, households were found to spend proportionately more on energy goods as a group. However, changes in income did not necessarily lead to more energy consumed for cooking. In the north, increased income led to more heating, and in some areas, increased income led to greater demand for electrical appliances. As income increased, residents showed some interest in securing more efficient and cleaner devices, but consumer preferences were complicated and location specific. The growth of rural towns is changing the nature of energy consumption due to increased income and increased use of commercial fuels (Leinwen 2003).

Transition from biomass to modern commercial fuel sources is still at an early stage, and evidence shows that incomes will have to rise substantially in order for absolute biomass use to fall. The main driving forces of the energy transition away from biomass in rural households are, in order of importance: location, geographic condition, income, occupation, education level, household size, household expenditure, and sex of head of household (Leinwen 2003).

Fuelwood consumption was shown to be negatively correlated with income while coal (if available) was positively correlated to income (ESMAP 1996).

Factors found to be correlated with consumption of energy use and specific fuel use:

- Per capita total energy consumption: household expenditure, followed by location and annual temperatures;
- Per capita consumption of coal and electricity: accessibility;
- Per capita consumption of biomass: climate, followed by household size and household expenditure.

(Leinwen 2003)

4.3 Drivers of household energy demand

As demonstrated in the section above, there are factors which appear to drive (or influence) energy consumption or consumption of a specific fuel. Two of these “drivers” are discussed below.

4.3.1 Availability: use what is found locally

As found in the survey data discussed in the section above, fuel availability drives demand. A summary of the diverse energy consumption patterns found in the ESMAP-survey is included in the

Appendix (see Appendix 8 .). One indication of this pattern is the widely different household fuel mixes at the provincial level (see Figure 4.5). Another indicator of this use pattern is the geographic distribution of different fuels. Maps of coal resources and natural gas resources and pipelines are included (see Appendix 9 . , Appendix 10 . , Appendix 11 .).

4.3.2 Climate: the North-South divide

In 1990, heating and cooking comprised 90% of residential energy use. In rural areas, cooking consumed 57%, while heating consumed 33% (Wang 1997). Given the climatic differences in China, heating can greatly effect household energy consumption and vary widely. Some of the consumption has been traditionally regulated by the government. The Chinese government divided the country into three zones for allocation of heating resources using climatic zones.

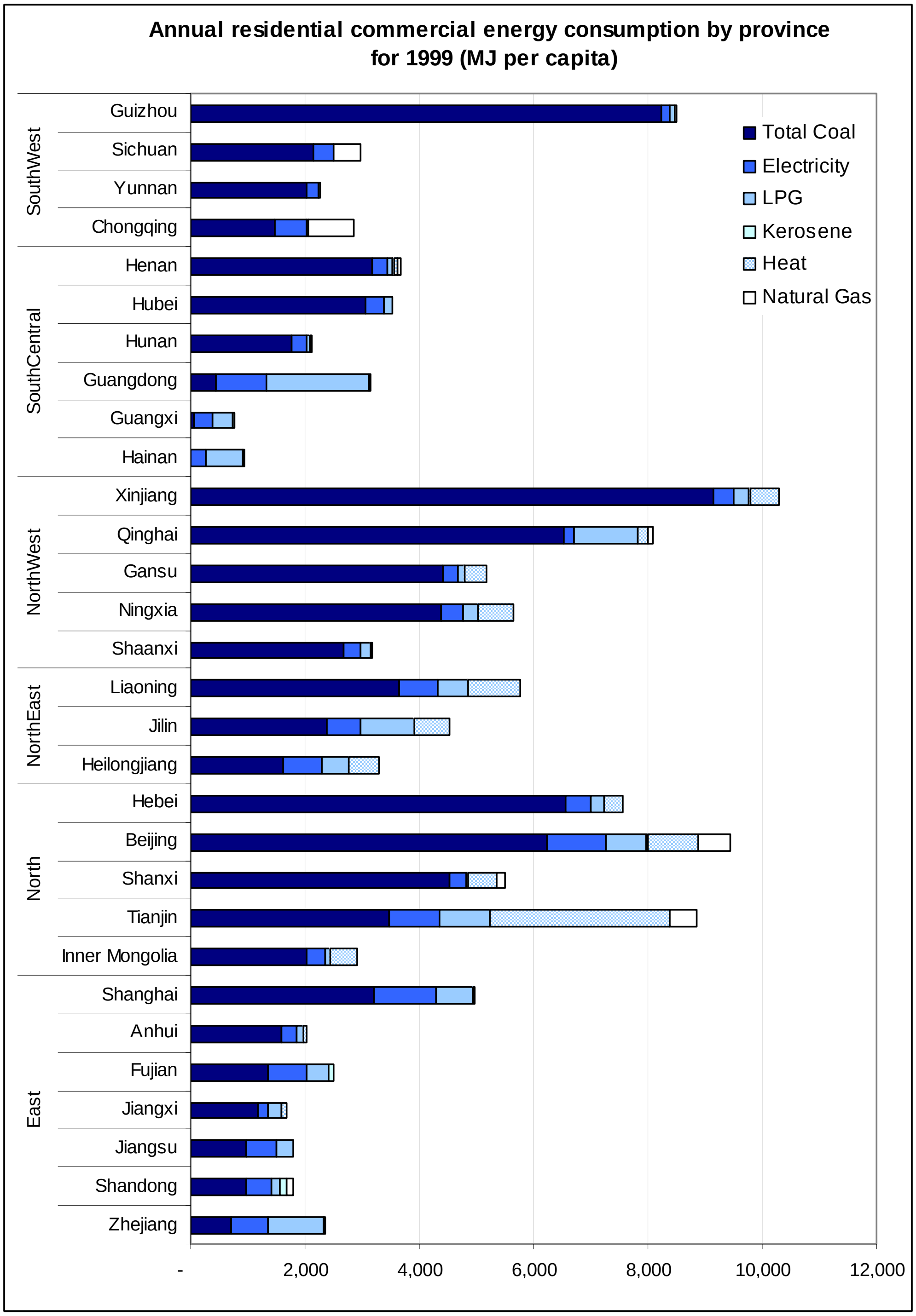
The first heating zone, primarily in the North, Northeast and Northwest, is where formal heating facilities are permitted and residents are allocated fuel for this purpose. This zone is defined by areas where the average daily temperatures are lower than 5 degrees C for more than 90 days of the year. In urban areas, heating is generally permitted between November 15 and March 15. Rural homes, however, in this heating zone do not receive an allocation from the government and heating fuels must be paid for privately (Wang 1997).

The second heating zone is mainly between the Yellow River and the Yangtze River. The government does not allocated heating resources to this zone and generally there are no centralized facilities. With rising incomes, however, there is demand for heating in the winter, where daily minimum temperature is lower than 5 degrees C for about two months per year. The transitional zone has great potential for increased demand in the future (Wang 1997).

The final zone is called the non-heating zone, and is mainly South of the Yangtze River (Wang 1997).

Urban households rely on coal stoves, central heating for individual or various buildings, or district heating. A widely cited estimate (circa 1997) is that 75% of urban residential and commercial buildings in the heating zone were heated by coal stoves. Rural households rely on either coal or biomass stoves for heating (Wang 1997). It is not hard to imagine that in both of the heating zones, rural energy consumption for heating would rise with income.

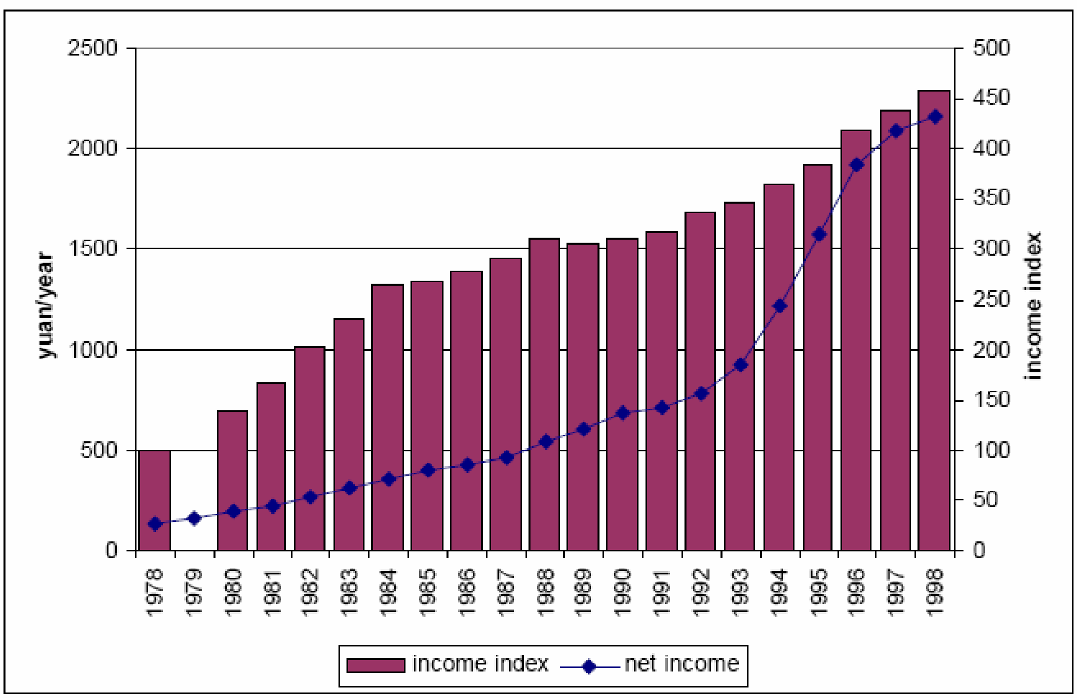
Figure 4.5: Per capita household energy consumption by fuel in 30 Chinese provinces (Energy Research Institute 2001)



Box 1: Discussion of macro energy trends in rural China
Extracted from Leinwen 2003

"[The] pattern of change in rural household energy consumption in the past two decades has been affected by many economic, social, and political factors. One key factor may have been patterns of income growth. While China as a whole has experienced rapid economic development, the growth has been geographically uneven. Rural household incomes increased significantly in most of the 1980s, but gains slowed down at the end of 1980s and in the early 1990s, before resuming a rapid increase (Figure below). Before the 1980s, rural households suffered serious energy shortages. Improved economic conditions allowed rural households to increase significantly their energy consumption in the form of both biomass and commercial energy in order to meet their basic needs. In the 1990s, biomass scarcity, in addition to income growth, may have also played a role in declining biomass use. Moreover, new environmental regulations aimed at curbing worsening land erosion, desertification, and river sedimentation may have limited access. For example, many rural areas closed off access to mountains to allow reforestation. In the meantime, the accessibility of electricity, coal and other modern fuels in rural areas continuously improved, and with rapidly increasing incomes since the mid-1990s, demand for electric appliances grew. These factors may have combined to shift energy consumption further toward commercial energy sources."

Figure Box 1: Changes in rural household per capita income. Note: Income index is adjusted for inflation and sets the income of 1978 = 100.



Chapter 5 . Household Fuels, Stove Technology and Emissions

Summary: The complex array of fuel-stove combinations makes it even more challenging to measure and analyze solid-fuel emissions and exposure in the home.

Even within each fuel group the situation can be complex. Data show that coal use is increasing in rural areas. However, coal is not a uniform product and varies widely across the country in composition, caloric value, preparation, and price. Biomass likewise encompasses a wide variety of fuels.

Within one household it is common to find a number of stoves that are used for different tasks, such as cooking, warming tea water and space heating, and also to find that stoves are used differently throughout the year. The stove-fuel combinations ultimately affect the level of emissions and exposure in the household.

In addition to the fuels discussed up to this point, biogas development has been significant in China. In 2001, the Chinese government estimated that there were almost 10 million household biogas systems installed that produced gas for cooking and heating from between 8-10 months out of the year. In addition, there are over 300,000 biogas multi-purpose systems installed which provide gas for household use and also fertilizer and other benefits for agriculture.

5.1 A complex landscape

One characteristic that seems consistent across Chinese rural homes is the variety of fuel and stove combinations that exist, even within one home. A range of fuels is available. In addition, there is a range of household needs which are often met using a combination of stoves to cook, warm water for tea and provide space heating. Cooking can needs vary widely as well; for example, flash cooking in a wok requires different heating patterns than preparing stews or rice.

In a recent study of just over four hundred homes, over 28 fuel-stove combinations were identified in the summer months, and around 32 in the winter months (K. Smith, personal communication). Given the number of fuel-stove combinations, determining which technologies households actually use, how much fuel is consumed and the resulting emissions and exposure is extremely complex (see results of stove-fuel testing Appendix 12 . , Appendix 13 .).

5.2 Household fuels

The specific fuels that are used by Chinese households are discussed in detail in Figure 5.1 and Figure 5.2 As discussed in the review of the energy ladder model (Appendix 3 .) fuels that are favored by more affluent households typically have greater calorific values. Figure 5.3 below shows the typical calorific values for a selection of common household fuels.

Figure 5.3 shows that the energy content of coal lies between biomass fuels and cleaner-burning fossil fuels, which is what might be expected from a “transition fuel.” It also demonstrates that the type of coal used in China can vary substantially. Figure 5.4 shows the per capita use of

Figure 5.1: Major residential energy sources

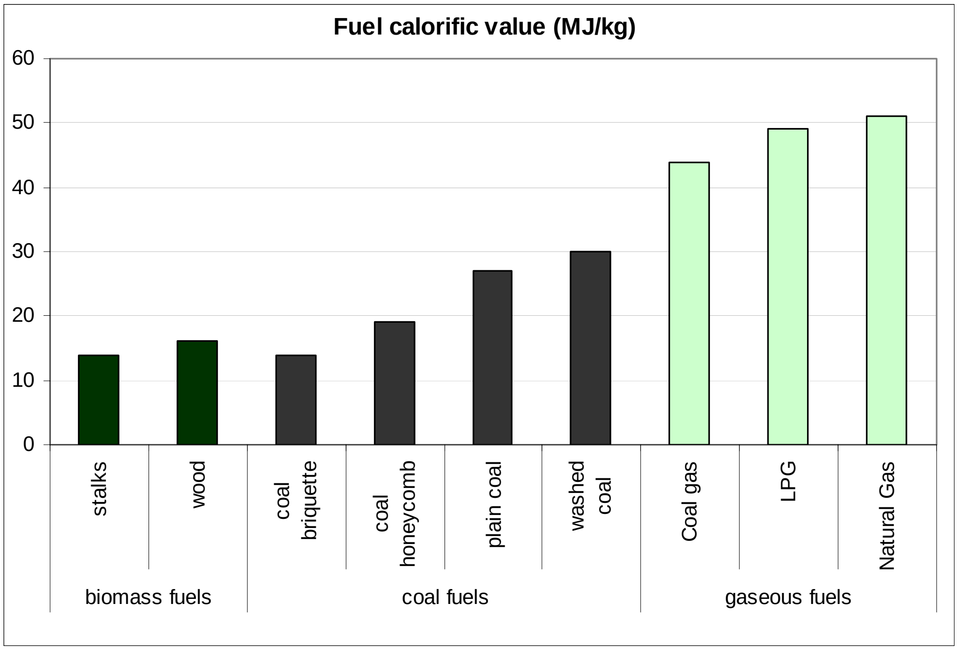
Fuel	Energy value per typical unit		Source	Used for…			
				Cooking	Heating	Lighting	Comments
Coal	27.3	MJ/kg	b	✓	✓		Coal is used in many forms in China - it may be used raw, washed, or processed into briquettes or honeycombs. The energy value given here is for unprocessed coal. See the text for a discussion of the differences in these types of coal
Electricity	3.6	MJ/kWh	-	✓		✓	China has undergone rapid growth of electricity consumption, with residential use growing at an average of 15% per year through the 1990s. This growth has been driven both by expanding service provision (particularly in rural areas) and by increasing demand in households that already have access.
Wood	16.2	MJ/kg	b	✓	✓		Wood is almost exclusively a rural fuel and continues to be used in those areas of China though, according to the LBL database, its use has leveled off in recent years.
Crop stalks	15.3	MJ/kg	b	✓	✓		Similarly, crop stalks and other agricultural residues are used as fuel exclusively in rural areas. Like wood, the use of crop residues has leveled-off in recent years.
LPG	49.0	MJ/kg	b	✓			LPG is a mix of light hydrocarbon gases - primarily butane, propane and ethane - which are produced from petroleum distillation. It is a popular cooking fuel in many urban areas. LPG consumption increased sharply in the early 1990s, and continued to grow over 20% per year until 1999, the last year for which data is available. Like other gaseous fuels, it is used mainly in urban areas (Energy Research Institute 2004)
District Heating	-	-				✓	District heating is available in many urban areas of China. It is generated from centralized boilers. These boilers burn natural gas, coal or fuel oil. In 1996, the most recent year for which data is available, natural gas was the most common fuel for district heating - only 18% of energy for district heating was derived from coal. However, in over one third of China's provinces, 75% or more of the centrally distributed heat was derived from coal, with potentially significant impacts on outdoor air quality(Energy Research Institute 2004).

Figure 5.2: Minor residential energy sources

Coke		MJ/kg	a		✓		Coke is a solid fuel derived from coal. When coal is heated in an oxygen-lean environment, the volatile matter is driven off (making coke-oven gas) and a solid fuel remains that is mostly fixed carbon. Coke is typically used in steel production, and is only used as a residential fuel in 3 of China's provinces (Energy Research Institute 2004).
Coke oven gas	28.47	MJ/kg	a	✓			Coke oven-gas is a medium calorific value gas derived from coke production. It is produced in centrally located facilities and distributed to residences. Historically, between 10 and 20% of coke oven gas production has been used in the residential sector, almost entirely in urban areas(Energy Research Institute 2004). Often referred to as "town gas".
Other gases (e.g. coal gas)	43.8	MJ/kg	b	✓			Other gas consists primarily of coal gas, which is produced by the thermochemical breakdown of coal. Like coke-oven gas, between 10 and 20% of coal gas is typically used by the residential sector, and its use is limited largely to urban areas (Energy Research Institute 2004).
Kerosene	43.3	MJ/kg	b	✓		✓	Kerosene is used primarily in rural areas. It is used as both a cooking fuel and a lighting fuel. Its use is far below levels in other developing countries.
Natural Gas	51.3	MJ/kg	b	✓			Natural gas is a high calorific value gas consisting mostly of methane (CH_4). Consumption in China has grown steadily over the past 15 years, but not nearly at the same pace as LPG. The residential sector has also seen steady increases in natural gas consumption, however, unlike LPG, where 60-80% of consumption occurs within the residential sector, natural gas is consumed largely within industry (Energy Research Institute 2004). Use is limited to urban areas with access to supply infrastructure. Use is concentrated along the east coast (Fridley, personal communication).
Biogas	17.7	MJ/kg	c	✓		✓	Biogas is a low calorific value gas made from the anaerobic digestion of organic waste. It burns very cleanly and is used for cooking and lighting.

Sources of fuels data: a - (IPCC 1996), b - (Zhang, Smith et al. 2000), c - (Smith, Uma et al. 2000)

Figure 5.3: Calorific values of common Chinese household fuels (Zhang, Smith et al. 2000).

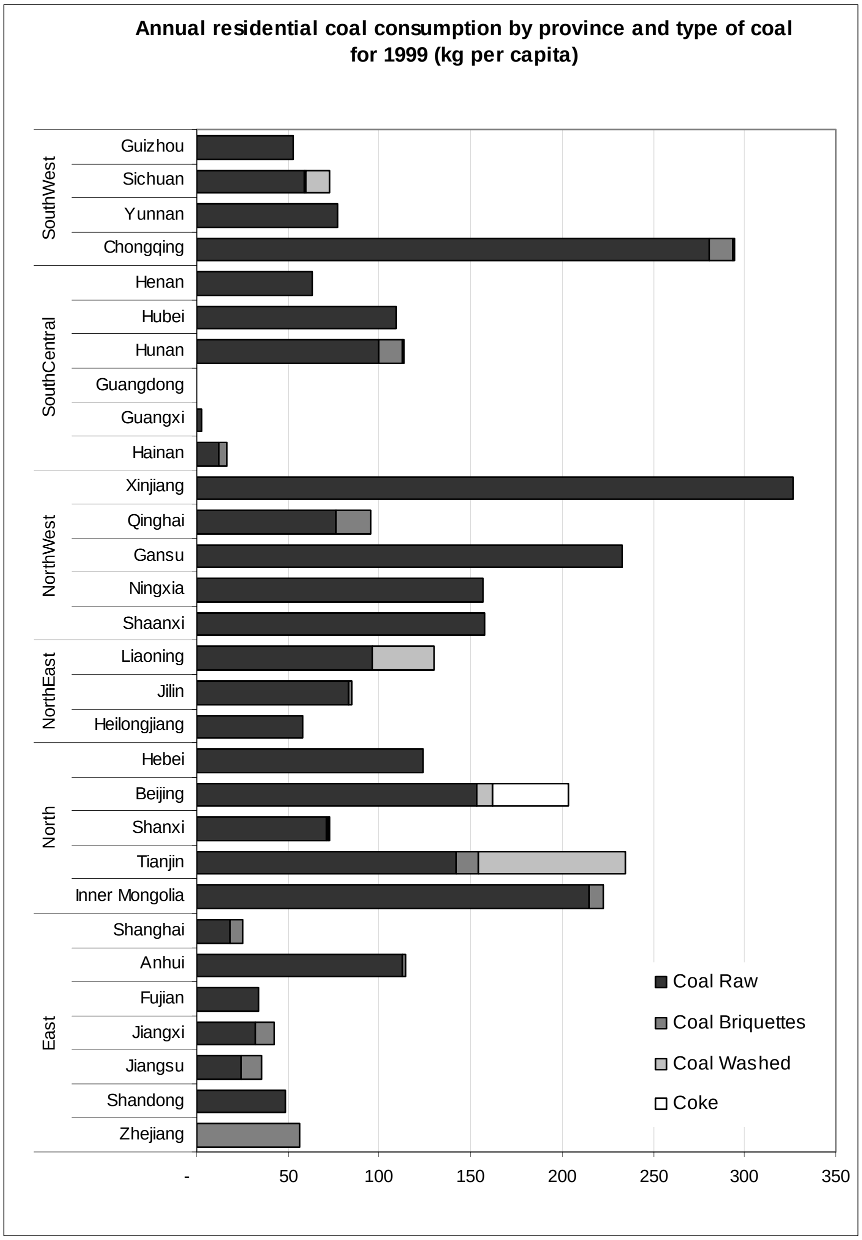


different kinds of coal by province in 1999 (the most recent available data). The type of coal that is used has significant implications for the overall health impacts, and if detailed data is available, analysts should avoid basing research and policy decisions on analyses that consider coal a homogeneous fuel.

The data show that there are large differences in the type and quantity of coal that is used, but several common patterns emerge. Most importantly, raw coal, also known as plain or unwashed, dominates in all but two provinces. Also, alternatives to raw coal, such as washed coal or coal briquettes, are only available in 14 of the 30 provinces reporting (Energy Research Institute 2004). Coal briquettes are manufactured from coal dust mixed with a binding material such as clay or starch. This binder lowers the calorific value, but can also reduce the harmful emissions. Washed coal is coal that has been washed to remove impurities. This raises the calorific value and lowers the sulfur content.

The variation of consumption is also driven by price and availability. While coal prices in urban areas are fairly constant, in rural areas price varies greatly given variables related to supply, transportation costs and subsidy. Some coal used for residential energy is subsidized. In rural areas, however, more than half of all coal that is purchased comes from the market. Generally, subsidized coal does not reach poor rural households (ESMAP 1996).

Figure 5.4: Household use of different types of coal in China's provinces in 1999 measured in kg per capita (Energy Research Institute 2001).



5.3 Stove-fuel combinations

For coal, and for other fuels, the emissions of health damaging pollutants depend both on the characteristics of the fuel and on the stove technology. While some pollutants, like SO_2, depend only on the chemical composition of the fuel, other pollution emissions are strongly linked to the efficiency of combustion, which is determined by a complex combination of factors related to the fuel, the stove, the stove-user(s) and the household microenvironment. Figure 5.5 shows the stove efficiency measured under lab conditions, which control for the last two groups of factors.[9] Note that identical fuels behave very differently when they are used in different stoves (demonstrated by the case of coal honeycomb briquettes in three different stoves).

While the use of gaseous fuels like LPG and, to a lesser extent, natural gas, has taken off in urban areas, improvements in the way that rural households access energy for cooking and space heating have been largely limited to shifts from biomass to coal and to changing stove technologies (discussed above).

Unfortunately, little data is available to western audiences concerning the actual technologies that are in use today. It seems that a significant portion of rural stoves may have chimneys, either as part of the improvements installed under CNISP or because chimneys were an element of the traditional stove design in some regions.

Reviews of the CNISP published a decade ago focus more on the numbers of stoves disseminated rather than on the actual technology (FAO 1993; Smith, Shuhua et al. 1993). The reference from the FAO does include a review of some of the improved stoves that had been stoves promoted for household cooking and/or heating, but the stoves discussed add to a little over 140,000, which is less than 1% of the total number of stoves disseminated at the time. Ten years and another *100 million stoves* later, the picture presented to outsiders is even hazier (see Section 6 for more details on the Chinese National Improved Stove Program).

5.4 Stove-fuel emissions

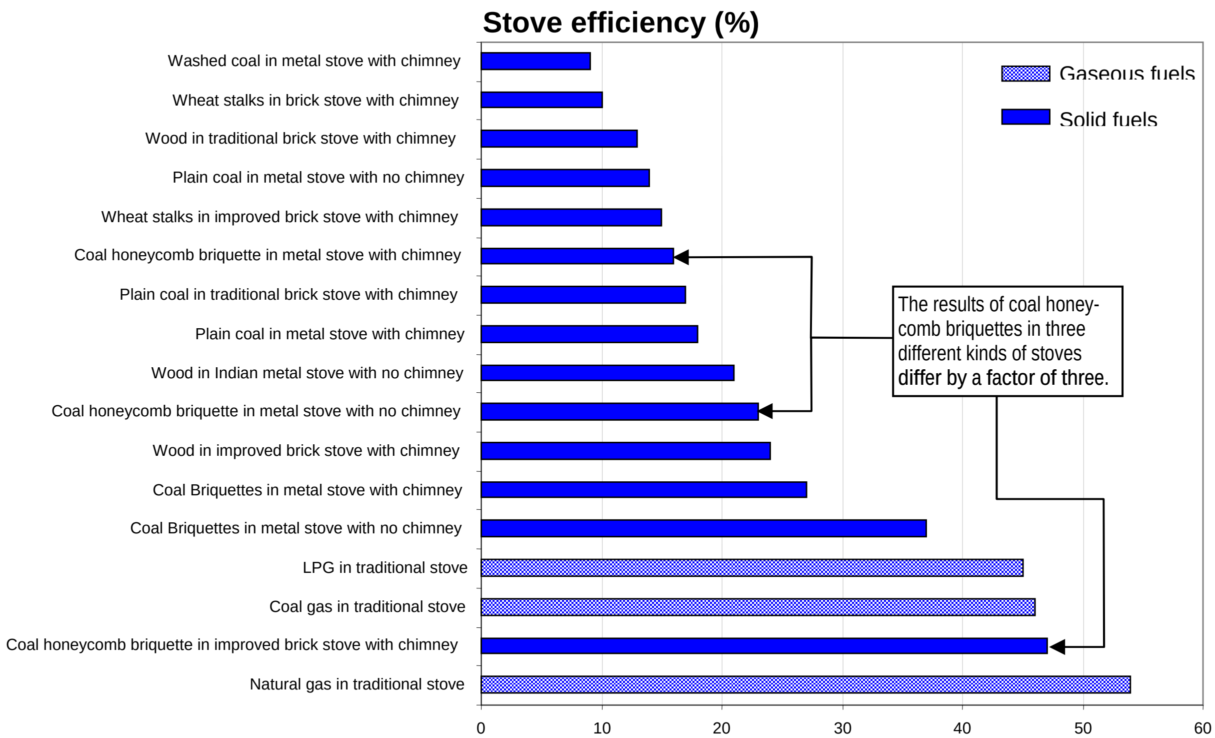
As discussed above, stove emissions depend on a complex range of factors, including human behavior. In addition, the impact of emissions on human health is mediated through exposure. Exposure to a given pollutant is a product of pollution concentration, which depends on emissions as well as on environmental factors like ventilation, and the length of time that people are present in the polluted environment, which also depends on human behavior.

It is especially important to draw the distinction between emissions and exposures in the context of improved stoves. The dissemination of improved stoves may have introduced a chimney to traditional stove models that did not have them. This can affect the combustion characteristics of the stove in such a way that, all things being equal the stove emits more pollutants. However, the chimney removes the pollutants from the indoor environment where the likelihood of exposure is quite high, and transfers them to the outdoor environment where

[9] These researchers measured efficiency as the fraction of fuel energy content transferred to the cooking pot in a cooking task simulated by boiling water. Because they were working in lab conditions and were able to control user behavior and microenvironment, these results can be expected to be a rough upper bound of efficiencies that might be observed in real Chinese kitchens.

the concentration and ultimately the human exposure to the pollutants are likely to be lower. Figure 5.6 shows PIC[10] emissions per unit energy delivered for a selection of fuel-stove pairs comparing stoves with and without chimneys. Note the stoves without chimneys systematically emit fewer PICs, which implies that they have cleaner combustion. However, if the chimneys function properly, it is highly likely that the stoves with chimneys result in lower exposures and thus in fewer health impacts.

Figure 5.5: Stove efficiencies of some common Chinese household fuel-stove combinations (adapted from (Zhang, Smith et al. 2000)).



The pollutants that are of particular concern from the standpoint of human health are PICs like particulate matter (PM), carbon monoxide (CO), and hydrocarbon compounds including Polycyclic Aromatic Hydrocarbons (PAH), benzene and formaldehyde as well as oxides of Sulfur and Nitrogen (SO_2 and NO_x) (Discussed in Appendix 2 .)

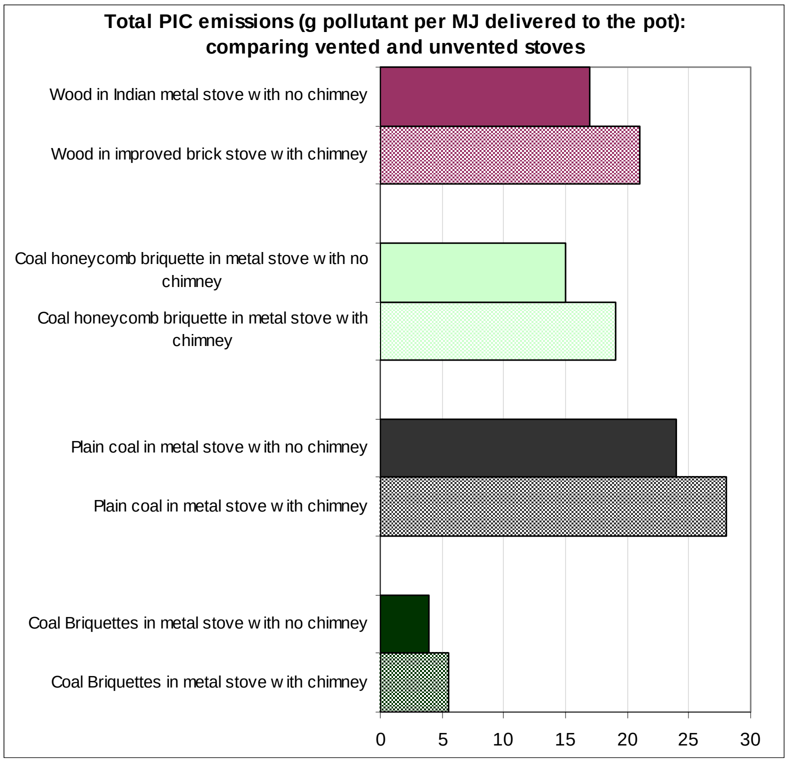
It is worth noting that if environmental impacts are to be considered more broadly, then the release of greenhouse gases like carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20) also warrants attention (Edwards, Smith et al. 2004). The widespread use of coal in China's residential energy sector results in significant greenhouse gas emissions from this sector, which may be in contrast to other low and middle-income countries that rely largely on biomass. Finally, with the high incidence of household coal use, other pollutants, such as

[10] PICs are Products of Incomplete Combustion and indicate the extent to which combustion was not ideal. They include any compound that would not appear if, in theory, the fuel had been fully combusted. In this case, the PICs given are the sum of CO, CH_4, PM and the carbon content of the net non-methane hydrocarbons (NMHCs).

fluorine and arsenic, found only in coal from particular areas of China, may also be emitted (see Chapter 3 .).

Figure 5.7 shows the mean, minimum and maximum emissions of health damaging pollutants that were measured in a study of common Chinese stoves and fuels (Zhang, Smith et al. 2000). The pollutants are grouped by fuel, but represent the outcome of tests run on different stoves, which explains the wide spread in the data.

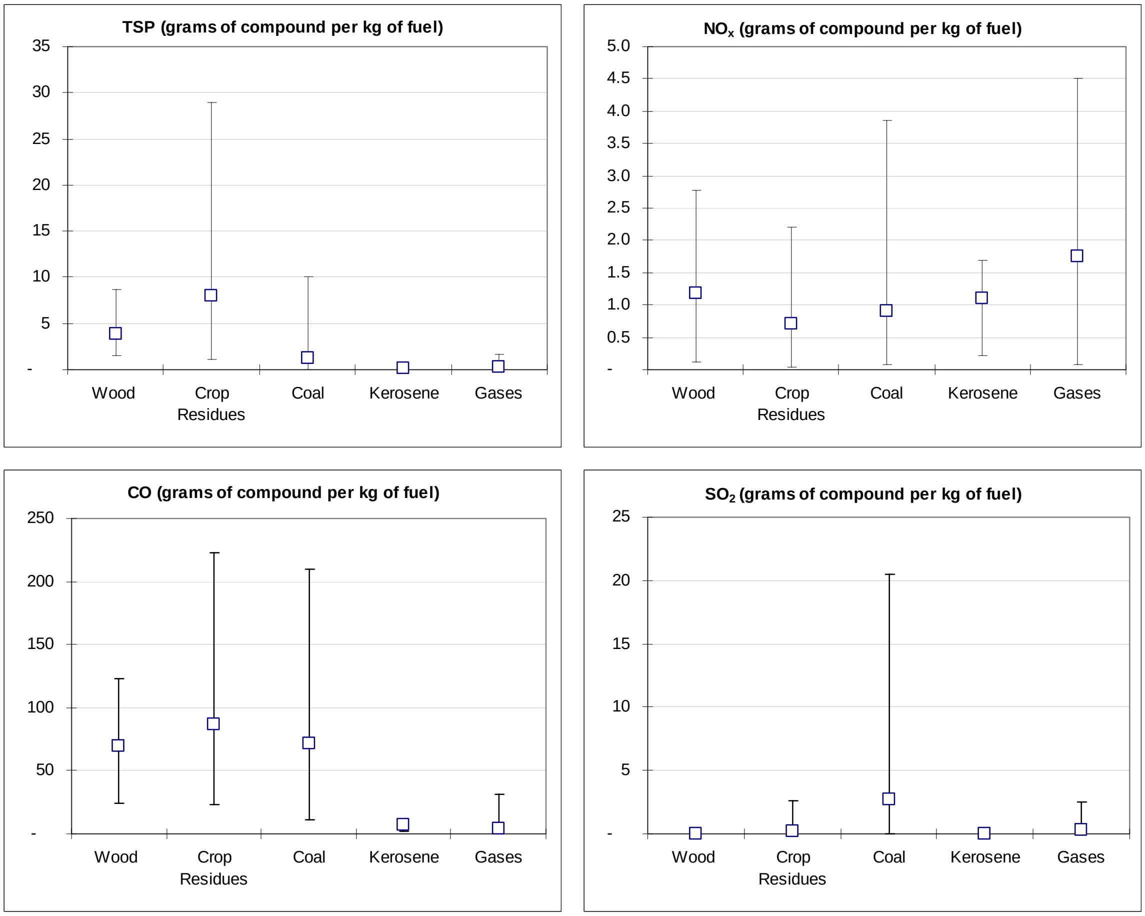
Figure 5.6: Total PIC emissions per unit useful energy coal and wood burned in stoves with and without chimneys (adapted from (Zhang, Smith et al. 2000)).



In the Appendix there is a more exhaustive list of the fuel-stove combinations based on the work of Zang, Smith and colleagues (2000) (Appendix 12 . , Appendix 13 .).

Figure 5.7: Average emissions of health damaging pollutants from common Chinese household fuels (Zhang, Smith et al. 2000).

Note: Each fuel was tested in several different kinds of stoves and the error bars show the observed minimum and maximum levels of each pollutant in each fuel category.



5.5 Biogas systems

In China, biogas fuel is rising in popularity in some rural areas. There have been significant advances in biogas system development and use, relative to other countries. Biogas systems in China fall into three general categories: household systems, multi-function systems, and industrial systems. The industrial systems, which attempt to deal simultaneously with China's growing demand for energy and increasing environmental problem with livestock and agricultural waste, fall outside the scope of this document.

By 2001 the Chinese government estimated that approximately 10 million farmer household systems were in use. This represents 4% of total farm households and almost 7% of all households suitable for biogas in China (Jiuchen 2003). Biomass inputs include crop straw and stalks and animal waste. Improvements in household biogas digesters in the 1980s led to a significant increase in gas production (50% claimed) (Biogas China).

Currently biogas work is conducted by the Ministry of Agriculture as well as by local government agencies. In 1979 the Chengdu Biogas Scientific Research Institute, managed by the Ministry of Agriculture, was established to aid in Chinese biogas development in China (TCDC in China). Since 2001, the Ministry of Agriculture increased support of biogas development from 100 million RMB Yuan ($US12 million) to 350 million RMB Yuan ($US42.3 million). In 2002 the Ministry of Agriculture developed the National Plan on Biogas Development in Rural China (Jiuchen 2003).

The household biogas systems produce gas that is used for cooking and lighting, generally during 8-10 months of the year. In winter, there is a higher reliance on other fuels for cooking and heating. Government programs have worked to distribute improved stoves and low pressure lamps that work with the biogas systems.

The multipurpose biogas system designs are different in the North and the South. In the north, the multipurpose biogas systems are called 4-in-1, and include a toilet, pigs, a digester and a greenhouse. There are approximately 300,000 of these systems installed (Jiuchen 2003). While eliminating animal and human waste, the systems also provide household energy for the majority of the year and provide heat, fertilizer and increased levels of CO_2 (from the pigs) for the greenhouse. The basic system is sized around ten pigs and a family of four. Pigs are raised widely in rural areas given the high demand for pork in China (South-North Institute for Sustainable Development).

In the South, the multipurpose system is called pigs-biogas-fruits, as there is no need for the greenhouse component. However, all the other benefits remain. There are approximately 2 million such systems installed (Jiuchen 2003). In the southern Province of Jiangxi, one county claims that 65% of households have pig-biogas-fruit systems. After ten years of use the reported benefits in that country were; reduced biomass collection leading to greener mountains and cleaner local water sources, and increased capacity for livestock and fruit and fruit production leading to increased income and enhanced standard of living at the household level (Biogas China).

In Appendix 17 . there are several figures related to biogas use in China.

In addition to household biogas, there are almost 1,000 large and medium biogas systems located on farms, and over 400 biomass gasification systems which supply over 82,000 households (Jiuchen 2003).

Chapter 6 . Health Policy and Programs Related to Indoor Air Pollution

Summary: While China once had an exemplary health care system, it fell into decline after the economic reforms of the 1980s. The current situation in rural areas is very different from the 1970s when approximately 90% of rural inhabitants had some form of health insurance, and the rural medical system was the envy of the developing world. Today less than 10% of rural inhabitants have any type of medical insurance, there is a very low ability to pay for services out of pocket, and rural facilities are poorly staffed and stocked. The result is an underutilized rural health care systems and poverty induced by high medical costs. While healthcare in rural China is still probably better than in many developing countries, it is a national priority to reform the medical system in order to provide effective rural healthcare. So far, however, pilot interventions with a wide range of international agencies have not succeeded.

In March 2003, the Chinese government put into effect the first set of standards for indoor air quality in households. The standards were released jointly by the State Administration for Quality Supervision, Inspection and Quarantine, the Ministry of Health, and the State Environmental Protection Agency. There does not appear to be a clear enforcement mechanism.

6.1 Background

Between 1950 and 1970, China developed a path-breaking cooperative medical financing scheme called the Cooperative Medical System (CSM). It worked in coordination with the rural cooperatives and served to fund and organize prevention, primary care, and secondary health care for rural areas. Under the Cultural Revolution (1966-1976), CSM was given political priority and developed rapidly. It was in coordination with this program that the "barefoot doctors" were able to provide preventative and primary care for the rural population. CSM enabled China to extend health care to rural areas at relatively low cost by leveraging and mobilizing local resources (Genesis Technology Group).

At its peak, before economic reforms, 90% of China's rural population was covered by CSM. Along with improved basic living conditions over the same period, the resulting improvements in basic health indicators during the 1960s and 1970s became the envy of many developing countries. Given the political attention to and financial resources invested in the health care system, health gains were greater than would have been expected based purely on the country's economic progress (Genesis Technology Group).

This picture began to change in the 1980s, however. As the government initiated economic reforms, the portion of government spending on health care declined from 36 to 16 percent. By 1993, only 3.8 percent of GDP was spent on health care, which is low when compared to other countries, and per-capita health spending (private and public) was four times higher in urban than rural areas (AusAid 1999). Despite rapid increases in GDP and in household incomes across China since the 1980s, overall health gains have slowed, most significantly in poor rural areas (Genesis Technology Group).

By 1003 these changing economic priorities and reforms contributed to the downfall of CSM, which already suffered from poor management and the challenge of sharing health risk over relatively small groups of people in local cooperatives. Currently, less than 10 percent of China's rural villages have coverage through CSM. At the same time, with reduced government funding, rural health clinics set prices at levels necessary to cover costs with little regard for the local population's ability to pay. Rural health care is now largely available only to those who can pay for it themselves, and most households cannot. An average hospitalization exceeds average annual income for 50 percent of the rural population. Illness-induced poverty is a serious issue in China; an estimated 30 percent of the destitute people have become so through costs related to a serious illness.

6.2 Health care delivery system and administration

The health care delivery system in both urban and rural areas is three-tiered and designed to provide broad reach and efficient allocation of resources. In rural areas, the three tiers are: village stations, township centers and district hospitals. Village stations have practitioners with very basic education and skills. The township center will have 10-20 beds and be staffed by a physician with three years of medical school training post high school. The district hospital will have 250-300 beds and be staffed with physicians with additional years of schooling along with nurses and technicians.

Administration and governance of the health sector is complex. The Ministry of Health (MOH) sets the policy direction and provides technical support. At the provincial or more local level, health care institutions are taken care of by Bureaus of Health (BOH). While the MOH maintains a leadership role in policy and program development, fiscal responsibility is devolving to the local level (AusAid 1999). Along with this fiscal devolution comes some ability for provincial health leaders to decide on local priorities based on locally specific problems. For example, infectious diseases are often geographically specific, with more tuberculosis in the north and northwest provinces and more HIV in the southern provinces. Local officials can often use their new freedom to add priorities, as long as they continue to support the central government's policies.

6.3 Health care priorities

Since the 1980s, rural health care has developed unevenly, and regional inequities have steadily grown (China Foreign Loan Office ca. 2001). Rural services now suffer problems of coverage, utilization, quality, efficiency and financial viability (AusAid 1999, Genesis Technology Group). Improving the rural health care system is a national priority. Unlike in the early economic reform years, there is now a realization that there is a close link between public health and continued economic development. In recognition of the need to address rural health care, some structural changes were made in the Ministry of Health (MOH), most notably in 1998 when the Basic Health Services and Maternal/Child Health were elevated to a department level.

Creating a new rural health system that includes an insurance component is of vital importance. Many experiments have been run, but all have failed. Many international organizations have tried to work on innovative health care financing at the rural level, including the World Health Organization, the World Bank, UNICEF, but none of the programs could sustain a rural insurance program. One of the problems consistently encountered by these programs was self-selection. The more someone needed insurance, the more likely they were to participate in a program. Insurance programs work best, and rates can be kept low, when risk of illness and disease over the entire participating population is relatively low (Hu 2004).

Addressing this issue is a major theme for the current leadership of China, which sees that providing a functional health insurance plan and health system will help maintain social stability in rural China (Hu 2004). One new central government pilot program will match provincial and farmer contributions to insurance premiums. Under this scheme, each party would contribute 10 Yuan for a total of 30 Yuan per-person-per-year (slightly less than $US 4). This amount would be able to help with major illnesses.

While different documents and professionals tend to vary slightly in their understanding of national health care priorities, a number of common goals emerge:

- Improvement of rural health care system;
- Reform of the rural and urban health insurance system to extend coverage to people who currently are unable to afford medical care;
- Containment of urban medical costs; and
- Prevention of new and re-emerging infectious diseases.

6.4 International organizations involved in health care

A range of international agencies and organizations are involved in China. The majority appear to be involved in health care system reform and infectious disease containment. A list of organizations known to be active in China is included below. In addition a list of the activities on a provincial level of the most active agencies is included in the Appendix (see Appendix 14 .).

Bilateral Agencies

- Department for International Development (DIFID)
- The Australian Government's Overseas Aid Program
- Japan International Cooperation Agency
- Canadian International Development Agency

Multilateral Agencies

- World Bank: Health VIII Program (see below)
- World Health Organization
- United Nations Children's Fund
- United Nations Development Program
- United Nations Joint Program on HIV/AIDS
- United Nations Population Fund

Non Government Organizations

- Ford Foundation
- Medicin Sans Frontiers
- China Foundation

World Bank's loans to China for health programs have been on-going. Currently, the loans are being used for the eighth such program, called "Strengthening Basic Health Services in China's Poor Rural Areas" (Health VIII). The following summarizes the program.

> "[The program's] goal is to improve the ability of poor rural areas to provide health services and increase the level of utilization of health services; to ensure that residents of these areas receive basic health services and to enable the population of poor countries to achieve sustained health improvements. This poverty alleviation health project, covering 31.78 million people in 71 nationally and provincially designated poor counties in 7 central and western provinces, reaches a relatively large number of poor areas and people" (China Foreign Loan Office ca. 2001)

6.5 Indoor air pollution

On March 1, 2003, the first set of standards for indoor air quality in residences and offices went into effect in China. Theses standards were issued jointly by the State Administration for Quality Supervision, Inspection and Quarantine; the Ministry of Health; and the State Environmental Protection Agency (see Appendix 15 . The National Gas Cookware Testing Center, which is under the National Quality Monitoring Supervision Center, is also working on performance and safety standards for residential gas stoves (see Case 8.1: Gas stove market explosion and maturation).

There appears to be some interest on the part of the government in IAP as evidenced by the IAP standards referenced above, the Ministry of Science and Technology IAP grant in the 10^{th} Five-Year Plan (discussed in 7.2 Programs since CNISP), and the work currently being done by the Chinese Center for Disease Control (CCDC) with the World Bank (WB).

The CCDC/WB project aims to combine technological and behavioral interventions in four Chinese provinces, based on detailed monitoring of air pollutants through multiple exposure routes. The initiative plans to address both technology and behavior, and for the technology, both its development and dissemination. Additional information on this program will be forthcoming in 2004 (Ezzati 2004).

Despite this promising initiative and the other energy projects described in Chapter 7, IAP is not an established national priority, nor does it appear to be a priority at the provincial level. One of the barriers that may be preventing IAP from becoming a national health priority is the lack of data connecting IAP to mortality. The registration of death and disease does not show IAP as the cause of respiratory disease or death, even though it is the most relevant environmental risk factor (Hosang 2004).

6.6 Behavior Change

Behavior change is an important component of the policy approach to reducing death and disease related to indoor air pollution exposure. Most rural individuals have limited education, which makes it more difficult for them to understand the health effects of indoor air pollution, and limited access to information about health issues. This in turn limits their ability to make healthful choices with regards to fuel selection, stove design and placement, and flue installation and ventilation. In fact, the authors have heard informal comments from researchers indicating that smoke may be viewed as positive stove attribute because it is thought to spread heat through the home and it can be used to preserve food.

In many areas, fuel and stove choices are most likely made on the basis of traditional cooking and food preparation techniques. For example, crop residues are favored for stir-frying because they offer a short, intense burst of heat. Coal stoves, in contrast, seem to be preferred to heat rooms and water as they offer a constant sustained temperature (Smith 2004, Du 2004).

A successful health education campaign could help individuals make stove and fuel decisions in a broader context, including both cooking and health considerations. Because of the variability of stove-fuel combinations in rural China there is unlikely to be a national, one-size-fits-all technical solution to IAP. Instead, people need to be educated to apply advances in technology to their own local fuel and economic situation for the best possible health outcome.

The authors of this report have not found any public education campaigns in China, either currently or during the CNISP, designed to raise awareness of the effects of indoor air pollution. One Chinese development professional did mention that China Central Television Station recently ran a series of reports on coal-related illnesses in Guizhou Province (see Chapter 3), but it is not clear if this is part of a larger awareness building campaign or who might have organized it.

As important as behavior-change communications may be, there is evidence from related health fields, like family planning, that they may prove challenging to implement in China. At the institutional level, the Chinese government officials have tended to decline offers from foreign organizations to implement behavior change campaigns directly with rural populations, even in support of established health priorities. This makes it more difficult to do implementation than in other countries. International organizations working in family planning have instead provided the Chinese government with technical assistance and travel opportunities that help in policy formation in the area of behavior change.

The World Bank’s health care and poverty alleviation program, referenced above, provides valuable lessons on the cultural barriers to behavior change. The following excerpt from the Health VIII report, evaluating a World Bank health initiative in a rural area, implies that there is little foundation upon which to build a health-focused public awareness campaign about the dangers of IAP, but that such activities are critically important.

> "The traditional attitudes and level of knowledge of project area residents to a certain extent limits project implementation and the development of priority health interventions. Therefore, the intensity of health promotion should be increased, and there should be comprehensive health education, allowing the public to gradually change poor health notions. Only by making the public truly understand and participate will it be possible to achieve smooth and sustained development."(China Foreign Loan Office ca. 2001)

Chapter 7 . Energy Policy and Programs Related to Household Energy Use

Summary: China is responsible for one of the most impressive rural biomass stove programs in history. From 1982 to 1992, over 100 million households adopted a new stove; this represented perhaps as many as 65% of rural homes. Follow-on programs resulted in another 70 million installations. The program has now concluded, and long-term results, including the number of stoves still in sue, are currently being evaluated[11].

At this time, there are two relatively small government stove programs underway. The first addresses deforestation and flooding (Ministry of Forestry), and the other targets human poisoning by emissions from coal with high levels of fluorine and arsenic (Ministry of Health).

There is one key government agency which looks at rural energy, National Development and Reform Commission, and other agencies involved in rural poverty alleviation (Offices of Western Development) and IAP (Ministry of Science and Technology). There is limited involvement from NGOs and multilateral agencies.

7.1 Chinese National Improved Stove Program (CNISP)

(This section is a summary of Smith, Shuhua et al. 1993)

The Chinese National Improved Stove Program (CNISP) was active between 1982 and 1992 and is reported to have resulted in the installation of 129 million improved stoves, representing around 65% of all rural households. While the focus was mainly on biomass cookstoves, some attention was also paid to heating needs in the North. The program was developed due to concern over fuel shortages at the household level, depleted forests and soils, and potential competition between rural and urban areas for commercial fuels. The CNISP was seen at the time as a relatively low-cost program with quick return in terms of energy savings.

The CNISP was developed in the Ministry of Agriculture (MOA) by the Bureau of Environmental Protection and Energy (BEPE). The program relied on an extensive and pre-existing network of over 1,500 Rural Energy Offices (REO) that had served to also promote biogas and micro-hydro programs. One of the successful aspects of CNISP was that BEPE contracted pilot projects directly with counties, by-passing the provincial bureaucracy. Each year around 100 pilot counties were identified after a careful screening based not only on need, but also on availability of resources and desire. Critical in the implementation were 1) local “checking” groups that served as program quality control, and 2) local policies to accelerate adoption of the stoves. It is useful to indicate that some of the local policies were quite strict. For example, in one county a permit for a new home was tied to the installation

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[11] In 2002, a team of U.S. and Chinese researchers collaborated on an independent review of China’s improved stove programs, funded by the Shell Foundation. At the time when the research for this report was underway, the results of the review were not yet available. They have since been published in *Energy for Sustainable Development*, Volume VIII No. 3.

of an improved biomass stove. In other provinces, permits were not given for fuelwood collection without the installation of an improved biomass stove.

Research and development in CNISP was initially focused on modifications to better match local fuel and cooking with existing stoves. Later in the program, the focus shifted toward durable inserts that could be easily manufactured and used in home-built stoves. It was hoped that standardization of the components of home-built stoves would increase combustion efficiency. In 1985 a training and research center was established outside of Beijing. It worked with 25 or so research institutes across the country.

In 1988 there were approximately 1,000 rural energy manufacturing and service companies (RECOs). These companies played a very important role in "offering a way to harness forces of competition to improve quality and cost effectiveness" and "promise(d) to be the best route to move CNISP to full commercialization (i.e. to greatly reduce involvement of national and province bureaucracies during 1990s)." The provincial REOs observed that the RECOs tended to be more successful in the southern parts of China where people had the reputation of "being more open to entrepreneurial innovations". By the end of CNISP, RECOs were assumed to be an important part of future work since increasing efficiency of the stoves was dependent on the pre-manufactured components RECOs could manufacture and distribute.

Outstanding in the eyes of the international community was the relatively low cost of the CNISP. The Chinese government decided not to subsidize the stove itself except in a limited number of cases where households were too poor to afford some of the input materials. In general the households paid for the labor and materials for the new stove, while the government paid for training, promotion and administration costs. In addition, the government provided a tax break to the RECOs working on improved stoves. In this fashion the government paid for less than 20% of the overall cost of the stove program (including the new stoves).

Researchers evaluating the CNISP found that coal stoves were an often overlooked, yet critical component in household energy. Of the 122 households visited in one study, 88 had a small coal stove in the corner for heating and warming tea water which was often constantly on, especially in colder months. This led one researcher to comment: "Compared to the impressive improved biomass stoves now in many Chinese rural households, the coal stoves we saw were ugly, awkward, and dirty, and did not seem to have benefited from much of the coal stove R&D that had gone on in recent years." People liked coal since it required less attention, in contrast to efficient wood stoves, which needed constant feeding due to the small combustion chamber. Even in cases where woodfuel was abundantly available and in close proximity, households would use coal due to its convenience. Coal heating stoves, like coal cooking stoves, were not integrated into the CNISP dissemination strategies. This led researches to conclude that while local improved stove programs have ignored the coal issue, "this may have worked in past but is becoming increasingly unrealistic" due to commercial fuel use and indoor air pollution concerns.

Researchers made some suggestions regarding future improved stove work about the time the CNISP was ending:

- Move from home-construction to manufactured stoves in order to provide quality control;

- Reach population at national fringe (income, geography, culture); and
- More fully integrate stoves into national energy strategies, as “rural incomes continue to grow, urban-rural interactions increase, and fuel switching accelerates.”

There are differences between China and other countries that may have been critical for the widespread dissemination.

- There was a unique combination of centralized government bureaucratic network (able to tightly control process unlike in other countries) and early entrepreneurship and open markets (able to use “entrepreneurial drive” unlike other countries with planned economies).
- Quality of life and infrastructure in China were relatively good compared to other developing nations.
- Chinese rural households had a stronger ability to pay for stoves compared to their peers in poorer countries, such as India and Nepal.
- Traditional biomass stoves in China were more similar to the “improved” stoves in India and other countries; China started with a more robust baseline of installed stoves.

What can be learned from the CNISP experience?

- Work in the best areas first (pilot selection went well beyond need and included available resources and desire).
- Promote rural energy companies.
- Stay bureaucratically lean; with direct transfers from central government to county pilots.
- Minimize direct government contribution (training, administration and promotion).
- Minimize money flow.
- Conduct independent monitoring through locally established committees.

While this report focuses exclusively on the CNISP, provincial governments also implemented improved stove programs. The long-term results of all these programs are still unclear and are currently being evaluated by a team, led by Kirk Smith, which is funded by the Shell Foundation.

7.2 Programs since CNISP

(Source: (Smith 2004))

By the end of the 1990s, the total number of improved stoves disseminated in rural China had reached 200 million (Edwards, Smith et al. 2004).

At the conclusion of the CNIPS, the Ministry of Agriculture (MOA) continued with a program called the National Improved Stove Program. It too focused on fuel savings and on biomass stoves. Many of the stoves installed as a result of this program had chimneys. The program ended by the mid-1990s. Currently there are not many people left at the MOA who worked on the stove programs. However, the Rural Energy Offices are still intact. No longer doing stove work, these offices are involved with biogas and greenhouse work.

The Ministry of Health (MOH) has initiated a very small pilot project to deal with areas of the country (approximately 100 counties) which have endemic coal that is contaminated with fluorine and arsenic. When burned for heating, cooking or drying food, this coal is poisonous and has tremendous health consequences (see Section 2.2).

The Ministry of Forestry (MOF) initiated a biomass stove program in the Yangtze River Valley to increase fuel efficiency. This was a result of tremendous floods there; the MOF wanted to slow down hillside erosion and promote reforestation.

7.2 Other government agencies involved in household energy

- National Development and Reform Commission (NDRC): The NDRC was formed as a result of a recent government reorganization. This was significant in two main ways to the topics covered in this paper. First, the NDRC brought two groups working separately on energy issues together: the State Economic and Trade Commission (SETC) and the State Development and Planning Commission (SDPC). Now, both of the rural and renewable energy groups from SETC and SDPC are together in NDRC in the Energy Division. Second, the replacement of the word "Planning" in the agency name, referring to planned economy, to "Reform", referring to a reformed market economy, is an indication of the direction of the political-economy. The NDRC is the head agency for the formation of the Five-Year Plans.

  The Renewable and Rural Energy Division of the NDPC is headed by Shi Li San. This division has a diverse portfolio of work; from wind concessions to rural township electrification. The latter program is has the goal of electrifying over 1,000 townships, representing over 1 million people in total. Electricity will be generated by mini-hydro, solar PV and PV-wind hybrids (Ku 2004).

- Offices of Western Development: A newer central government agency formed to work on poverty alleviation. They may have an interest in improving household energy options and reducing IAP-related illness.

- Ministry of Science and Technology: The Ministry developed a grant for controlling IAP for the first time, under the 10^{th} National Five Year Plan. Little public information is available about this, and it will require further inquiry.

7.3 Other organizations involved in household energy

There are a handful of national and international organizations that are also active in the area of rural energy. Below a few of these organizations are listed and their work briefly described.

- China Association of Rural Energy Industry (CAREI): Represents manufactures of rural energy technologies, including stoves. The association is involved with a number of international donors, and is very supportive of market-approaches to solve indoor air quality issues. Madame Deng Keyun, who had a leadership role in the CNISP and is now retired from the government, is President of CAREI. Mr. Hao Fangzhou is one of the key staff person for stoves.

- Sino-Dutch Co-Project: Promotion of Rural Renewable Energy in Western China.: Implementing a $5 million energy program in seven provinces over five years. The program seeks to tap renewable energy sources to provide reliable household energy in rural areas. Technologies include hydro, wind and solar power for electrification and biomass, solar and biogas for household cooking and heating. The focus will be on building capacity, demonstrating and disseminating new technologies. The program has a stove component and is also interested in monitoring IAP. CAREI is the main implementing partner, and the Environmental Health Sciences Department at UC Berkeley is providing indoor air quality monitoring.

- World Bank: The World Bank Group considers the household energy situation in China fairly advanced in comparison to most countries (Personal conversation D. Barnes, ESMAP, April 2004). Their stove work in China currently focuses on a coal stove program in Inner Mongolia that takes a market approach. The World Bank is also awaiting the approval of a large rural renewable energy program in China.

- The Nature Conservancy (TNC): TNC is conducting a biomass stove program in southern China. The focus of the work is on improving the fuel efficiency of wood fuel-based cook stoves used by rural people in really remote, mountainous villages in order to protect biodiversity. This work is conducted in partnership with World Wildlife Netherlands.

- National Renewable Energy Laboratories (NREL): NREL's work is done under an agreement signed by the Chinese Ministry of Science and Technology and the US Department of Energy. The Ministry then finds other agencies for NREL to collaborate with, according to different project needs. NREL's work initially was more at the provincial level and focused on technology issues. Partners, for example, are the provincial-level Inner Mongolia Ministry of Science and Technology, Tsinghua University and other research institutes. Currently, NREL is involved with more work at the central government level and does more capacity building. It seems like one of the reasons for NREL's success in China has been the "technology" focus, which has been non-political, and has fit into pre-formulated policies of the Chinese government. An example of this is providing technical assistance on the Chinese Township Electrification Program. NREL is managing two programs for US Environmental Protection Agency (USEPA).

  NREL is involved in two projects with USEPA in China. The first is **Integrated Environmental Strategies (IES**). The work is funded by USEPA and is implemented in various countries, including China, India, South Africa and Brazil. The program works with city governments to form energy scenarios which help create policy measures. IES worked with both the city governments of Shanghai and Beijing. Currently work is beginning to study energy and environmental issues in rural areas. NREL is also involved in the **Wind Technology Partnership** with USEPA. This was previously called the Climate Technology Partnership and was implemented in various countries.

- Others: Other organizations that may have rural energy activities in China are GTZ, the United Nations Development Program, the Energy Foundation, Japanese New Energy Development Office, and the UK Department for International Development (implemented through IT Power China). These activities may not include solid fuel burning in the home, cooking or air pollution, however, they may have critical lessons learned to share.

Chapter 8 . Commercial Stove Activity

Summary: In the coal stove market, approximately 10 million stoves are sold per year. While there are several large manufactures that distribute products over a multi- province area, the vast majority of stoves are produced and sold locally. The market tends to be very competitive as there are low barriers to entry. Customers have demonstrated interest in replacing their current coal stove with a model that minimized their exposure to emissions. The growing demand for commercial products in rural areas can be taken as an opportunity to more actively market improved coal stoves. Increased commercial activity in rural areas is due in some places to increased purchasing power, desire to emulate urban lifestyles, and improved distribution channels.

Note: This section focuses on the coal stove market. Few comments are made on biomass stoves sales or the market for pre-manufactured stove components, as no information was available.

8.1 Market overview

The stove market is segmented into three large segments, based on stove type.

1) Fixed-brick stove: This stove is built with mortar and brick and is designed to hold a big pot on the top. The stove is fixed in one location and used mainly for cooking, although it can be used for space heating, and it is common to find people sitting around it in rural China. This stove uses mainly fuelwood. Some of these stoves were the types promoted under the CNISP.
2) Portable coal cook stove: This is used mainly for cooking. However, since it can be moved, it is often taken into the living space in the cold winter months and used for heating. This stove is very common in small cities, rural townships and villages where coal is available. Industry association figures indicate that annually more than 10 million coal stoves of this type are sold. (Note: One manufacturer said that 30-50 million were sold every year.)
3) Heating stove: This is common in the north of China, where winter temperatures are much lower. Designs range in their efficiency, venting capacity, and number of households served. Industry association figures indicate that 1.8 million heating stoves are purchased each year; 2.3 million are manufactured.

In addition to these large market segments, some other smaller technologies exist, including companies that sell biomass stoves with pellets. These can get extremely high efficiencies (claims as high as 60%) and have low pollution levels. Some newer stoves combine solid fuel with electricity for small fans to improve efficiency (Smith 2004).

The official usable life of the portable coal stoves is five years, but according to the industry association, customers tend to replace stoves more frequently, on average every 2-3 years.

Limited information is available on the price of stoves. The figures reported here are meant only as indicators, as they are based on limited research.

- Mini-portable coal stove (under 28cm): $1.5-2.2
- Cook stove (more robust): $3.3
- Model that uses coal and gas: $80 (could use electricity as well)

No information is available on biomass stove prices, some of which are constructed in the home with pre-fabricated pieces. A market study is recommended to better understand the coal and biomass stove market, which would be expected to vary greatly by region and by household economic status.

8.2 Manufacturers

The supply side of the stove market has traditionally been divided by geography and function. In gross terms, portable coal cook stoves are made and sold south of the Yellow River. This stove is popular because it can serve for daily cooking and heating. North of the Yellow River larger heating stoves are produced and sold since winters are colder and customers require a more robust heating system. Today, more competitive manufacturers are going across this traditional "stove border" and developing products that are multi-functional, serving both heating and cooking purposes.

In the provinces south of the Yellow River, the cook stove industry has the following structure.

Number of stoves sold annually	**Number of companies**
More than 1 million	Only one company: Wanjia Stove Industrial Co.
Around 100,000	Around 10 companies nationwide
10,000-40,000	50 companies in every province that are south of Yellow River

Some of the leading companies now pay more attention to quality, and a small number have been ISO 9000 certified in an attempt to demonstrate quality management.

On the other hand, every county has a coal stove manufacturer. These smaller companies can survive because of their proximity to the customers. In general they are characterized as having poor governance structures and leadership teams. As family businesses, they find it hard to recruit talented people from outside the family and often suffer from lack of self-correcting mechanisms. For example, if the founder makes a mistake, the whole company is put into jeopardy.

The main challenges faced by coal stove manufacturers are the following:

1. Small manufacturers lack economies of scale.
2. Imitations from small-scale producers disrupt the market.
3. The very simple nature of the technology presents low entry barriers.
4. There is an overall weakness in product innovation.

8.3 Rural markets

Rural markets vary substantially across China and depend on the level of economic development of each region. In counties that are relatively poor, the rural market can be very fragmented and primitive. In these areas, it is unusual to find distributors who have coverage over more than one county. Often the main commercial venues for household appliances and agricultural products are the farmers' market, which is held on a weekly or bi-weekly basis. What is unique about these events is that they are scheduled on a rolling basis across an area so that dealers can travel to different market centers sequentially. In addition to the dealers operating at the village level, there are stores in townships and at the county-level that serve as distributors to the vendors in the farmers' markets.

In regions with relative wealth, for example along the east coast or near a capital city in some of the inland provinces, local dealers are much more sophisticated and have become savvy at running businesses at much larger scale. In these situations, it is not uncommon for the dealer to pay a manufacturer a large sum of money to secure an exclusive right for product distribution. The rationale is that the product has good market potential and the company will make a large profit by distributing and selling the product in its local area. These agreements can exceed $US10,000.

Multinational corporations are also discovering that Chinese rural consumers can be a profitable, untapped, market segment. Whirlpool, for example, is one of a number of international and domestic companies that is making lifestyle-improving products engineered for rural conditions and budgets. Whirlpool recently introduced a new and inexpensive washer, called Super Hand-Washing Washer, for $US150-200. It is manufactured in China and targeted at the rural marketplace, which is now becoming more attractive due to rising incomes, among other factors (see Appendix 16 .).

8.4 Customers

Rural incomes are generally low which makes prospective customers price-sensitive and wary of trying new products. According to stove manufacturers, the introduction of any new technology takes considerable consumer education, including hands-on training and demonstration. They noted two trends that affect the products that customers want to purchase:

- rural stove customers want to mimic urban lifestyle and are interested in stoves that more closely resemble the urban situation; and
- customers are interested in products with enhanced quality, function, appearance, and after-sales-service.

Customers value the following product attributes.

- <u>Function</u>: Customers demand a stove that is functional, reliable, light and portable.
- <u>Price</u>**:** The stove should be competitive in the marketplace. The most popular model retails for about US$3.
- <u>Appearance</u>**:** Customers like stoves to have a nice appearance. For example, porcelain enamel is widely used on stoves to make them more attractive.

A rural marketing expert made the following observations.

- In China the key to succeeding in the rural marketplace is the product. The product design, cost and distribution all need to bear the consumer in mind. Market research to determine customer preferences should be conducted before products or any promotional activities are launched. The up-side to all the market research and product development is that the cookstove market is huge.

- Any new product will have a better chance of success in areas that are not too remote or too poor. In the case of the introduction of an improved coal stove, the market should have already demonstrated a demand for coal stoves and an eagerness for new features.

8.5 Product innovation and indoor air pollution

Barriers to entry into the coal stove market are relatively low due to the ease with which the stove technology and stove innovation can be copied. As a result, competition in the coal stove market is fierce. Advances in stove design and technology is one of the most important aspects of competitive advantage. However, unfortunately, intellectual property rights are hard to protect, especially against larger and more sophisticated manufacturers.

Product innovation could result in reduced indoor air pollution levels in household. Two possible areas (among many) of innovation are described below. First, cleaner fuels could be bundled with appropriate stoves. This strategy has enjoyed some success in northern China and was driven by demand for higher efficiency stoves. The question is whether this approach would work more widely in country, and to reduce air pollution. Second, stoves could be designed with electric fans to increase the efficiency of combustion. Electric fans are a natural fit in rural China due to widespread rural electrification. While electricity is not generally used for cooking, it could be used to increase the efficiency of solid fuel consumption leading to reduced emissions in the household. Many factors are in place to support such innovation, such as the strong manufacturing base in China, the frequent replacement of stoves and the demand expressed by some consumers for cleaner and more modern stoves.

Rural customers are increasingly aware of the negative impacts of indoor air pollution from their stoves. An owner of one coal stove manufacturer said that energy-efficiency and "healthfulness" are two aspects that will drive his product development since he is confident that customers will upgrade to stoves that excel in those two aspects.

Case 8.1: Gas stove market explosion and maturation

Demand for gas stoves, both LPG and natural gas, has been growing in China. It is an interesting case for comparative purposes with the coal stove market. Of particular note is a recent government intervention to set industry standards and improve product quality on the market.

The structure of the supply side of the gas stove market is similar to the coal stove market: there are a few large manufacturers and many small producers. There are an estimated 1,000 officially registered gas stove manufactures in China, and 3,000 unregistered. Of this huge number of manufacturers, the top three account for almost 30% of production. The top ten have almost 60% of the market.

The manufacturers can be put into three groups:

1) The largest manufacture with 1.5 million units of production per year (Huadi Group in Guangdong Province).
2) Large manufactures that together produce about 5 million units per year. Currently there are seven. Some of the leaders; Haier, Wanjale, Xuda, Yuli, and Bos.

3) Small manufactures whose production does not exceed 50,000 units per year.

Small gas stoves typically range in price from $25-$50 (200-400 Yuan), and the highest quality stoves have a lifespan of about eight years. The majority of the stoves are not of high quality, and their productive lifespan is only two to three years. This implies tremendous product turn-over in installed capacity every year.

In 2001, 11.6 million units were sold. This represented a 24% increase from the previous year. Ownership levels were reported as high as 89.6% in urban areas in 2002. Although these numbers seem higher than other statistics, this may be due to the definition of "urban". In any case, it does demonstrate a huge and growing demand for gas stoves in urban areas. An estimated total of 90 million gas stoves were installed in urban areas by 2002. Penetration does decrease from the eastern part of the country (over 90%) to the West (around 80%).

Some of the problems with the lower quality stoves have to do with poor material selection. Given the use of highly flammable and explosive fuels there is an important role for government regulation of the manufacturers.

Currently standards are being drafted by the National Gas Cookware Testing Center, which is part of the National Quality Monitoring Supervision Center. The standard would force manufacturers to become certified. Of the 1,000 gas stove manufacturers currently registered, 300 are expected to gain certification. An estimated 600 manufacturers are expected to be eliminated due to low quality products and process.

The standards, which are currently in a draft form, are being circulated for comment. The standards are expected to be approved by the end of 2004. Below is a list of the range of topics included in the standards:

1) Corporate governance;
2) Company resources (including environmental manufacturing standards, equipment and employees);
3) Filing system for technical and process documents;
4) Quality control of input materials;
5) Quality control of production facilities and process;
6) Quality control of product; and
7) Quality control of customer service (communication channels and service).

Source for case: Articles from China Info Bank.com translated by Tom Du.

Case 8.2 Coal home hot water boilers

Another interesting case of technology improvement, this one driven by climate change and urban air pollution, is home hot water boilers. This focuses on the difficulty of engaging the small manufacturer in product innovation and change.

NREL was involved with the Chinese government to reduce the emissions from coal-fired, hot-water boilers. Most home boilers use unwashed coal. By simply washing the coal and sorting it by size, large gains in efficiency and 7-8% reduction in emissions can be achieved.

After investing in coal washing and sorting facilities, the government discovered that the market for the improved coal was elusive. Many of the boilers were made by small manufacturers, essentially mom-and-pop shops, who had little incentives to improve their product design to accommodate the superior coal. Each small shop formed such a tiny piece of the overall market that their individual actions would do nothing to alter customer demands in the marketplace. In areas where government strictly mandated cleaner air, like in Beijing for the Olympics, a new market for cleaner coal did form (Ku 2004).

Chapter 9 . Discussion

The discussion section is divided into three parts; findings, implications and suggested next steps. The discussion, like the rest of the document, is a snapshot in time based on the best available information. At this point the authors would like to reiterate that these points are the result of limited secondary research without the benefit of on-the-ground investigations in China, which is a vast country with many players (some of whom may have been missed in this analysis).

9.1 Findings

- **Transition to cleaner fuels and better technology in rural areas is slow, and associated health problems will persist.**

Although an energy transition is taking place in China at the residential level, the burning of solid fuel in the home will be a health issue for decades to come. In urban areas, there is a greater reliance on cleaner and more convenient fuels like electricity, LPG and natural gas and a shift away from coal use. However, in rural areas, biomass use is holding constant, and as households move up the energy ladder, they will burn more coal in those areas where it is available and affordable. In order for a substantial shift away from current levels of biomass and coal use to occur, average rural incomes would have to rise to the level currently enjoyed by only the top ten percent of rural households. All evidence points to increased coal use and continued biomass use over the long term in rural areas.

- **Household energy patterns are very complex and are shaped by local fuel availability, endless variation in stove-fuel combinations, and multiple household uses for fuel.**

Availability drives fuel selection and use, as has been emphasized throughout this report. High-level aggregate provincial data show that household fuel-use profiles vary distinctly among provinces. Even more variation is shown to occur at the county level. Fuel availability is governed by the extent of local resources, by local prices and by government policies, such as fuel subsidies to encourage consumption or mandates limiting biomass collection to encourage efficiency. China has a medley of store-bought and home-built stoves in use. Add to this the wide variety of fuels available, and there are a huge number of possible stove-fuel combinations. In addition, stoves are used for various purposes within Chinese households, including cooking, boiling water, and space heating.

- **China is a middle-income country, but socio-economic divides are great and growing**.

A theme throughout this report is the two distinct faces of China that are emerging in terms of income, fuel use, health and market access. There are rural areas that are enjoying increased wealth and access to commercial markets, while other regions remain poor, isolated and outside the reach of current market structures. While some households are and will be in the position to make stove purchases that will improve family health, others are not.

- **China has a unique history, both in terms of household energy programs, and with regards to political and economic development.**

It is ironic that one of the most centralized economies in the world has been the most successful at creating an independent and robust market for household stoves. At the time, there was both a centralized government with a high capacity for policy implementation along with an energetic and new entrepreneurial class; the combination resulted in a highly successful program in terms of number of improved stoves installed. Outstanding in the eyes of the international community was the relatively low cost of the CNISP, which disseminated improved stoves to two-thirds of the rural population with almost no consumer subsidies. The market for improved stoves has continued to evolve and grow since the end of the program.

- **More effort has been made to alter household energy practices in China than in perhaps any other country, yet data on the topic is limited and difficult for Western audiences to access.**

Limited data is available on allocations of fuel within household, pertinent health statistics, and performance of stoves. Health impact monitoring with respect to indoor air pollution in China is limited. In the 1980s, there were various studies performed in China to measure indoor air pollution levels and human exposure in homes using solid fuels, but most of them did not study health impacts. Thus many of the connections between solid fuel use and ill health in China are not well characterized, and the leverage points for reducing disease are unclear.

9.2 Implications

- **Carefully defining the location of pilot projects is a strategy for success.**

When assessing the health burden carried by rural areas due to solid fuel use and evaluating potential solutions, it is critical to accurately characterize local variations in fuel, stoves and emissions. By framing a specific problem with defined geographic boundaries, it is possible to develop accurate baseline data, track progress and show results. Restricting the location of pilot projects will also reduce the number of players and partners to more manageable levels. The success of the CNISP was based on working in the best areas first, according to its established criteria.

- **The robust market for household stoves offers opportunities to improve public health.**

There is value in working with customers who can pay for an improved stove. This report indicates that coal stove manufactures believe their customers would purchase stoves which have more healthy attributes. By tapping into the strong entrepreneurial spirit of the robust coal stove industry (especially in the south), it may be possible to develop more healthful coal stove designs and also expand the use of cleaner processed coal. Stove manufacturers might want technical support in aspects of stove design, indoor air pollution monitoring, intellectual property protection, and even rural marketing. International collaboration could foster innovations for those customers who are willing to pay and result in a new line of improved coal stoves, producing increased profits for stove manufactures, which might encourage them to expand into more marginal areas. This approach is not limited to coal stoves, but could be expanded to incorporate other types of stoves such as biomass or biogas in order to respond to local market conditions.

- **The renewed focus on development goals offers opportunities to reach poor and marginalized populations.**

This report presented evidence that the central government is beginning to re-focus attention on the poor and fringe populations that have been left behind during China's incredible economic boom over the last twenty plus years. It may be possible to engage policy makers who want to address persistent development issues in discussions about indoor air pollution and its effects on health. A market approach will not touch a large portion of the population currently using solid fuel in their homes. Whether because they are too poor, unaware, beyond the reach of the market or using other fuels, many households would not benefit from improved coal (or other types of) stoves even if these were made available in the marketplace. Indeed there were many needy populations not reached by the CNISP for these reasons. It may be necessary to work within the context of broader social development or health programs in order to reach this population.

- **Capacity building initiatives offers opportunities to collaborate with the government**.

Engaging the Chinese government on this issue may prove challenging but there are some strong models to follow. Given the interdisciplinary nature of this subject, there are many ministries and institutions that could be approached. In addition, as illustrated in the NREL case study, a successful first step to collaborative work in China is pursuing opportunities to provide technical assistance and capacity building, while allowing the central government to select an appropriate location and local partner for any pilot activity. An opportunity might also arise to collaborate with a provincial government health office to address the health problems associated with indoor air pollution. Given the apparent greater level of autonomy now afforded to provincial health leaders, this could be an interesting point of entry. If an approach is proven to work in one province there may be opportunities to showcase it and try to apply it more broadly.

- **Behavior-change and awareness-building is critical**.

Behavior change concepts are likely to play a valuable role in successful stove programs that work either through commercial markets or though sponsored development programs. Activities that raise public awareness regarding the problems of indoor air pollution could complement activities that make more healthful options available in the marketplace or through government programs. Given the numerous stove-fuel combinations in any given house, no one technology intervention will solve the indoor air pollution problem (as evidenced by the coal stoves still in use with the improved biomass stoves of the CNISP). General awareness and practical generalized recommendations to reduce exposure could empower individuals to make better household energy choices appropriate to their particular circumstances. While behavior-change activities are critical, they may be challenging to implement directly in China as an outside organization.

9.3 Suggested Next Steps

- **Support data collection and analysis.**

Many aspects of China's household energy situation and the related health impacts remain to be studied. It is important to ensure that these activities are coordinated and received adequate funding. Research needs include:

- **Stove and fuel market surveys**: Commissioning studies on the supply, distribution, pricing, marketing and demand for improved coal and biomass stoves and the associated fuels used would be valuable in determining what a pilot market intervention might look like, what policy support would be needed and which locations might offer best opportunities for early success. In addition, it would be valuable to assess the current state of the more than 1,000 small energy businesses that sold and installed improved biomass stoves, as well as that of the manufacturers who supplied the components

- **Political analysis**: Gain increased understanding of the potential partner government agencies and key staff who would champion this issue.
- **Epidemiological research**: One of the challenges in the field of IAP is demonstrating the link between exposure and health. Generally governments of larger countries prefer studies done on their soil. In the process of preparing this report, only limited evidence that IAP effects health was found. An extensive epidemiological study to link IAP levels with health has not been performed. It may be critical to make sure a study of this nature is undertaken in order to motivate Chinese health and development officials to take the issue more seriously.

➢ **Engage stove market and industry association in dialog.**

Engage both the stove industry players and association in a dialog about how to motivate the industry to produce more healthful stove options for the marketplace. Be clear about possible program offerings like technical assistance, market research, indoor air pollution monitoring, etc. Goal of collaboration should be increasing the number of market viable lower emission and/or lower exposure stoves on the market. (While this recommendation is focused on the coal stove market, the biomass and biogas market players could also be approached.)

➢ **Forge links with health and development programs**.

Numerous multinational agencies, bilateral organizations, and international foundations are already involved in addressing public health challenges in China. There are rich lessons to be learned from those who have conducted health programs in rural China. Interviewing directors of these programs could help identify opportunities to engage policy makers in IAP issues, address IAP at the rural level and accelerate adoption of improved stove technology. In addition, it may be advantageous to share logistical and infrastructure costs with some of these players.

➢ **Identify tangible and focused opportunities**.

Since household energy is a complicated issue, and China is a huge country, it is critical to identify specific opportunities where measurable progress can be made. The provinces contending with arsenic and fluorine poisoning offer this type of opportunity.

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Appendix 1 . Summary of Acute Respiratory Infections and Other Major Diseases in China

Source: Tom Du, Haas School of Business, MBA Candidate

Below are some statistics and results based on the Statistical Report issued by the Information Center of Ministry of Health (MOH) in 2003

According to the preliminary statistical result of nation-wide 27 different kinds of infectious diseases in 2003, the total incidence of infectious disease was 192.18/100,000, mortality 0.48/100,000, death rate 0.25%. Compared to 2002, the incidence of infectious disease remained stable. Hepatitis, pulmonary tuberculosis, and diarrhea were ranked on top of the incidence of diseases.

Result from the statistics is that disease of respiratory system ranked constantly among the top 3 death reasons in both urban and rural areas in China.

The table below summarizes the top 10 death diseases in urban and rural areas in 2002 and 2003.

Urban 2003		**Rural 2003**	
Disease	**Mortality (# per 100,000)**	**Disease**	**Mortality (# per 100,000)**
Malignant Neoplasms	134.5	Malignant Neoplasms	95.7
Cerebrovascular disease	105.4	Cerebrovascular disease	89.9
Diseases of Respiratory System	77.3	Diseases of Respiratory System	70.9
Heart disease	76.21	Heart disease	45.5
Injury and poisoning	32.6	Injury and poisoning	21.5
Digestive system disease	19.3	Endocrine, Nutritional & Metabolic Diseases	14.5
Endocrine, Nutritional & Metabolic Diseases	14.1	Digestive system disease	10.5
Disease of the Genitourinary System	7.1	Disease of the Genitourinary System	7.2
Neural system disease	4.8	Disease originated in the prenatal period	372.2 per 100,000 live delivery
Disease originated in the prenatal period	162.1 per 100,000 live delivery	pulmonary tuberculosis	4.2
% of top 10 death diseases	89.1%	% of top 10 death diseases	92.9%

Urban 2002		**Rural 2002**	
Disease	**Mortality (# per 100,000)**	**Disease**	**Mortality (# per 100,000)**
Malignant Neoplasms	135.4	Malignant Neoplasms	84.3
Cerebrovascular disease	100.6	Cerebrovascular disease	70.6
Diseases of Respiratory System	89.9	Diseases of Respiratory System	63.8
Heart disease	84.1	Heart disease	58.5
Injury and poisoning	50.4	Injury and poisoning	41.5
Digestive system disease	19.6	Endocrine, Nutritional & Metabolic Diseases	4.9
Endocrine, Nutritional & Metabolic Diseases	14.1	Digestive system disease	14.5
Disease of the Genitourinary System	9.7	Disease of the Genitourinary System	5.9
Neural system disease	5.2	Disease originated in the prenatal period	4.4 per 100,000 live delivery
Disease originated in the prenatal period	4.9 per 100,000 live delivery	pulmonary tuberculosis	4.3
% of top 10 death diseases	89%	% of top 10 death diseases	87%

Below is a table from the 2003 Public Health Statistical Yearbook about the Inpatients in Hospitals in China, indicating that respiratory diseases ranked No. 1 of the hospital inpatients in China.

2002年卫生部门医院住院病人前十位疾病构成(ICD-10)				
Percentage of 10 Main Diseases of Inpatients in Hospital of Health Sector in 2002(ICD-10)				
顺序 Rank	市 City		县 County	
	疾病种类 Disease	构成 %	疾病种类 Disease	构成 %
1	呼吸系病	11.23	损伤、中毒和外因	18.50
	Diseases of the Respiratory System		Injury, Poisoning & External Causes	
2	消化系病	11.00	呼吸系病	15.67
	Diseases of the Digestive System		Diseases of the Respiratory System	
3	妊娠、分娩和产褥期病	10.68	妊娠、分娩和产褥期病	15.11
	Pregnancy, childbirth & the Puerperium		Pregnancy, childbirth & the Puerperium	
4	损伤、中毒和外因	9.13	消化系病	14.00
	Injury, Poisoning & External Causes		Diseases of the Digestive System	
5	恶性肿瘤	6.36	脑血管病	5.14
	Malignant Neoplasms		Cerebrovascular Disease	
6	泌尿生殖系病	5.77	传染病和寄生虫病	4.21
	Disease of the Genitourinary System		Certain Infectious and Parasitic Diseases	
7	脑血管病	4.88	泌尿生殖系病	4.16
	Cerebrovascular Disease		Disease of the Genitourinary System	
8	缺血性心脏病	4.14	缺血性心脏病	2.49
	Ischaemic Heart Disease		Ischaemic Heart Disease	
9	传染病和寄生虫病	3.25	围生期病	2.48
	Certain Infectious and Parasitic Diseases		Disease Originating in the Perinatal Period	
10	内分泌、营养和代谢疾病	3.19	恶性肿瘤	2.01
	Endocrine, Nutritional & Metabolic Diseases		Malignant Neoplasms	
	十种疾病合计 Total	69.63	十种疾病合计 Total	83.77

Appendix 2 . Global Review of Household Energy and Health

Source: Prepared by Rob Bailis, PhD Candidate, Energy and Resources Group, UC Berkeley, 2004.

When solid fuels are burned in small-scale household devices, it is very difficult to achieve complete combustion. As a result, these devices release hundreds of compounds in addition to the CO_2 and water vapor that are released by "clean" hydrocarbon or biomass combustion. These compounds include many that are known to have a negative effect on human health including particulate matter (PM), carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAH), formaldehyde, and oxides of Nitrogen and Sulfur (NO_x and SO_x). The pollutants, biophysical mechanisms and potential health impacts are described in the table below.

Figure 1: Pollutants associated with solid fuel combustion, biophysical mechanisms and potential disease outcomes (adapted from (Bruce, Perez-Pedilla et al. 2000)).

Pollutant	Mechanism	Potential health impacts
PM (small particles less than 10 microns PM_{10}, and particularly less than 2.5 microns aerodynamic diameter $PM_{2.5}$)	• Acute: bronchial irritation, inflammation and increased reactivity • Reduced mucociliary clearance • Reduced macrophage response and (?) reduced local immunity	• Wheezing, exacerbation of asthma • Respiratory infections • Chronic bronchitis and chronic obstructive pulmonary disease • Exacerbation of chronic obstructive pulmonary disease
Carbon monoxide	• Binding with hemoglobin to produce carboxy hemoglobin (COHb), which reduces oxygen delivery to key organs and the developing fetus.	• Low birth weight (fetal COHb 2–10% or higher) • Increase in perinatal deaths
Polycyclic aromatic hydrocarbons (e.g. benzo[*a*]pyrene)	• Carcinogenic	• Lung cancer • Cancer of mouth, nasopharynx and larynx
Nitrogen dioxide (NO_2)	• Acute exposure increases bronchial reactivity • Longer term exposure increases susceptibility to bacterial and viral lung infections	• Wheezing and exacerbation of asthma • Respiratory infections • Reduced lung function in children
Sulphur dioxide (SO_2 - primarily from coal combustion, biomass has very little sulfur)	• Acute exposure increases bronchial reactivity • Longer term: difficult to dissociate from effects of particles	• Wheezing and exacerbation of asthma • Exacerbation of chronic obstructive pulmonary disease, cardiovascular disease
Biomass smoke condensates including polycyclic aromatics and metal ions	• Absorption of toxins into lens, leading to oxidative changes	• Cataracts

The diseases listed in Figure 1 have been associated with human exposure to combustion-related IAP with varying degrees of certainty. For example, acute respiratory infection (ARI), which results from exposure to PM, is ***very strongly*** associated with exposure to IAP from solid fuels. ARI is one of the leading causes of illness and death in children under five worldwide. The WHO estimates that ARI is responsible for roughly 17% of the total disease burden in that age group (WHO 2003). Moreover, the WHO estimates that IAP from solid fuel use is responsible for over 35% of ARI cases worldwide (WHO 2002). In a recent review of quantitative epidemiological studies using internationally recognized standards of disease diagnosis, Smith found a that odds ratios[12] linking biomass fuel use to acute lower respiratory infections (ALRI) in children under five varied from 2.2 to 9.9 (Smith, Samet et al. 2000). These studies are summarized in Figure 2.

Figure 2. Summary of studies linking ALRI in young children with exposure to biomass smoke in developing countries (Smith, Samet et al. 2000).

Type of study	Countries where studies were conducted	No. of samples	Range of average odds ratios reported
Case-control studies (n=9)			
6 adjusted for confounders (3 not significant)	South Africa, Zimbabwe, Nigeria, Tanzania, Gambia (2), Brazil, India, Argentina	4311	2.2–9.9
Cohort studies (n = 4)			
2 adjusted for confounders (1 not significant)	Nepal, Kenya, Gambia (2)	910	2.2–6.0
Case-fatality study (n = 1)			
	Nigeria	103	4.8
Developed countries (n = 2)			
Case-control adjusted for confounders	USA (2)	206	4.8–7.0
The dividing line between developed and developing countries = $1000 per capita purchasing power in 1995 (UNDP, 1998).			

Other diseases listed in Figure 2 do not have the same degree of epidemiological evidence linking them to IAP exposure. Nevertheless, research has produced data suggesting that a causal relationship does exist with a number of diseases. This is synthesized below:

- Tuberculosis: An analysis of data from 200,000 cases of pulmonary tuberculosis in Indian adults found an association between self-reported cases of the disease and exposure to wood smoke. The likely mechanism of increased risk of infection from exposure to wood smoke is through reduced resistance to lung infection similar to the effect of chronic exposure to tobacco smoke (Bruce, Perez-Pedilla et al. 2000).

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[12] An odds ratio is the ratio of the risk that a particular disease outcome will occur in an exposed individual relative to the risk that it will occur in an unexposed individual. Definitions of *exposed* and *unexposed* vary between studies. Typically in studies concerning solid fuel combustion accurate exposure assessment of large populations is very difficult and exposure is simply defined as a binary variable: either the individual lives in a household that uses solid fuel or they do not.

- Asthma: Evidence linking asthma to solid fuel use is mixed. Asthma can be triggered by exposure to any number of allergens, but exposure to smoke from wood or coal can increase allergic sensitivities in susceptible individuals. In Nepal, where a positive association was made between the incidence of asthma and solid fuel use, researchers calculated an odds ratio of 2.3 for rural children 11-17 who were exposed to smoke from wood stoves relative to children using gas or kerosene (Bruce, Perez-Pedilla et al. 2000).

- Adverse pregnancy outcomes: Women exposed to solid fuel combustion emissions during pregnancy experience higher rates of stillbirth and low birth weight than unexposed populations. In Guatemala for example, children born in households using woodfuels tend to have a lower birth weight than children born in households cooking with gas or electricity after adjusting for socioeconomic and maternal factors. Similarly, study in India found an association between perinatal mortality and IAP with an odds ratio of 1.5. Again, this result is similar to observed effects of exposure to primary and secondary tobacco smoke (Bruce, Perez-Pedilla et al. 2000).

- Chronic obstructive lung disease (COLD) and associated heart disease in adults: where this occurs in LDCs it is thought to be almost entirely due to solid fuel combustion. COLD is a condition that develops after many years of exposure. 20-30,000 women in India under the age of 45 suffer from it (Smith 2000).

- Cancer:

  Lung Cancer - has not yet been directly linked to biomass combustion despite the presence of carcinogenic compounds in wood smoke. An association is suspected however because, while smoking is the principle cause of lung cancer in industrialized countries, in LDCs "non-smokers, frequently women, form a much larger proportion of patients with lung cancer" (Bruce, Perez-Pedilla et al. 2000). In addition, lung cancer plays a significant role in the burden of disease linked to household energy use in regions where coal is a common household fuel. Lung cancer is *strongly associated with indoor coal combustion*. Coal use is widespread in China, where research found odds ratios between 2 and 6 for rural women using "smoky coal". Incidentally, coal is also used as a household fuel in South Africa and some neighboring countries in Southern Africa, as well as in parts of India, though not to the extent that it is used in China.

  Oral, nasopharyngeal and laryngeal cancer - biomass smoke has been implicated though not consistently, in these types of cancers. Research in South America found odds ratios of roughly 2.7 for the use of woodfuels relative to cleaner burning fuels (Bruce, Perez-Pedilla et al. 2000).

Reviewing the evidence linking ill health outcomes to IAP from solid fuel use begs the question *how much illness and death can be attributed to the use of solid fuels?*

In their most recent assessment of the Global Burden of Disease (GBD), the WHO estimated global morbidity and mortality from 20 leading risk factors.[13] By their

[13] A *risk factor* is an exposure, activity, or behavior that increases the likelihood of a particular disease or ill-health outcome. This should be distinguished from the disease itself. For example, smoking tobacco is a *risk factor*. Engaging in that behavior increases the risk of contracting diseases like lung cancer or heart

assessment, exposure to indoor air pollution (IAP) from solid fuels is responsible for 1.62 million deaths per year, which makes it the 11th leading cause of death worldwide and the second leading cause of death that is due to environmental factors.[14] Assessing the *burden of disease*, which accounts for non-fatal illnesses as well as for years of lost life due to premature mortality, shifts the relative position of indoor IAP forward to the 8th position overall.[15] In addition, because the residential use of solid fuels is overwhelmingly concentrated in developing countries, the impact is also felt there far more than in industrialized countries. Thus, if the impact of exposure to IAP from solid fuels is considered only in developing regions, the rank shifts again to the 8th leading cause of regional mortality and the 6th leading contributor to the developing world's burden of disease. Figure 3 shows the ranking of the top 20 risk factors contributing to the GBD measured in DALYs.[16]

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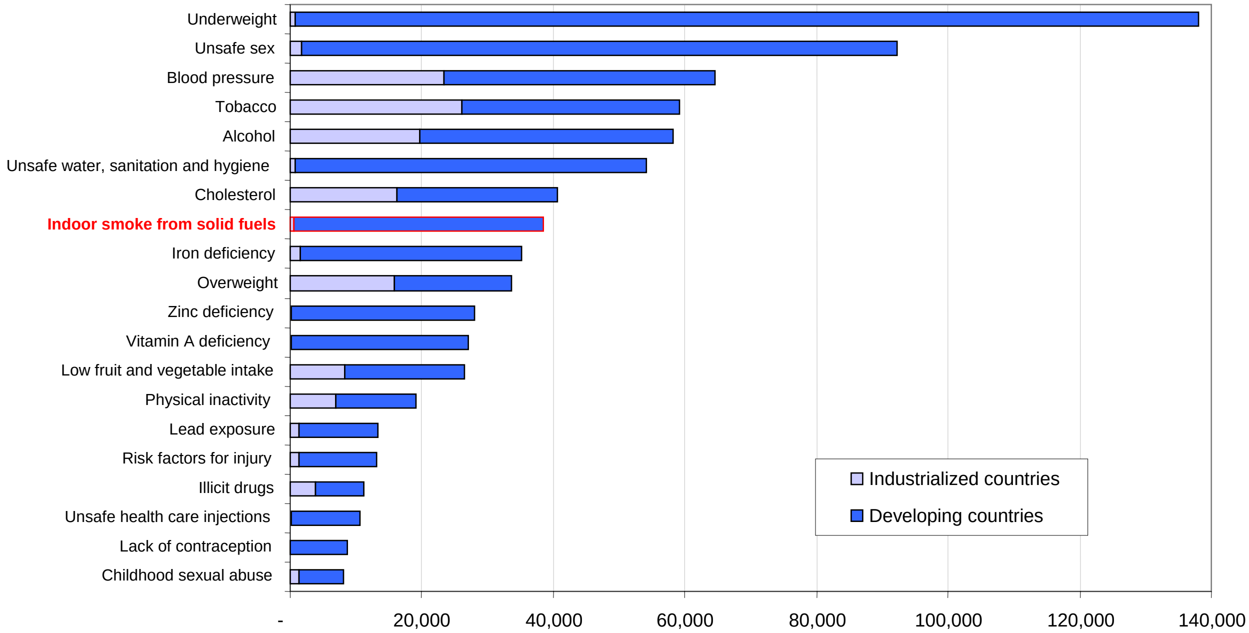
disease. Similarly, exposure to IAP from solid fuel combustion is a *risk factor* that can increases the risk of certain disease outcomes.

[14] The leading environmentally related cause of death and illness is unsafe water and poor sanitation WHO (2002). World Health Report: Reducing Risks, Promoting Healthy Life. Geneva, World Health Organization. Mortality and Burden of Disease estimates are for 2000, the most recent year for which data has been compiled WHO (2003). WHO Statistical Information System (WHOSIS). **2003**.

[15] This shift occurs because the BoD estimation places a greater societal burden on the death of a child than on the death of an adult. Exposure to IAP from solid fuels impacts children far more than adults.

[16] DALYs, or Disability Adjusted Life Years are the metric that the WHO uses to measure disease burden. They account both for premature death and for time spent in a state of ill-health. See Murray, C. and A. Lopez, Eds. (1996). The Global Burden of Disease. The Global Burden of Disease and Injury Series. Boston, Published by the Harvard School of Public Health on behalf of the WHO and the World Bank. for a full description of how DALYs are defined and quantified.

Figure 3: Global Burden of Disease from 20 leading risk factors by developed/developing regions (1000's of DALYs)



Appendix 3 . The Energy Ladder

(Excerpt from Clean Energy for Development and Economic Growth: Biomass and Other Renewable Energy Options to Meet Energy and Development Needs in Poor Nations, Kammen, Bailis, Herzog, 2001, Prepared for UNDP.)

Given the array of energy options that are potentially available to people in LDCs and the various constraints they face in meeting their energy needs, analysts use a simple model, the *'energy ladder'* (Smith, 1987; Leach and Mearns, 1988; Leach, 1992; Masera et al., 2000), to explain the evolution of energy choices, primarily at the household level. The model's basic premise is that different energy options can be characterized by traits such as cost, energy efficiency, cleanliness, and convenience, which all correlate to one another to some degree. Figure 1 shows a graph representing the rough correlation between stove cost and efficiency for some generic stoves commonly used in LDCs.

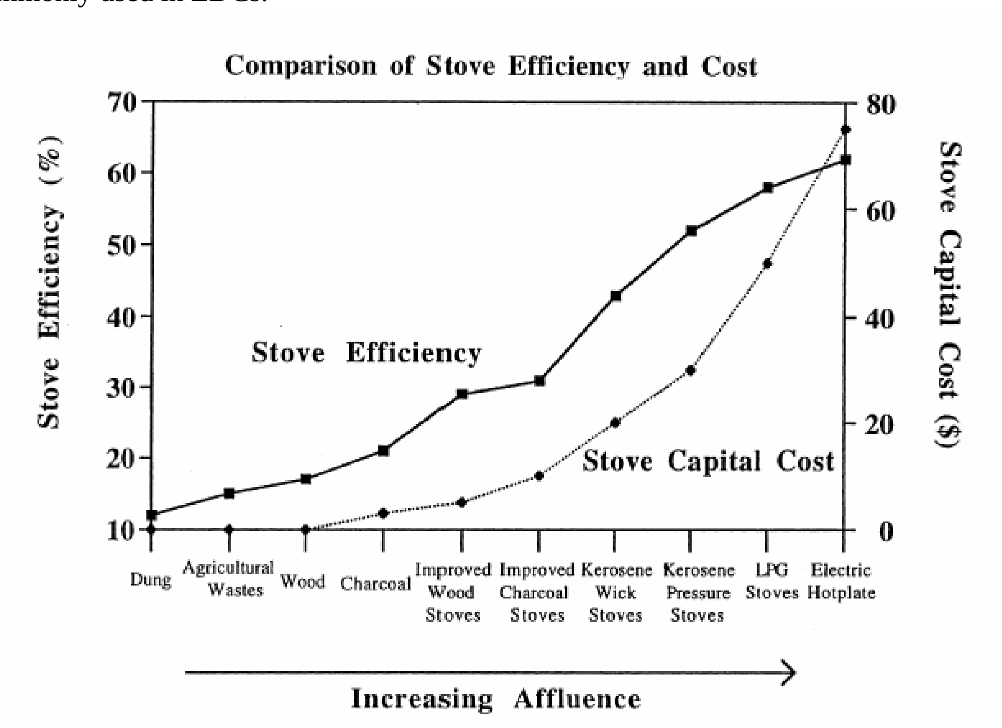


Figure 1: This graph shows a representation of the energy ladder hypothesis, which characterizes the general movement towards increased stove and fuel cost associated with increasing affluence. Adapted from Masera et al., (2000) and originally published in OTA (1991).

Fuels which are available for free or for very low cost, such as fuelwood, dung, and crop residues are the dirtiest and the least convenient to use; they require more labor to gather fuel, are difficult to light and extinguish, and do not allow for easy control of heat output. Cleaner, more convenient fuels tend to transfer heat more efficiently, are easily controlled over a range of heat outputs, and are much costlier; they may require large lump payments for the fuel as with LPG, and large up-front expenditure for the stove, as with gas and electric cookers. Table 2 shows some typical household fuels, their relative positions on the 'energy ladder', and some general barriers to their adaptation.

The problem with the energy ladder model is not with its original qualitative formulation, but with the simplified way that the model is applied to policy-making, and the mistaken conclusion that fuel choice is determined by purely economic factors. Household fuel switching is not a linear or unidirectional process, and economic factors are not the only variables that determine fuel choice. Complete switching, where one fuel totally substitutes for another, is rare. Different fuels are not perfect substitutes, and cultural preferences may cause a household to retain a fuel/stove combination to cook certain foods or to use on special occasions. Moreover, an increase in household income will not necessarily be spent on cookstoves or fuel. Rather than representing a step along a predetermined path that would lower or raise fuelwood consumption or combustion emissions in a predictable way, additional household income translates to additional freedom to choose a fuel or array of fuels. What the household actually does with an extra hundred pesos, kwacha, or rupees will be decided by individual household members influenced by differentiated gender-based priorities as well as cultural factors.

Table 2: Household fuel preferences and constraints

	Barriers to "climbing the ladder"		
Ladder of "preference"	**Equipment costs**	**Nature of payments**	**Nature of Access**
⇒ Electricity	Very high	Lumpy	Restricted
⇒ Bottled gas (LPG, butane, Natural Gas)	High	Lumpy	Often restricted, bulky to transport
⇒ Kerosene	Medium	Small	Often restricted in low income areas
⇒ Charcoal	Low	Small	Good, dispersed markets and reliable supplies though prices and supplies can vary seasonally
⇒ Fuelwood	Low or Zero	Small, zero if gathered	Good, dispersed markets and reliable supplies though prices and supplies can vary seasonally
⇒ Crop residues, animal dung	Low or Zero	Small, zero if gathered	Variable: depends on local crops and livestock holding. High opportunity where residues are used as fodder and/or dung is used as fertilizer
Adapted from Leach, 1992			

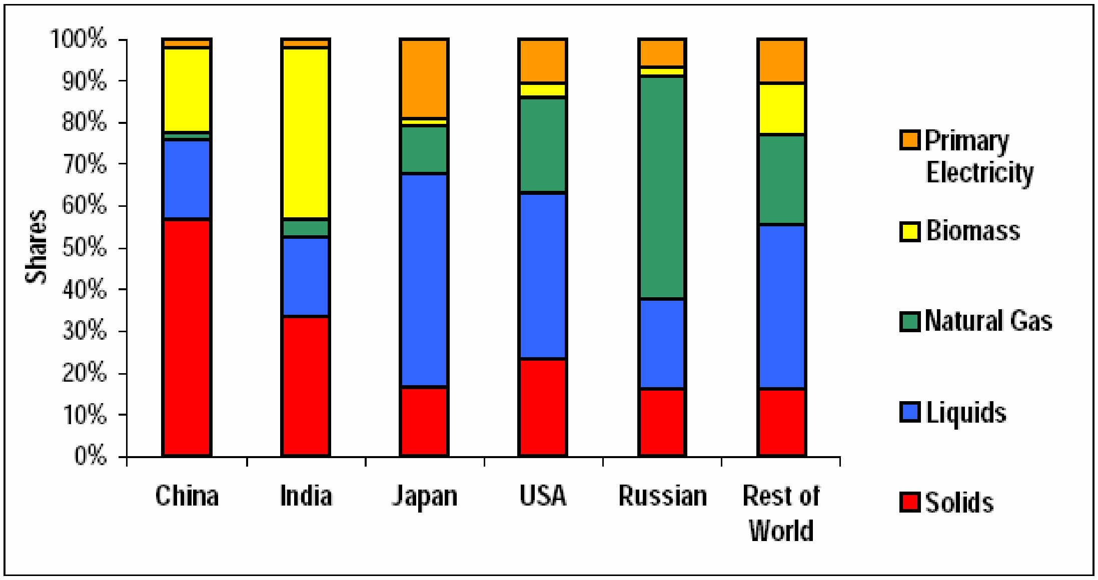
Ultimately, analysts will only be informed of those household decisions by direct observation, surveys, or interviews, and not through the application of a model, particularly a model applied across different geographical regions and cultures. Finally, access and consistent availability are also important: for example, even households that are willing and able to pay will not make the switch from charcoal to LPG if the gas, stove, and gas bottles are not consistently available in a convenient location.

A study by Masera et al. (2000) provides a good example of the complexities of fuel switching in rural households. The authors found that increasing wealth in Mexican households led to "an accumulation of energy options" rather than a linear progression from one fuel to the next. They also found that only one out of five locations studied showed a statistically significant difference in household fuelwood consumption between households cooking solely with fuelwood and households cooking with a mix of LPG and fuelwood. They conclude that "household fuels, rather than pertaining to a ladder of preferences with one fuel clearly better than the other, possess both desirable and undesirable characteristics, which need to be understood within a specific historical and cultural context" (Masera, et al., 2000, p. 2083-5).

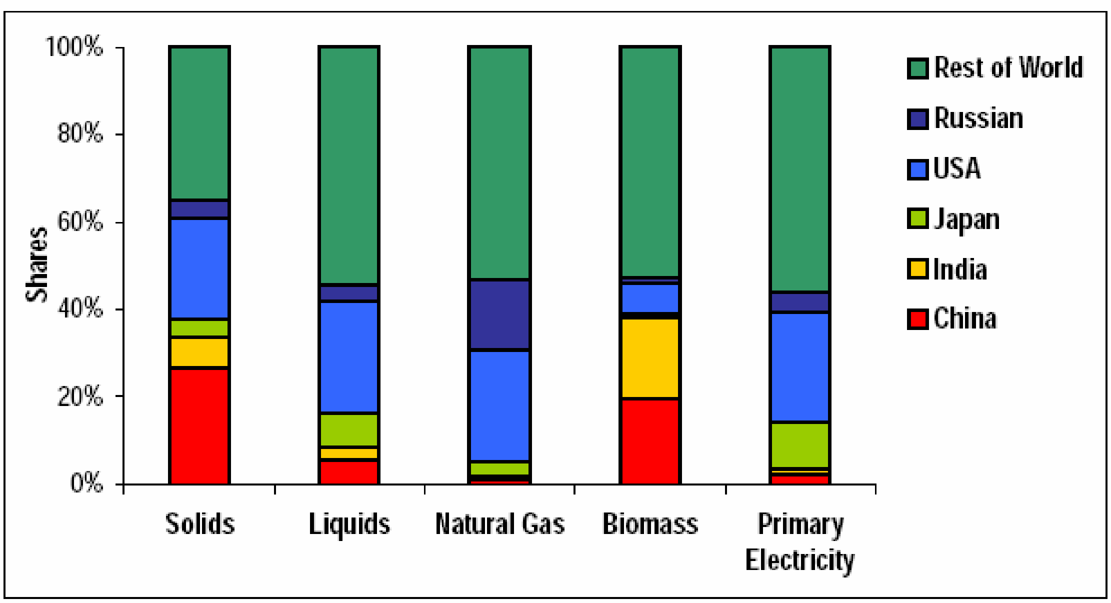
A second study, from Morocco, corroborates the findings from Mexico described above. In doing research on the degradation of the argan tree species in Morocco, it was found that while wealthier households enjoy additional energy options, they do not necessarily adopt completely non-traditional sources of energy. In the region of Wadi Nun, poorer households used fuelwood and charcoal, while wealthier ones used a combination of charcoal, gas and electricity. In both types of households, charcoal from the argan tree remained widely in use, particularly for cooking (Najib, 1993). In such communities, argan-derived charcoal carries a very strong socio-cultural value. It is not only a practical necessity but also holds an important traditional and cultural significance.

Appendix 4 . Country Comparative Energy Statistics

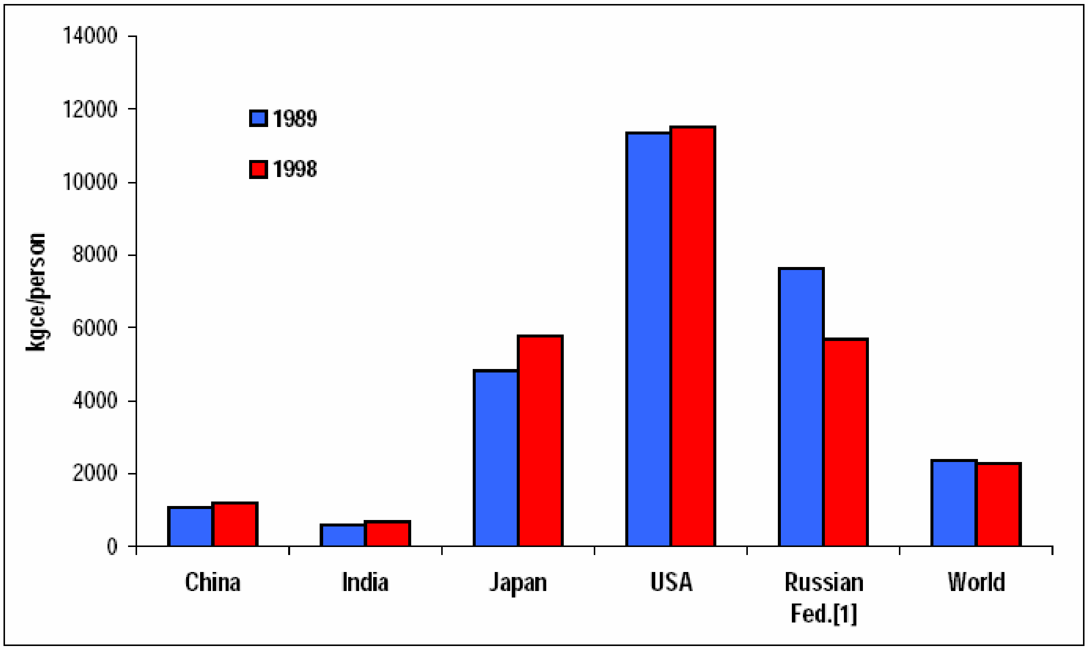
Share of Primary Energy Consumption by Energy Source, 1998 (Energy Research Institute 2001)



Shares of World Primary Energy Consumption by Country, 1998 (Energy Research Institute 2001)

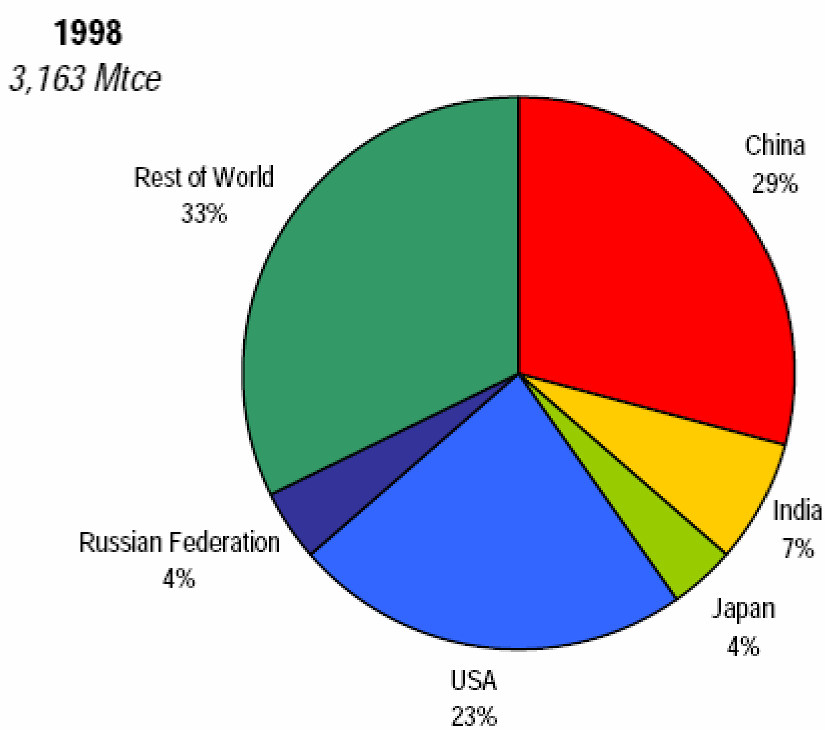


Per Capita Primary Energy Consumption, 1989 and 1998 (Energy Research Institute 2001)

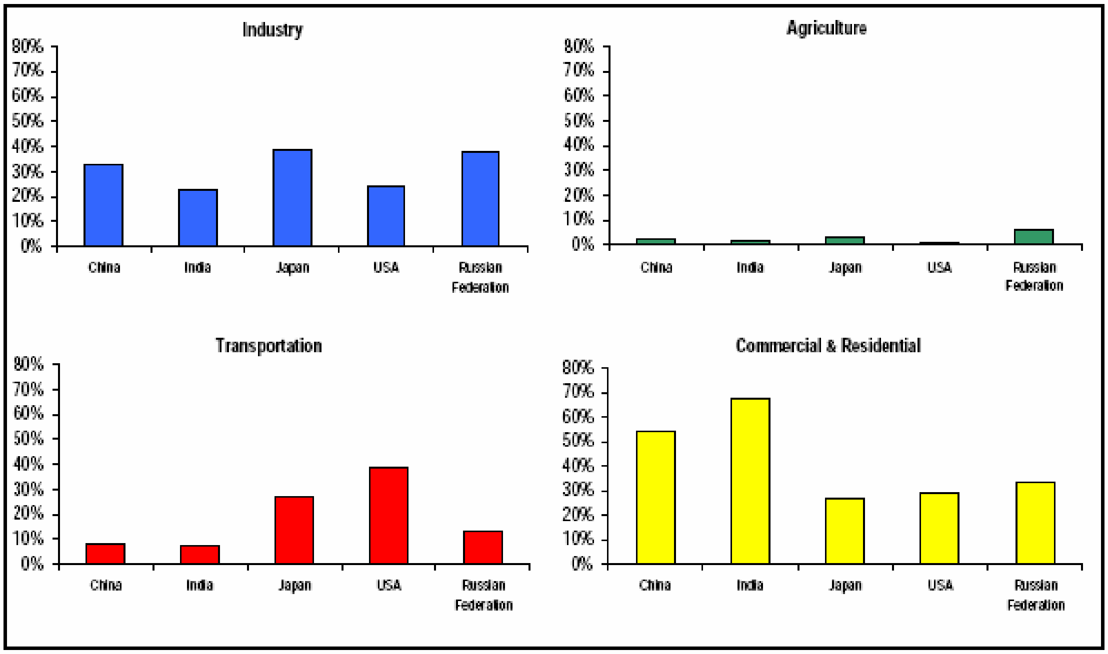


[1] Comparision years for the Russian Federation are 1992 and 1998.

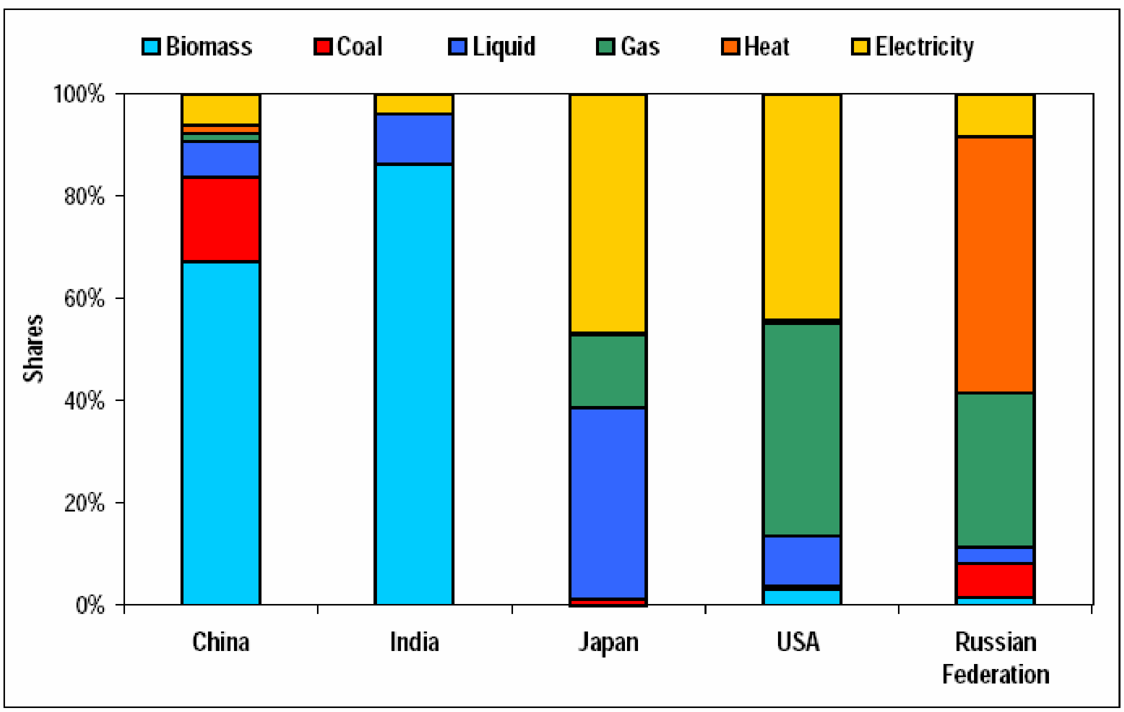
Coal Consumption Share by Country, 1998 (Energy Research Institute 2001)



Sectoral Share of Energy End Use, Commercial and Biomass, 1998 (Energy Research Institute 2001)

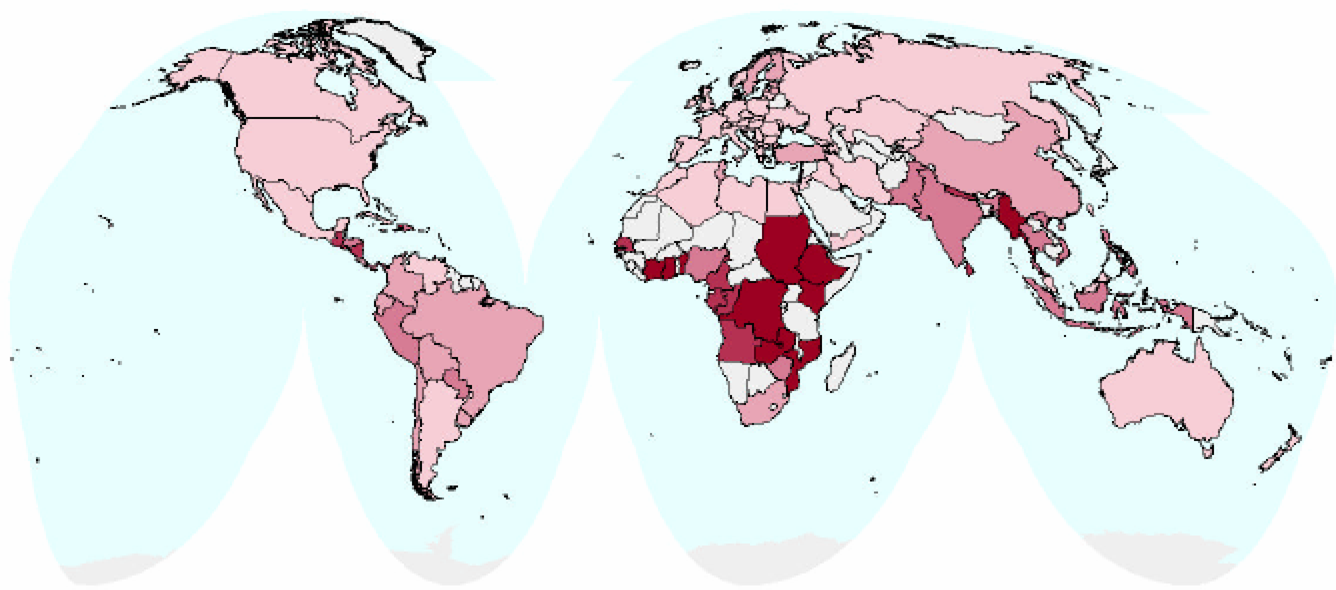


Residential and Commercial Energy Use, 1998 (Energy Research Institute 2001)



Appendix 5 . Share of Woodfuel in National Energy Consumption Worldwide

Share of Woodfuels in National Energy Consumption



Map Projection: Interrupted Goode's Homolosine

Citation: World Resources Institute - PAGE, 2000

Notes:

Wood energy includes fuelwood, charcoal, and black liquor, measured in thousand metric tons of oil equivalent (TOE).
Wood energy consumption is expressed as a percentage of total final energy consumpption from all energy sources in thousand TOE.

Percent share
- < 10
- 10 - 25
- 25 - 50
- 50 - 75
- > 75
- Data incomplete

Map Description:

Fuelwood, charcoal, and other wood-derived fuels (collectively known as woodfuels) are the world's most important form of nonfossil energy. Production and consumption are concentrated in low-income countries, with five countries -- Brazil, China, India, Indonesia, and Nigeria -- accounting for about 50 percent of the total. In addition to direct sources, wood residues from the forest products sector are also commonly burned as fuel. Statistics from the International Energy Agency (IEA) show the importance of wood energy in the lives of hundreds of millions of people. Biomass energy, which includes woodfuels, crop residues, and animal wastes, provides on average nearly 30 per cent of total primary energy supply in developing countries. Over 2 billion people depend directly on biomass fuels as their primary or sole source of energy. Although woodfuels are the dominant form of biomass energy, the current state of global data does not allow analysts to distinguish wood from other forms of biomass in many countries. The available data suggest that woodfuels account for more than half of biomass energy consumed in developing countries, or 15 percent of their total energy supply. If China is excluded (where agricultural residues are an important fuel), woodfuels provide about 20 percent of total energy supply in the developing world (IEA, 1996: II.289-308, III.31-187). In some countries, for example, Nepal in Asia, and Uganda, Rwanda, and Tanzania in sub- Saharan Africa, woodfuels provide 80 percent or more of total energy requirements.

Source:

1. International Energy Agency (IEA). 1996, Energy Statistics and Balances of Non-OECD Countries, 1994-95. Paris:IEA. pp.   2. Environmental Systems Research Institute. 1996, World Countries 1995. Redlands, CA: ESRI.

Analytical Overview:

Statistics on woodfuel consumption are still inferior to those compiled for industrial roundwood production and consumption. This map is based on the International Energy Agency's combustible renewables and waste database. IEA collects information from OECD countries via annual questionnaires. The product categories listed are solid biomass and animal products, gases derived from biomass and wastes, industrial waste and municipal solid waste. Energy data are expressed in thousand tonnes of oil equivalent. The questionnaire requests data on individual fuels such as wood, vegetal wastes, black liquor, and landfill gas. For non-OECD countries, IEA follows the same classification, but relies on a variety of information sources. Sources include national publications or statistics, regional organizations, and specific studies or surveys. Where other sources are unavailable, IEA data draws on UN information. WRI calculated woodfuel consumption as a proportion of total energy consumption for each country by summing the energy consumption of fuelwood, charcoal, and black liquor, and expressing this total as a percentage of total final energy consumption.

Appendix 6 . Rural Energy Consumption

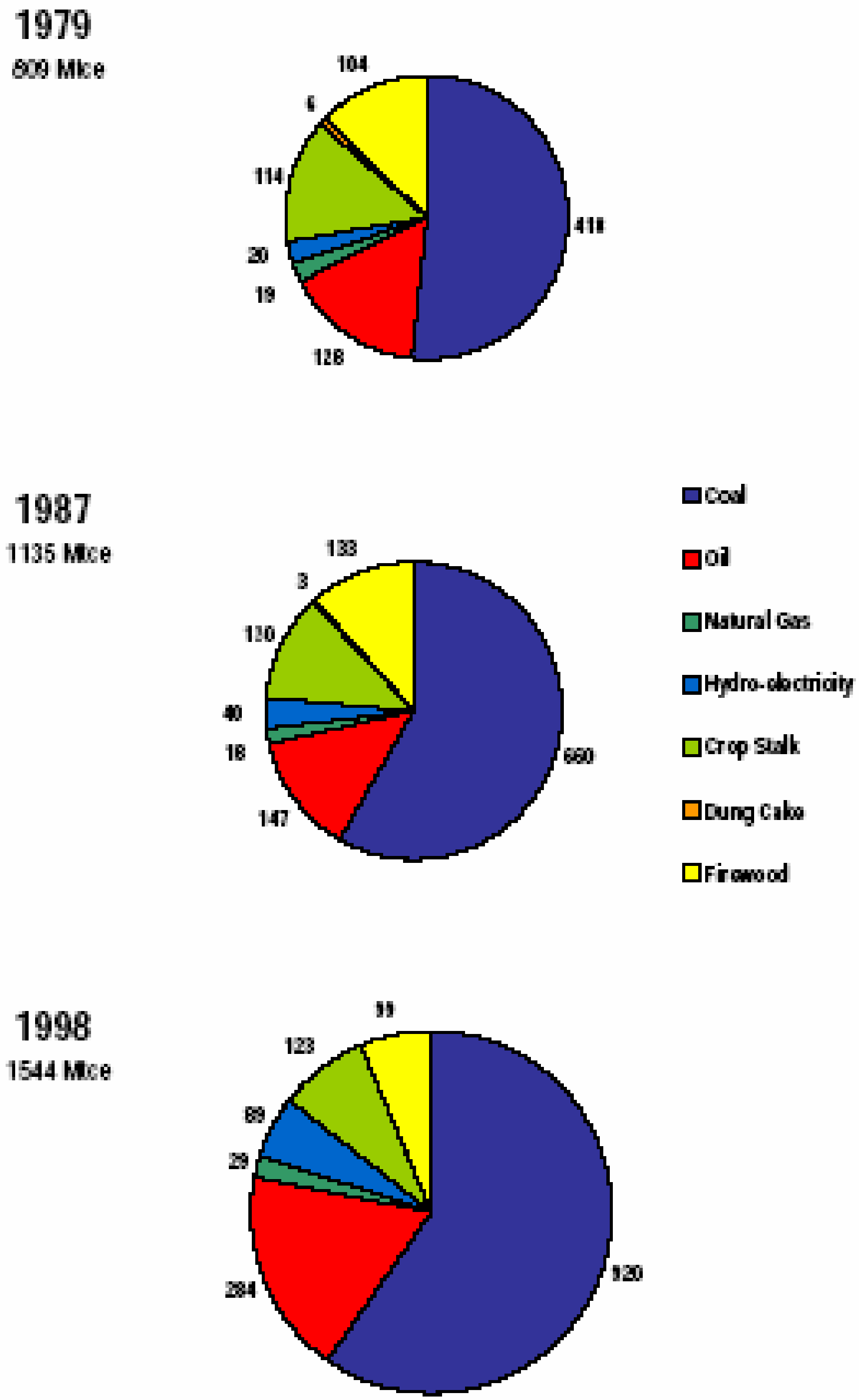
Source (Energy Research Institute 2001)

	Fossil Fuels[1]					Biomass Fuels[2]				
	Coal	Oil	Natural Gas	Hydro-electricity	Subtotal	Crop Stalk	Dung Cake	Firewood	Subtotal	Total
Energy Consumption (Mtce)										
1979	418	128	19	20	585	114	6	104	224	809
1987	658	147	18	40	866	130	3	133	266	1,132
1990	752	164	21	50	987	132		131	263	1,250
1991	798	177	21	50	1,038					1,038
1992	826	191	21	53	1,092	136		110	246	1,337
1993	866	211	22	60	1,160	137		110	248	1,408
1994	921	214	23	70	1,227	137		110	248	1,475
1995	979	230	24	80	1,312	129		92	221	1,533
1996	1,038	250	25	76	1,389	120		99	219	1,609
1997	991	282	23	86	1,382					1,382
1998	928	294	29	89	1,322	123		99	222	1,544
1999	819	285	34	82	1,220					1,220
Percent of Commercial Energy Consumption						**Percent of Biomass Energy Consumption**				
1979	71%	22%	3%	3%	100%	51%	3%	46%	100%	
1987	76%	17%	2%	5%	100%	49%	1%	50%	100%	
1990	76%	17%	2%	5%	100%	50%		50%	100%	
1991	76%	17%	2%	5%	100%					
1992	76%	17%	2%	5%	100%	55%		45%	100%	
1993	75%	18%	2%	5%	100%	55%		45%	100%	
1994	75%	17%	2%	6%	100%	55%		45%	100%	
1995	75%	18%	2%	6%	100%	58%		42%	100%	
1996	75%	18%	2%	6%	100%	55%		45%	100%	
1997	72%	20%	2%	6%	100%					
1998	70%	22%	2%	7%	100%	55%		45%	100%	
1999	67%	23%	3%	7%	100%					
Percent of Total Energy Consumption										
1979	52%	16%	2%	2%	72%	14%	0.8%	13%	28%	100%
1987	58%	13%	2%	4%	77%	11%	0.3%	12%	23%	100%
1990	60%	13%	2%	4%	79%	11%		11%	21%	100%
1991										
1992	62%	14%	2%	4%	82%	10%		8%	18%	100%
1993	62%	15%	2%	4%	82%	10%		8%	18%	100%
1994	62%	14%	2%	5%	83%	9%		7%	17%	100%
1995	64%	15%	2%	5%	86%	8%		6%	14%	100%
1996	65%	16%	2%	5%	86%	7%		6%	14%	100%
1997										
1998	60%	18%	2%	6%	86%	8%		6%	14%	100%
1999										

[1] Fossil fuels are counted in their primary forms. Hydropower is converted as 1 kWh = 0.404 kgce.

[2] Biomass figures are for rural household consumption. Since sources vary, official estimates of biomass use for various years may not be comparable.

Sources: ERI, National Rural Energy Planning, 1990; SPC, Energy Conservation in China, 1987; SSB, China Energy Statistical Yearbook, 1991-1996; ERI, China Rural Energy Statistical Yearbook, 1998-1999.



1979
809 Mtce
104
6
114
20
19
128
418
1987
1135 Mtce
133
3
130
40
18
147
660
Coal
Oil
Natural Gas
Hydro-electricity
Crop Stalk
Dung Cake
Firewood
1998
1544 Mtce
99
123
89
29
284
920

Appendix 7 . Rural Energy Survey (ESMAP)

2. Household and Production Energy Use (continued)

Energy Source	1992 Production Activity[a] Consumption	1992 Household Consumption	1992 Total Energy Consumption	1993 Production Activity[a] Consumption	1993 Household Consumption	1993 Total Energy Consumption
Crop Stalk		135.50	135.50		137.45	137.45
Firewood	16.82	93.47	110.29	16.82	93.48	110.30
Biomass Energy Subtotal	*16.82*	*228.97*	*245.79*	*16.82*	*230.93*	*247.75*
Electricity	42.00	11.20	53.20	47.18	13.24	60.42
Coal	159.56	78.91	238.47	164.45	86.18	250.63
Oil Products[b]	30.98	1.38	32.36	33.20	1.50	34.70
Commercial Energy Subtotal	*232.54*	*91.49*	*324.03*	*244.83*	*100.92*	*345.75*
Total Energy	249.36	320.46	569.82	261.65	331.85	593.50

Energy Source	1994 Production Activity[a] Consumption	1994 Household Consumption	1994 Total Energy Consumption	1995 Production Activity[a] Consumption	1995 Household Consumption	1995 Total Energy Consumption
Crop Stalk		137.45	137.45		129.00	129.00
Firewood	16.80	93.50	110.30		92.39	92.39
Biomass Energy Subtotal	*16.80*	*230.95*	*247.75*		*221.39*	*221.39*
Electricity	52.35	15.25	67.60	68.48	17.45	85.93
Coal	169.38	93.50	262.88	207.91	77.40	285.31
Oil Products[b]	35.45	1.60	37.05	34.39	1.60	35.99
Commercial Energy Subtotal	*257.18*	*110.35*	*367.53*	*310.78*	*96.45*	*407.23*
Total Energy	273.98	341.30	615.28	310.78	317.84	628.62

Energy Source	1996 Production Activity[a] Consumption	1996 Household Consumption	1996 Total Energy Consumption	1998 Production Activity[a] Consumption	1998 Household Consumption	1998 Total Energy Consumption
Crop Stalk		120.00	120.00		122.80	122.80
Biogas					1.29	1.29
Firewood	16.34	82.99	99.33	15.17	84.01	99.18
Biomass Energy Subtotal	*16.34*	*202.99*	*219.33*	*15.17*	*208.10*	*223.27*
Electricity	68.18	29.13	97.31	68.27	29.82	98.09
Coal	178.00	100.00	278.00	112.48	116.71	229.19
Oil Products[b]	45.17	1.60	46.77	41.65	6.46	48.11
Commercial Energy Subtotal	*291.35*	*130.73*	*422.08*	*222.40*	*152.99*	*375.39*
Total Energy	307.69	333.72	641.41	237.57	361.09	598.66

[a] Agriculture, transportation, rural industry, and services.

[b] Household oil use is kerosene and LPG. In practice, penetration of LPG into rural areas is very low.

Source: E.B. National Rural Energy Planning, 1990; Ministry of Energy, 1994; Energy Research Institute.

Appendix 8 . Rural Household Energy Survey in Six Counties

Source: (ESMAP 1996)

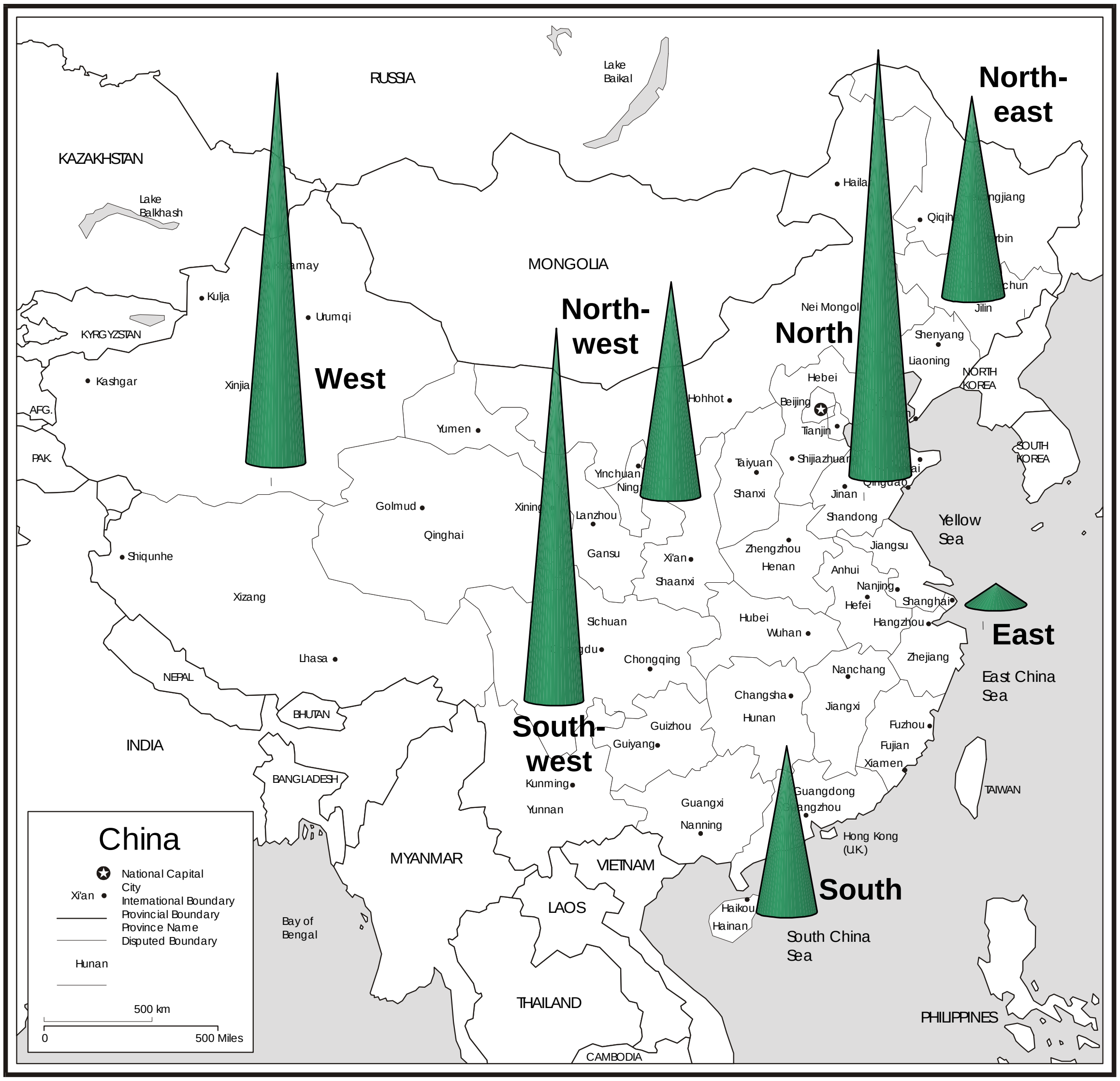
Table 3.2: Rural Household Energy Consumption by Source in Six Counties

Source	*Xiushui*	*Hengnan*	*Kezuo*	*Jianyang*	*Huantai*	*Changshu*
Electricity						
KgCE/year/person	1.1	1.1	2.5	1.9	4.7	5.3
Percentage	0.1	0.3	0.6	0.8	1.0	2.0
LPG						
KgCE/year/person	0.0	0.0	0.0	0.0	3.8	0.9
Percentage	0.0	0.0	0.0	0.0	0.8	0.3
Kerosene						
KgCE/year/person	3.4	2.7	0.2	2.9	0.7	0.8
Percentage	0.4	0.6	0.0	0.0	0.7	0.3
Coal						
KgCE/year/person	27.6	150.0	110.7	28.0	295.0	9.3
Percentage	3.4	34.7	27.3	11.9	62.3	3.5
Charcoal						
KgCE/year/person	9.2	0.1	0.0	0.0	0.0	0.0
Percentage	1.1	0.0	0.0	0.0	0.0	0.0
Firewood						
KgCE/year/person	574.7	170.0	36.1	34.1	0.1	5.8
Percentage	69.8	40.3	8.9	14.3	0.0	2.3
Straw and stalks						
KgCE/year/person	60.3	55.2	208.6	134.1	168.5	242.1
Percentage	7.3	13.2	51.5	56.3	35.4	91.5
Grass and leaves						
KgCE/year/person	145.1	45.2	45.8	36.7	0.0	0.4
Percentage	17.6	10.8	11.3	15.3	0.0	0.2
Biogas						
KgCE/year/person	2.2	0.0	1.5	2.6	0.7	0.4
Percentage	0.3	0.0	0.4	1.4	0.1	0.2
Dung						
KgCE/year/person	0.0	0.0	0.1	0.0	0.0	0.0
Percentage	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL						
KgCE/year/person	823.6	420.0	405.4	240.3	473.5	265.1
Percentage	100.0	100.0	100.0	100.0	100.0	100.0

Note: Some totals may reflect rounding errors.
Source: Rural Energy Survey.

Appendix 9 . Location and Relative Size of China's Natural Gas Reserves

Source: (Frindley)

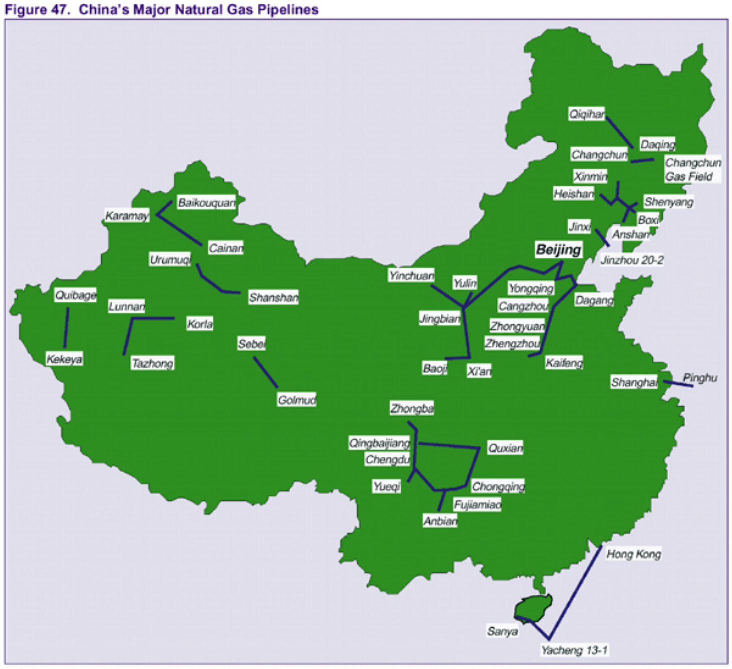


Appendix 10 . Natural Gas Pipeline Old and Proposed in China

Source: (Frindley)

Natural Gas is piped to the east coast (old and new)

Figure 47. China's Major Natural Gas Pipelines

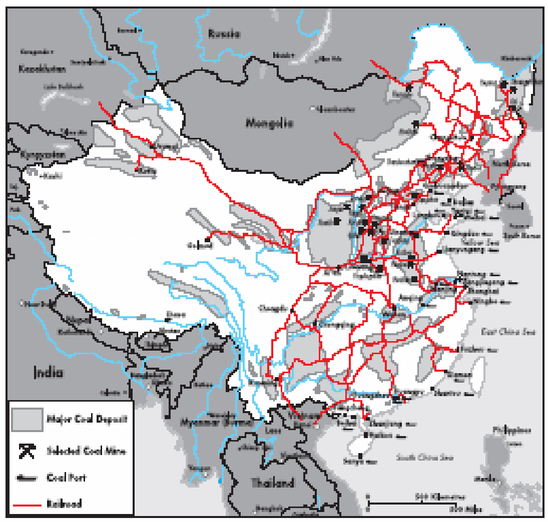


Source: Fesharaki Associates Consulting and Technical Services and East-West Consultants International, Ltd., *China's Natural Gas to 2015*, Multi-Client Study (Honolulu and Singapore, October 2000), p. 4-10.

Planned Routing of the West-East Pipeline

Appendix 11 . Coal Reserves in China

(International Energy Agency (IEA) 1999)



Source: US DoE. EIA. *Country Energy Profile. China.* February 1995.

Appendix 12 . Emission factors sorted by Total PIC emissions*

Source: (Zhang, Smith et al. 2000)
(gram of compound per 1 MJ delivered energy)

Fuel-stove combination	Stove efficiency (%)		Fuel calorific value (MJ/kg)	Total PIC emissions		CO_2		CO		CH_4		Carbon released as NMHC		TSP		NO_x		SO_2	
	mean	CV	mean	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV	mean	CV
Coal gas in traditional stove	46	10	44	0.0	22	93	10	nd	na	nd	na	0.00003	173	0.0098	22	0.089	3	0.1	33
Natural gas in IR stove	61	< 1	51	0.01	60	110	< 1	nd	na	0.00	173.0	0.01	119.0	0.01	27.0	0.02	45	nd	na
Natural gas in traditional stove	54	2	51	0.02	114	125	2.0	0.01	173.0	nd	na	0.003	101.0	0.004	76.0	0.11	29	0.0	117
LPG in traditional stove	45	5	49	0.3	72	140	5.0	0.1	141.0	0.02	173.0	0.2	99.0	0.02	172.0	0.15	12	nd	na
Kerosene in pressure stove	46	7	43	0.4	40	158	7.0	0.4	49.0	0.00	127.0	0.0	82.0	0.01	48.0	0.08	3	0.0	87
Kerosene in wick stove	45	7	43	0.5	15	162	8.0	0.4	17.0	0.00	58.0	0.0	33.0	0.00	39.0	0.03	59	0.0	87
LPG in IR Stove	42	21	49	1.3	90	153	23.0	1.0	84.0	0.02	96.0	0.2	118.0	0.00	45.0	0.00	35	0.0	173
Coal Briquettes in metal stove with no chimney	37	3	14	3.9	74	312	15.0	3.9	74.0	0.00	91.0	0.0	169.0	0.01	26.0	0.19	56	0.0	67
Coal Briquettes in metal stove with chimney	27	35	14	5.5	42	415	48.0	5.4	42.0	0.00	84.0	0.0	141.0	0.05	35.0	0.08	61	0.5	78
Coal honeycomb briquette improved brick stove with chimney	47	4	19	6.6	58	303	6.0	6.5	58.0	nd	na	0.0	94.0	0.05	116.0	0.05	55	0.0	169
Special coal honeycomb briquette in metal stove with chimney	44	8	20	8.3	45	267	5.0	7.7	41.0	0.41	97.0	0.1	149.0	0.07	120.0	0.12	34	0.9	6
Wood in traditional brick stove with chimney	13	19	16	12	12	750	20.0	11.1	10.0	0.29	43.0	0.1	101.0	0.76	36.0	0.22	91	nd	na
Coal honeycomb briquette in metal stove with no chimney	23	11	19	15	31	573	18.0	14.6	32.0	0.00	173.0	0.0	146.0	0.06	35.0	0.10	11	0.0	99

Wood in Indian metal stove with no chimney	21	37	16	17	59	458	59.0	14.6	60.0	0.66	38.0	0.5	50.0	0.97	84.0	0.27	64	0.0	101
Coal honeycomb briquette in metal stove with chimney	16	6	19	19	21	824	11.0	19.0	21.0	0.00	23.0	0.0	173.0	0.07	48.0	0.14	31	0.1	55
Wood in improved brick stove with chimney	24	9	16	21	60	388	8.0	17.2	58.0	0.83	73.0	1.3	94.0	1.08	47.0	0.14	71	0.0	92
Plain coal in metal stove with no chimney	14	na	27	24	na	643	na	18.1	na	2.65	na	0.6	na	2.24	na	0.04	na	0.0	na
Plain coal in metal stove with chimney	18	75	27	28	74	742	49.0	25.6	66.0	1.08	150.0	0.4	144.0	1.25	147.0	0.12	97	0.1	114
Maize stalks in brick stove with chimney	11	17	16	29	69	666	16.0	24.6	67.0	0.98	71.0	1.9	99.0	1.02	66.0	0.70	21	0.0	57
Maize stalks in improved brick stove with chimney	19	8	16	33	42	348	9.0	28.9	39.0	2.02	65.0	0.8	77.0	1.34	43.0	0.20	50	0.1	93
Brush wood in traditional brick stove with chimney	14	10	15	35	35	714	8.0	32.2	34.0	1.01	59.0	0.4	98.0	1.28	24.0	0.93	21	0.0	139
Brush in Indian metal stove with no chimney	17	2	15	42	15	545	1.0	36.6	16.0	1.95	19.0	1.7	17.0	1.60	13.0	0.61	7	0.0	173
Washed coal in metal stove with chimney	9	8	30	43	22	855	9.0	32.2	20.0	5.19	37.0	0.7	74.0	5.16	33.0	0.06	119	0.4	149
Plain coal in traditional brick stove with chimney	17	45	27	45	64	542	55.0	44.1	63.0	0.27	114.0	0.1	83.0	0.43	78.0	0.50	35	0.1	123
Brush wood in improved brick stove with chimney	14	na	15	51	na	636	na	44.4	na	3.35	na	1.1	na	2.08	na	0.66	na	nd	na
Wheat stalks in brick stove with chimney	10	11	14	55	43	976	7.0	46.3	40.0	2.01	52.0	2.7	66.0	3.65	66.0	0.81	70	0.0	48
Special coal in metal stove with chimney	7	< 1	21	65	1	1440	< 1	60.4	2.0	3.89	11.0	0.1	13.0	0.09	45.0	2.69	1	14.3	1
Wheat stalks in improved brick stove with chimney	15	8	14	101	36	447	22.0	83.9	29.0	4.19	94.0	4.6	108.0	8.48	62.0	0.11	64	0.0	173

*Total PIC = $CO + CH_4$ + NMHC (C)

Appendix 13 . Emissions of pollutants from 24 stove-fuel combinations

Source: (Zhang, Smith et al. 2000)

Tested by Zhang, Smith and colleagues in units of grams pollutant per MJ delivered to the pot.

	Stove eff (%)		Calorific value (MJ/kg)	Total PIC emissions		CO2		CO		CH4		NMHC (C)		TSP		NOx		SO2	
Fuel-stove combination	**mean**	**CV**	**mean**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**	**mean**	**CV**
Washed coal in metal stove with chimney	9	8	30	43	22	855	9	32.2	20	5.19	37	0.7	74	5.16	33	0.06	119	0.4	149
Wheat stalks in brick stove with chimney	10	11	14	55	43	976	7	46.3	40	2.01	52	2.7	66	3.65	66	0.81	70	0	48
Wood in traditional brick stove with chimney	13	19	16	12	12	750	20	11.1	10	0.29	43	0.1	101	0.76	36	0.22	91	nd	na
Special coal honeycomb briquette in metal stove with chimney	44	8	20	8.3	45	267	5	7.7	41	0.41	97	0.1	149	0.07	120	0.12	34	0.9	6
Plain coal in metal stove with no chimney	14	na	27	24	na	643	na	18.1	na	2.65	na	0.6	na	2.24	na	0.04	na	0	na
Wheat stalks in improved brick stove with chimney	15	8	14	101	36	447	22	83.9	29	4.19	94	4.6	108	8.48	62	0.11	64	0	173
Coal honeycomb briquette in metal stove with chimney	16	6	19	19	21	824	11	19	21	0	23	0	173	0.07	48	0.14	31	0.1	55
Special coal in metal stove with chimney	7	< 1	21	65	1	1440	< 1	60.4	2	3.89	11	0.1	13	0.09	45	2.69	1	14.3	1
Plain coal in traditional brick stove with chimney	17	45	27	45	64	542	55	44.1	63	0.27	114	0.1	83	0.43	78	0.5	35	0.1	123
Plain coal in metal stove with chimney	18	75	27	28	74	742	49	25.6	66	1.08	150	0.4	144	1.25	147	0.12	97	0.1	114
Wood in Indian metal stove with no chimney	21	37	16	17	59	458	59	14.6	60	0.66	38	0.5	50	0.97	84	0.27	64	0	101
Coal honeycomb briquette in metal stove with no chimney	23	11	19	15	31	573	18	14.6	32	0	173	0	146	0.06	35	0.1	11	0	99
Wood in improved brick stove with chimney	24	9	16	21	60	388	8	17.2	58	0.83	73	1.3	94	1.08	47	0.14	71	0	92
Coal Briquettes in metal stove with chimney	27	35	14	5.5	42	415	48	5.4	42	0	84	0	141	0.05	35	0.08	61	0.5	78
Coal Briquettes in metal stove with no chimney	37	3	14	3.9	74	312	15	3.9	74	0	91	0	169	0.01	26	0.19	56	0	67
LPG in IR Stove	42	21	49	1.3	90	153	23	1	84	0.02	96	0.2	118	0	45	0	35	0	173
Kerosene in pressure stove	46	7	43	0.4	40	158	7	0.4	49	0	127	0	82	0.01	48	0.08	3	0	87
Kerosene in wick stove	45	7	43	0.5	15	162	8	0.4	17	0	58	0	33	0	39	0.03	59	0	87

Maize stalks in brick stove with chimney	11	17	16	29	69	666	16	24.6	67	0.98	71	1.9	99	1.02	66	0.7	21	0	57
Maize stalks in improved brick stove with chimney	19	8	16	33	42	348	9	28.9	39	2.02	65	0.8	77	1.34	43	0.2	50	0.1	93
LPG in traditional stove	45	5	49	0.3	72	140	5	0.1	141	0.02	173	0.2	99	0.02	172	0.15	12	nd	na
Coal gas in traditional stove	46	10	44	0	22	93	10	nd	na	nd	na	0.00003	173	0.0098	22	0.089	3	0.1	33
Coal honeycomb briquette in improved brick stove with chimney	47	4	19	6.6	58	303	6	6.5	58	nd	na	0	94	0.05	116	0.05	55	0	169
Natural gas in traditional stove	54	2	51	0.02	114	125	2	0.01	173	nd	na	0.003	101	0.004	76	0.11	29	0	117

Notes:

- ⇒ CV is coefficient of variation (standard deviation ÷ mean) derived from three tests of each stove-fuel combination.
- ⇒ Total PICs in the sum of CO, CH_4, NMHC, and TSP (total suspended particulates).
- ⇒ NMHC (C) is the carbon mass of total non-methane hydrocarbons.

Appendix 14 . Distribution of Major Donor Health Projects Across China

Source: (AusAid 1999)

Province	WORLD BANK*	UNICEF**	DFID	AUSAID
Xinjiang	TB, EPI, MCH (9), HIV	MCH (40)		
Gansu	MCH (6&9), EPI, Basic Health Services, TB	MCH (40)	Basic Health Services	
Ningxia	TB, Qinba	MCH (40)		FP/MCH
Shaanxi	Regional Health Planning, MCH, EPI, Qinba	MCH		
Qinghai	MCH, Basic Health Services	MCH (40)		
Chongqing	MCH, Basic Health Servies, TB	MCH	Basic Health Services	Poverty
Sichuan	MCH, TB, HP, Schisto, Qinba	MCH	HIV, urban health	
Tibet		MCH		PHC
Yunnan	HIV, EPI, HP, MCH, Schisto, Poverty	MCH	HIV	
Guangxi	MCH, EPI, HP, HIV, Poverty	MCH		
Guizhou	MCH, EPI, Basic Health Services, Rural Health Workers, Poverty	MCH (40)		
Henan	EPI, HP, Basic Health Services, Rural Health Workers	MCH		
Hunan	TB, Schisto, MCH (9)	MCH		
Hebei	EPI, TB, Rural Health Workers	MCH		
Hubei	TB, Schisto	MCH		
Shanxi	EPI, Basic Health Services, HIV, Rural Health Workers	MCH		
Anhui	Basic Health Services, Schisto, Rural Health Workers	MCH		
Jiangxi	Regional Health Planning, MCH, Schisto	MCH		
Zhejiang	Regional Health Planning, Schisto	MCH		
Jiangsu	Schisto	MCH		
Fujian	HIV, Rural Health Workers	MCH		
Guangdong	TB	MCH		
Hainan	TB, MCH (9)	MCH		
Inner Mongolia	MCH	MCH		
Heilongjiang	TB	MCH		
Jilin	MCH (9)	MCH	urban health	
Liaoning	TB	MCH		
Shandong	TB, HP	MCH		

* (6) denotes Health VI while (9) denotes Health IX.
** (40) denotes involvement in the new 40-counties project

Appendix 15 . China's Indoor Air Quality Standards

Source: Upcoming report "Programs to Promote Improved Household Stoves in China: An Assessment of Program Performance", Smith, Kirk, et. al.

On 19 November 2002, China released its first set of standards governing indoor air quality in residences and offices (GB/T 1883-2002). These standards, issued jointly by the State Administration for Quality Supervision, Inspection and Quarantine, the Ministry of Health, and the State Environmental Protection Agency, went into effect 1 March 2003, though to date there appears to be no clear enforcement activity or mechanism. For PM_{10} and CO, as well as SO_2 and O_3, the IAQ standards correspond to the Class II (residential areas) ambient standards (GB 3905-1996). For NO2, the indoor standard corresponds to the ambient Class III (industrial and non-attainment areas) standard. The indoor B(a)P standard is ten times less than the ambient standard. Several pollutants covered by the ambient standards are not covered by the IAQ standard, i.e., TSP, NO_x, Pb, and F.

Type	Objective	Unit	Standard (maximum allowable level)	Remarks
Physical	Temperature	°C	22-28	summer air conditioning
			16-24	winter heating
	Relative humidity	%	40-80	summer air conditioning
			30-60	winter heating
	Air flow	m/sec	0.3	summer air conditioning
			0.2	winter heating
	Fresh air	m^3/(hr-person)	30	Unlike other standards, minimum allowable level.
Chemical	Sulfur dioxide (SO_2)	μg/m^3	500	one-hour average
	Nitrogen dioxide (NO_2)	μg/m^3	240	one-hour average
	Carbon monoxide (CO)	mg/m^3	10	one-hour average
	Carbon dioxide (CO_2)	%	100	one-day average
	Ammonia (NH_3)	μg/m^3	200	one-hour average
	Ozone (O_3)	μg/m^3	160	one-hour average
	Formaldehyde (HCHO)	μg/m^3	100	one-hour average
	Benzene (C_6H_6)	μg/m^3	110	one-hour average
	Toluene (C_7H_8)	μg/m^3	200	one-hour average
	Xylene (C_8H_{10})	μg/m^3	200	one-hour average
	Benzo[a]pyrene (B[a]P)	ng/m^3	1.0	one-day average
	Particulate matter ≤10μm (PM_{10})	μg/m^3	150	one-day average
	Total volatile organic compunds (TVOC)	μg/m^3	600	eight-hour average
Biological	Total bacteria (colony-forming units)	cfu/m^3	2500	impacting method
Radiation	Radon (^{222}Rn)	Bq/m^3	400	annual average (level at which mitigation action should be taken)

Appendix 16 . Rural Market Development in China by Whirlpool

The Wall Street Journal: Into China's New Frontier---Foreign Brands, Successful in Cities, Head for Tough Rural Markets (02/20/03)

By BEN DOLVEN

Huainan, China   CHINESE COMPANIES MAY be flooding the world with ever-cheaper washing machines, refrigerators and air conditioners. But there's a source of hope for the world's appliance makers: They're gobbling up market share-in China.

Last year, foreign brands made up 420/c of China's nationwide market for fully automatic washers, up from 15% in 1999. Companies such as %Whirlpool Corp., Korea's LG Electronics Inc. and Germany's Siemens AG have carved out a chunk of the market in China's affluent coastal cities, and now many are trying to push inland into the tougher but larger parts of the Chinese market.

To see how they do it, spend a day with a four-person team, from Whirlpool traveling around the poor, rural province of Anhui in eastern China. They're riding hip after a visit to Huainan, a city of 2.1 lion, where they lunch with the local Communist Party secretary, who asks them to, consider more investments, maybe even build a factory. Downtown, at the Hualian Commercial store, Whirlpool has a big brightly lit display and has sold 33 washers in a month-its best performance in the province.

Whirlpool already has double-digit shares of the market in several richer provinces, including 18% in the commercial center of Shanghai. Last year, more than half of the Michigan-based

Company's China washing machine markets--Shanghai; Beijing; Guangdong province near Hong Kong; and Chengdu, the capital of Sichuan.

But in China, more than half the total midrange and high-end washers sold each year are sold outside 26 largest cities, according to market-research company ACNielsen. So Whirlpool is pushing farther afield. "Every market is on our map except Tibet," says Ko-Lin Feng, the Shanghai-based commercial director of Whirlpool China.

For years, forays into China's interior, have left companies stuck in snake pits distribution hassles, uncooperative retailers, politically connected local competitors and unmet sales targets. But there are forces changing that, among them the growth in - small-city incomes: Although the per-capita income in Hefei, the capital of Anhui, is just 800 yuan ($97) a month less than the price of Whirlpool's cheapest washer-a growing middle class has the money to buy better products. Then there's the development of nationwide retail chains, and a perception that although nouveau riche consumption patterns in China's biggest cities are established, opportunities remain for new players to set them in places like Anhui.

For Whirlpool, China makes up only a small part of overall revenue, but the growth potential is clear. Whirlpool Asia President Garrick D'Silva points to 35% an annual revenue growth in the past three years. “ The sort of growth rates we’re seeing in China we're not seeing in our operating portfolio anywhere else in the world," he says.

The company says its China businesses have been turning operating profits since 1999, after it sold off money-losing refrigeration and home air-conditioning ventures. The washing-machine business itself has yet to make money on Whirlpool's $60 million investment, but Mr.. D'Silva says it should break even this year (Whirlpool also makes microwave ovens in China, mostly for export, and supplies compressors to air-conditioning makers).

As it tackles new markets in China, Whirlpool faces a difficult dance with retailers. The company continually struggles to convince stores that customers will go for its machines, helping the retailer grab more sales. In Anhui, its two-man sales team buses back and forth between small cities, wining and dining retailers and trying to negotiate down prices for retail space.

Still, they run into walls. Ms. Feng shakes her head as she walks through a store in Hefei, which in return for display space is asking for a payment of 80,000 yuan ($9,674). "We'd have to sell 100 washers a month to do this," she says.

Often they find that stores outside provincial capitals are more eager to do deals. Whirlpool will make most of its early efforts in Anhui in cities north of Hefei, even though the largely agricultural area is less affluent.

The expansion of chain stores also provides a foothold for foreign brands. Whirlpool has links with several retail chains. So when Shanghai-based chain Guomei Electronics built stores in the inland cities of Xian and Zhengzhou, Whirlpool went with it.

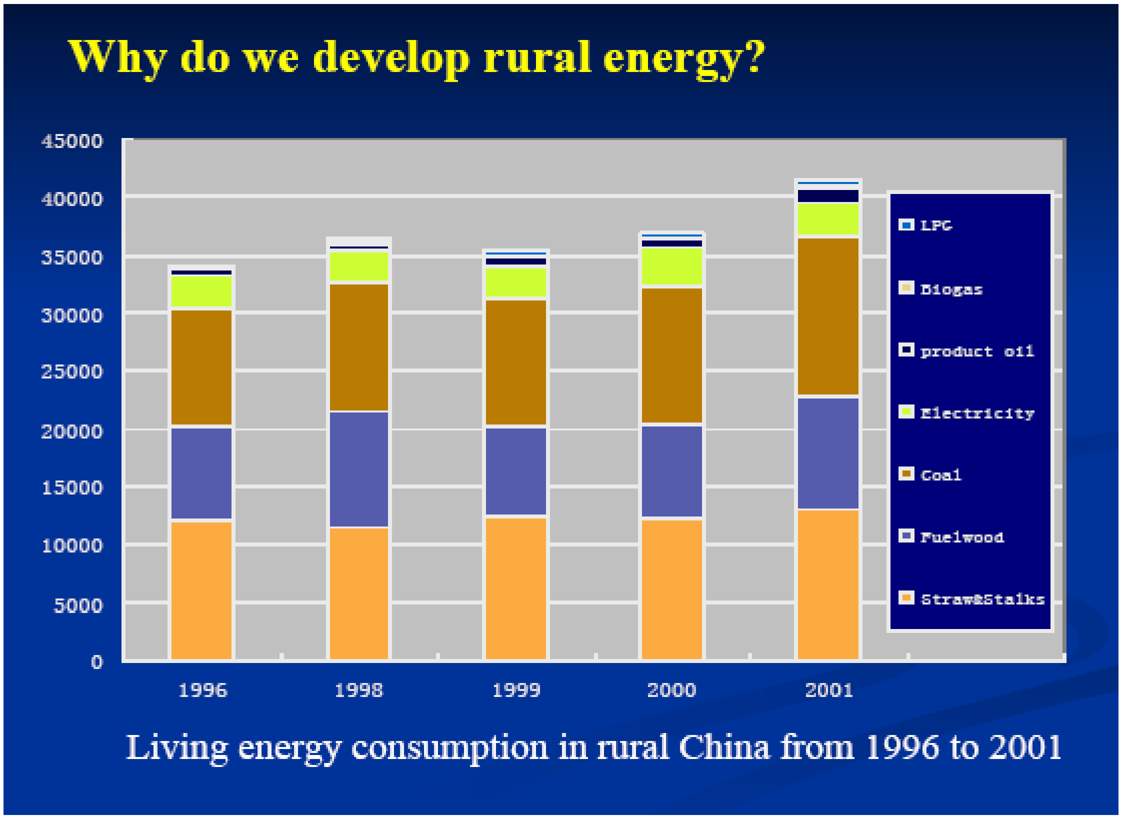
Once the company gets its machines in stores, competition is fierce. It vies with multinational competitors like LG and Siemens on the high end, while the bulk of Chinese sales are still taken up by homegrown giant Haier Group and lower-end Chinese brands with names like Wuxi Little Swan and Little Duck. Competition is driving, down prices by 10% to 15% a year, squeezing profit margins. Haier still dominates, accounting for 26% of the nationwide market (Wirlpool's share is about 7%).

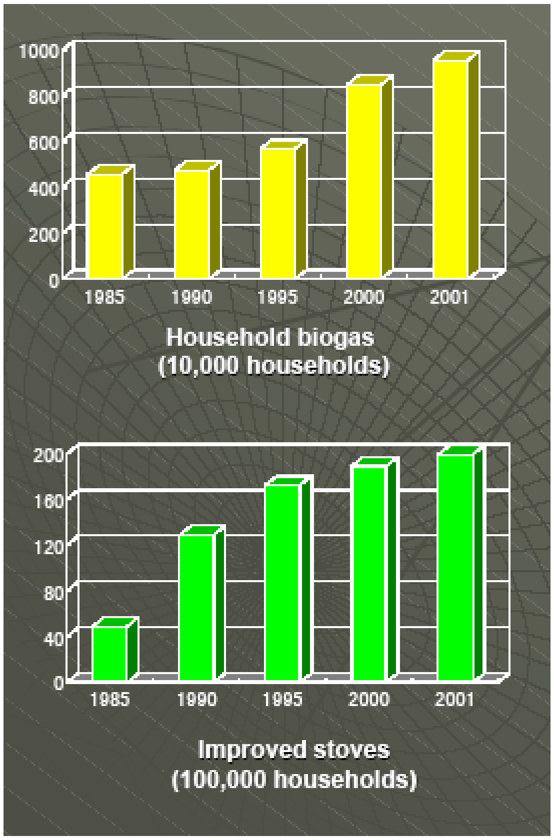
Xie Jinhua, the sales manager in Anhui, says he'd like to hire more people, but is quickly shot down by his boss, Adele Tao, the business manager for central China. "When we're selling 1,000 units a month," she says, "we can consider more people.

For the original article, please read The Wall Street Journal of Feb. 20, 2003 at page 10.

Appendix 17 . Household Biogas Use in China

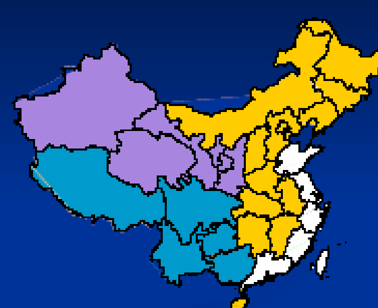
The following figures were extracted from a presentation made at Energy Week 2003 at the World Bank by representatives of the Chinese Ministry of Agriculture (Jiuchen 2003).

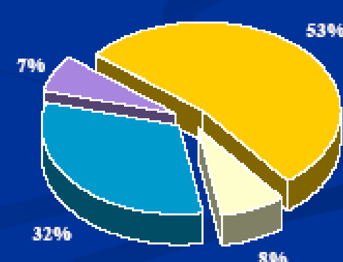

Why do we develop rural energy?
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1996
1998
1999
2000
2001
LPG
Biogas
product oil
Electricity
Coal
Fuelwood
Straw&Stalks
Living energy consumption in rural China from 1996 to 2001



Potential users of household biogas

Regions	Total households (10,000)	Suitable households (10,000)
Southwest	5186	4500
Northwest	1844	950
Central	13078	7550
East	4040	1100
Total	**24148**	**14100**





Note: existing 9.57 million household using biogas only occupies 4% of total farm households and 6.8% of total suitable households respectively.

Appendix 18 . Contacts and Resources

Section I: Contacts within China

1. Chinese Association of Rural Energy Industry (CAREI)
Sino-Dutch Co-Project: Promotion of Rural Renewable Energy in Western China
Mdm. Deng Keyun
President and General Executive
Room 201 No41, Maizidian Road, Chaoyang, Beijing, China 100026
Tel: 86-10-6501-3364
Fax: 86-10-6530-1462

2. Chinese Association of Rural Energy Industry (CAREI)
Mr. Hao Fangzhou
Senior Engineer
Routine Member of China Association of Rural Energy Industry
No. 17-1404 Shuiduizi Beili, Chaoyang District, Beijing, China 100026
Director of Committee of Stove and Furnace of CAREI*
Tel: 86-10-8598-9148
Fax: 86-10-8598-9148
Email: haoTc@sina.com
* This may sometimes be translated as the Rural Cook Stove Association & Chinese Efficient Cookstoves Association

3. Ministry of Agriculture
Ms. Hao Xianrong
Division of Energy and Ecology
Department of Science, Education, and Rural Environment
Tel: 86-10-6419-3032
Fax: 86-10-6419-3068

4. Government of the Netherlands
Mr. Martien Beek
First Secretary for Environment, Dutch Embassy
Beijing, China
Tel: 86-10-6532-1131 x243
Email: martien.beek@minbuza.nl

5. Chinese Center for Disease Control and Prevention
Dr. Yu Guangqian
Institute for Endemic Fluorosis Control
Center for Endemic Disease Control
Email: yuguangqian@yahoo.com.cn

6. Tsinghua University
Dr. Zhang Xiliang
Institute of Energy, Environment, and Economy
Energy Science Building

Beijing, China 100084
Tel.: 86-10-6278-8911
Fax: 86-10-6277-1024
Email: xiliang@inet.tsinghua.edu.cn

7. International Development Enterprises/Guizhou University
Professor Luo XiaoPeng
IDE China representative & Director, Center for Poverty Alleviation Studies
Administration Building, Room 110
Guizhou University, South Campus
Guiyang City, Guizhou Province, China, 550025
Tel: 86-851-8298122,
Fax 86-139-85113375
E-Mail: luox0006@yahoo.com

8. The Nature Conservancy
Mr. Xia Zuzhang, Alternative Energy Program Director
Yunnan Provincial Meteorological Bureau, 8th Floor
77 Xichang Road
Kunming, Yunnan, China 650034

Section II: Contacts in U.S. and Europe

1. University of California, Berkeley
Professor Kirk Smith
Environmental Health Sciences
Tel: +1-510-643-0793
Email: krksmith@uclink4.berkeley.edu
http://ehs.sph.berkeley.edu/krsmith/page.asp?id=1

2. Lawrence Berkeley National Laboratories
Dr. Jonathan Sinton
Environmental Energy Tech [EEEAC]
1 Cyclotron Road, Mailstop 90-4000
Berkeley, CA 94720
Tel: +1-510-486-7081
Fax: +1 510-486-6996
Email: jesldc@dante.lbl.gov
http://china.lbl.gov/

3. EUBIA - European Biomass Industry Association
Mr. Giuliano Grassi, Secretary General
Rond Point Schuman 6, BE 1040 Bruxelles
BELGIUM
Tel: 32 2 28 28 420
Fax: 32 2 28 28 424
E-mail: eubia@eubia.org
Website: www.eubia.org

4. World Bank, Energy and Mining Group
Mr. Salvador Rivera, Senior Energy Specialist
1818 H Street, N.W
Washington, DC 20433 U.S.A.
Tel: +1-202 473-1000
Fax: +1-202 477-6391
Email: arivera2@worldbank.org

5. National Renewable Energy Laboratories (NREL)
1617 Cole Blvd.
Golden, CO 80401-3393

Mr. Colin Green
Senior Project Leader, Integrated Environmental Strategies
Tel: +1-202-646-5034
Fax: +1-202-646-7780
Email:collin_green@nrel.gov

Mr. Ralph Overend
Research Fellow
Tel: +1-303-384-7787
Fax: +1-303-384-6877
Email: ralph_overend@nrel.gov