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EAST ASIA AND PACIFIC CLEAN STOVE INITIATIVE SERIES



China

Accelerating Household Access to Clean Cooking and Heating

September 2013



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The World Bank

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Asia Sustainable and
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Foreword

Some 2.8 billion people around the world continue to rely on solid fuels, such as biomass and coal, to cook and heat their homes. Most of these households use primitive open fires or poorer-quality stoves that burn solid fuels inefficiently due to incomplete combustion, releasing toxic pollutants into the indoor or outdoor cooking environment. The Global Burden of Disease Study 2010 estimates that household air pollution (HAP) resulting from the use of solid fuels for cooking and heating contributes to 4 million premature deaths each year. Unlike malaria, tuberculosis, and HIV/AIDS, for which the death toll is declining every year, the number of premature deaths linked to HAP is on the rise. How can this trend be reversed?

China is among the few countries that have long recognized the seriousness of the issue, having implemented a number of stove dissemination and household energy policies that aim to improve household cooking and heating conditions. During the 1980s and 1990s, China's National Improved Stoves Program (NISP)—the world's largest and most successful national improved stoves program—distributed 180 million improved stoves. Today China represents the world's largest biomass stove industry, accounts for the greatest number of installed biogas digesters, and has the largest stock of solar cookers. However, the country also faces enormous challenges. More than half of its population, mostly in rural areas, still relies on solid fuels for cooking and heating. Most of these households use traditional stoves, and helping them to access cleaner and more efficient cooking and heating solutions is a daunting task.

The China Clean Stove Initiative (CSI), a collaborative effort of the Chinese government and the World Bank, aims to scale up access to clean cooking and heating stoves for poor, primarily rural households, who are likely to continue using solid fuels beyond 2030. Launched in 2012, the China CSI is part of the East Asia and Pacific (EAP) CSI, which includes country-specific programs in Indonesia, Mongolia, and Lao PDR, as well as China, and a regional forum for knowledge-sharing. The China CSI comprises four phases: (1) initial stocktaking and development of the implementation strategy; (2) institutional strengthening, capacity building, and piloting of the strategy; (3) scaled-up program implementation; and (4) evaluation and dissemination of lessons learned. This phase I report synthesizes the knowledge to date, emphasizes the market-based approach to achieving sustainability, and proposes a way forward toward achieving universal access to clean cooking and heating solutions.

It is our hope that this report will serve as a knowledge base and roadmap to encourage and engage all interested parties in working together on this important agenda. We will continue to use the EAP CSI as a platform for sharing China's experiences and promoting regional learning and collaboration. We look forward to working together with all our partners in the next phase of the China CSI to implement the key policy recommendations offered in the report and thus accelerate China's journey toward universal access to clean cooking and heating solutions. The benefits are many, including better health, reduced poverty, improved gender equality, and less pressure on the local and global environment.

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Acronyms and Abbreviations

AQSIQ	Administration of Quality Supervision, Inspection, and Quarantine	RBF	Results-Based Financing
BUCT	Beijing University of Chemical Technology	RMB	Renminbi (currency)
CACS	China Alliance for Clean Stoves	SAC	Standardization Administration of the People's Republic of China
CAREI	China Association of Rural Energy Industry	SEPA	State Environmental Protection Agency
CDM	Clean Development Mechanism	SFA	State Forestry Administration
CSI	Clean Stove Initiative	WBT	Water Boiling Test
GACC	Global Alliance for Clean Cookstoves		
GFRC	Glass-Fiber Reinforced Concrete		
GFRP	Glass-Fiber Reinforced Plastic		
HAP	Household Air Pollution		
IWA	International Workshop Agreements		
M&E	Monitoring and Evaluation		
M&V	Monitoring and Verification		
MOA	Ministry of Agriculture		
MOF	Ministry of Finance		
MOH	Ministry of Health		
MOST	Ministry of Science and Technology		
NDRC	National Development and Reform Committee		
NEA	National Energy Administration		
NISP	National Improved Stoves Program		
R&D	Research and Development		

Units of Measure

cm	centimeter
kg	kilogram
km	kilometer
kW	kilowatt
mg	milligram
m ²	square meter
m ³	cubic meter
tce	tons of standard coal equivalent
tCO ₂ e	tons of carbon dioxide equivalent
W	watt

Currency Equivalents

Currency Unit = Renminbi
RMB 6.25 = US\$1

Main Messages

More than half of China's population still relies on solid fuels (coal and biomass) for cooking and heating; many of these households, located mainly in rural areas, are likely to continue using solid fuels in the near future. Switching to modern energy alternatives would be the most effective way to achieve clean cooking and heating solutions and should be encouraged; yet such fuels are more expensive than solid fuels, requiring more costly stoves and delivery infrastructure. Poorer rural households without access to affordable modern fuels and improved stoves are unlikely to transition up the energy ladder on a large scale and will likely continue to depend on solid fuels as their primary source of cooking and heating energy. The International Energy Agency estimates that, by 2030, some 280 million people in China will still rely on solid fuels for cooking and heating.

Effective strategies to scale up the dissemination of clean-burning, fuel-efficient stoves for household cooking and heating can mitigate the health hazards associated with the burning of solid fuels. It is estimated that household air pollution (HAP) from solid fuel use results in more than a million premature deaths each year in China. In addition, the combustion of locally-produced coal with high

fluoride and arsenic content is a major cause of endemic fluorosis and arseniasis.

Scaled-up access to clean and efficient stoves is consistent with China's strategy to promote energy conservation, reduced carbon emissions, and green energy in villages. Achieving universal access to modern energy services by 2030 is the goal set by the United Nations, which declared 2012 as the Year of Sustainable Energy for All. With its large population lacking access to modern energy services, China will play a key role in achieving this global goal.

The China Clean Stove Initiative (CSI) reflects the World Bank's shared commitment with China's government to bring clean cooking and heating solutions to all of the country's citizens by 2030. In collaboration with the Ministry of Agriculture's Department of Science, Technology, and Education, the World Bank launched the China CSI in early 2012. The initial CSI stocktaking exercise calls for a comprehensive strategy comprising institutional strengthening and building of an enabling policy and regulatory environment, market and business development, and stimulation of household demand, supported by an innovative, results-based financing approach.

Executive Summary

Despite China's impressive achievements in economic growth and poverty reduction, more than half of the country's population still relies on solid fuels for cooking and heating, and many households are likely to continue using solid fuels in the near future. Today, nearly half of China's 263.8 million rural households use wood and agricultural residues as their primary cooking fuels, while another 57.6 million depend on coal. Transitioning up the energy ladder to such modern alternatives as liquefied petroleum gas (LPG) and electricity would be the most effective way to achieve clean cooking and heating solutions and should be encouraged; yet such fuels are far more expensive than solid fuels, requiring more costly stoves and delivery infrastructure. By contrast, biomass resources, which are relatively abundant and accessible, can be freely collected from the local environment or purchased for significantly less than other fuels. The International Energy Agency estimates that, by 2030, some 280 million residents—including many poorer rural households—will still depend heavily on solid fuels for cooking and heating.

During the 1980s and 1990s, China's National Improved Stoves Program (NISP), one of the world's most successful stoves programs, distributed some 180 million improved stoves. After the NISP ended in late 1990s, the private sector assumed responsibility for stove commercialization. As of 2011, it was producing about 2.6 million clean coal heating stoves, 20 million honeycomb coal cooking stoves, and 1.6 million clean biomass stoves. **Yet stove development and production have not kept pace with the multidimensional challenge of promoting clean stoves; at the current pace, it will take decades for advanced stoves to reach all households.**

Household burning of solid fuels is a major health hazard in China. It is estimated that household air pollution (HAP) from solid fuel use results in more than a million premature deaths each year in China. In addition, the combustion of locally-produced coal with high fluoride and arsenic content is a major cause of endemic fluorosis and arseniasis. In 2000, for example, nearly 34 million people in 201 counties were affected by coal-burning endemic fluorosis. Mitigating the health hazards associated with household burning of solid fuels will require developing and implementing strategies for scaling up the dissemination of clean-burning, fuel-efficient stoves for cooking and heating that rural households are willing to adopt.

Scaled-up access to clean and efficient stoves is consistent with China's strategy to promote energy conservation, reduced carbon emissions, and green energy in villages. Achieving universal access to modern energy services by 2030 is the goal set by the United Nations, which declared 2012 as the Year of Sustainable Energy for All. With its large population lacking access to modern energy services, China will have an important role to play in achieving this global goal.

The China Clean Stove Initiative (CSI) aims to scale up access to clean cooking and heating solutions for poorer, primarily rural households who are likely to continue relying on solid fuels beyond 2030. The World Bank, in collaboration with the Ministry of Agriculture's Department of Science, Technology, and Education, launched the China CSI in early 2012. This initiative, one of four country-specific programs under the East Asia and Pacific CSI, funded by the Australian Agency for International Development (AusAID), focuses on capacity building, policy development, and support of selected government action plans. The program consists of four phases: (1) initial stocktaking and development of the proposed strategy; (2) institutional strengthening, capacity building, and piloting of the strategy; (3) scaled-up program implementation; and (4) program evaluation and dissemination of lessons learned. This study reflects the findings of the initial stocktaking review, which included a stove supply survey and stakeholder consultations.

Across China's vast rural landscape, most rural households' energy consumption is for cooking and heating and the majority rely on solid fuels to meet these needs. Cooking and heating account for 90 percent of rural household energy use. Eighty-six percent of rural households use solid fuels as their primary cooking energy. Biomass (wood and straw) comprises more than three-fifths of rural household energy for cooking, while coal accounts for one-quarter. In Central China, coal accounts for nearly two-fifths of household cooking energy, surpassed only by biomass. Less reliance on solid fuels for cooking is found only in a few more economically developed provinces in the East. Demand for household heating, which accounts for more than one-third of rural energy consumption, continues to rise, along with improving living standards and greater demand for comfort. Coal is the predominant heating fuel for rural households without central or electric

heating, with the exception of Southwest China, where wood predominates.

Households' selection of energy sources for cooking and heating depends, in large part, on the interdependent factors of fuel availability, accessibility, affordability, and cultural acceptability. Availability of fuels is a primary consideration for fuel and stove selection. For example, in agricultural areas, biomass straw is the primary cooking fuel, while animal dung predominates in pastureland and firewood in mountainous regions. In addition, households must select their fuels from those that are accessible. For example, they might be prevented from collecting firewood in certain areas owing to natural physical limitations or policy and regulatory restrictions. Another key factor is fuel affordability, which depends on households' income level and the cost of stoves and fuels. Finally, fuels must be culturally acceptable, meaning that they must meet households' preferences for food taste and fit well with local cooking habits, cultural traditions, and climatic conditions. For example, the widespread use of solar cookers in Tibet is driven not only by the region's abundant availability of solar energy resources. Additional drivers of fuel selection are the lack of other energy resources, such as coal and biomass, as well as the portability of solar cookers, which fits well with the nomadic lifestyle of Tibetan farmers.

China has one of the world's largest biomass stove industries; yet reliance on subsidies is heavy, with little commercialization. Some procurement programs have paid more attention to stove price than quality. Delays in setting product standards have meant that some stove products have been on the market for several years without having national or industry standards. Also, the quality and performance of stoves on the market vary significantly, and pirating of quality brand names is not uncommon. In addition, after-sales service and training are insufficient, small enterprises often lack technological innovation, and some stove designs are inferior. A top concern among producers is the lack of a biomass briquette supply chain, owing to high cost and a low technology level.

China's coal stove market is highly commercialized, having developed rapidly due to the large market potential; at the same time, product quality is patchy, performance varies considerably, and household demand can be widely dispersed. Since poorer families tend to prioritize stove price over concerns of safety, efficiency, and pollution, demand is met with low-quality, lower-priced products. Since the market is insufficiently regulated, it is flooded with shoddy imitation products. Simple, low-efficiency stoves still comprise about four-fifths of coal cookstoves in most parts of China.

Development of China's household biogas industry has been impressive; however, recent years have witnessed a diminishing enthusiasm among farming households for constructing and using biogas systems. Over the past decade (2000–10), the number of farming households using biodigesters has risen sharply—from 8.5 million to 38.51 million—owing, in large part, to government-supported efforts. At the same time, the service system has lagged far behind the needs of biogas users. Decreased individual cultivation of livestock has led to a decline in the raw materials used for generating biogas and thus the number of qualifying households for installation. The required upfront investment is large, while the subsidy level cannot compensate for the increasing cost of system construction; and slow technological progress has restricted innovation.

China has the largest stock of solar cookers in the world; however, sales rely mainly on government procurement and subsidies. The purely commercial market for solar cookers accounts for less than one-fifth of sales because demand is centered in poorer regions, where profitability is low. Also, the quality of solar cookers varies greatly, suggesting a strong need for better production technology and greater capacity in standardizing product performance.

Successful stove dissemination programs across these four market segments—biomass, coal, biogas, and solar cookers—offer valuable lessons that can be applied to designing and implementing future interventions. Stove promotion strategies must be based on local conditions, including fuel availability, climatic conditions, income level, and lifestyle. Also, a market-based approach to promoting stoves should be explored to ensure sustainability. In addition, product standardization and quality control are needed to build an enabling environment for market development. Furthermore, strong government commitment is required, while the subsidy scheme must be designed carefully to ensure sustainable development. Finally, by integrating stove promotion into broader programs (e.g., energy efficiency and conservation, poverty alleviation, and health improvement) that include awareness-raising campaigns, multiple issues can be targeted to generate co-benefits.

China's stove dissemination and household energy policies have achieved numerous positive results, yet issues remain that impede the potential for larger-scale success and longer-term sustainability. Systematic programs with a firm policy commitment are needed to achieve sustainable development of the stove market. Also, since clean cooking and heating solutions involve cross-cutting issues, they require strengthened cooperation and collaboration among relevant departments at all levels. In addition, more flexible subsidy schemes that incorporate

monitoring and evaluation (M&E) are needed to directly link program results to subsidy disbursement. Furthermore, public-awareness campaigns that center on the benefits of clean stoves must be strengthened in order to change household behavior and thus develop demand for better products. Moreover, research is needed to obtain better data on the supply chain, stove market segments, and stove technology.

To scale up access to clean stoves, the CSI strategy calls for (1) strengthening institutional capacity and building an enabling environment, (2) supporting supply-side market and business development, and (3) stimulating household demand for clean and efficient stoves.

Key elements of institutional strengthening and building an enabling environment include establishing/strengthening an institutional focal point; a cross-sectoral coordination mechanism and platform for communication and cooperation; and stove standards, testing, and certification. Supply-side support includes providing financial incentives for delivering clean cooking and heating solutions to households and supporting market research and R&D on better stoves and fuel-processing technologies; while demand-side support requires promoting broad-based awareness-raising campaigns, along with engaging communities and civil society, motivating consumers, and providing suppliers user feedback.

To make government funding support more effective and efficient, Results-Based Financing (RBF) is recommended.

This innovative approach disburses public resources against demonstrated, independently verified outputs or outcomes instead of project inputs. This distinguishing feature can mean better use of public funds and improved

support of market interventions. The conceptual framework for using RBF in programs to promote clean stoves could include three key building blocks—(1) defined clean stoves, (2) results-based incentives, and (3) a monitoring and verification (M&V) system—supported by two pillars—(1) institutional strengthening and capacity building and (2) awareness-raising campaigns. The RBF framework not only integrates all of the strategy's intervention priorities; it also helps to clarify the roles of government and the private sector in delivering the results; that is, the government plays a facilitating role, providing policy support and financial incentives to motivate market development, while the private sector responds to the incentives and delivers the results.

The next phase of the China CSI will focus on (1) improving the stove standards, testing, and certification system; (2) strengthening institutions and building the capacity of key market players; (3) supporting pilots; and (4) supporting preparation of China's second national clean stoves program and provincial activities.

Improving stove standards and testing will include strengthened coordination with the Global Alliance for Clean Cookstoves, building of a regionally recognized stove testing center, and developing compatibility between China's clean-stove standards and the international framework. Institutional strengthening will focus on the cross-sectoral coordination mechanism and the platform for communication, learning, and cooperation. The RBF approach will be piloted in areas identified as representative and scalable. Finally, the CSI will work closely with the Ministry of Agriculture to support preparation of China's second national clean stoves program and provincial rural energy projects that target increased access to clean cooking and heating solutions.

Introduction

Today more than 700 million people in China—nearly two-thirds of the country’s rural population and one-third of urban residents—rely heavily on solid fuels to meet their daily cooking and heating needs. Although switching to clean modern fuels (e.g., natural gas, liquefied petroleum gas [LPG], and electricity) would be the most direct and effective way to achieve clean cooking and heating solutions and should be encouraged, such fuels are usually more expensive than solid fuels, requiring more costly stoves and delivery infrastructure. By contrast, many types of biomass can be freely collected from the local environment or purchased for significantly less than other fuels. Thus, large-scale fuel switching, particularly in rural areas, is unlikely to occur until rural economies become substantially more developed. Over the next decade, it is estimated that heavy reliance on solid fuels for cooking and heating will continue, especially in rural areas.

Overview of Program Context

During the 1980s and 1990s, China’s National Improved Stoves Program (NISP) was one of the world’s most successful stoves programs, distributing some 180 million improved stoves countrywide. When the NISP ended in the late 1990s, the private sector assumed responsibility for stove commercialization; as of 2011, the private sector produced approximately 2.6 million clean coal heating stoves, 20 million honeycomb coal cooking stoves, and 1.6 million clean biomass stoves. Despite these achievements, the development and production of advanced biomass stoves has not kept pace with the multidimensional challenge of promoting clean stoves. At the current pace, it will take many years for advanced stoves to reach all households. Clearly, China’s government needs to take more proactive steps, building on its earlier successes.

BOX 1.1 WHAT ARE THE HEALTH IMPACTS OF HOUSEHOLD AIR POLLUTION IN CHINA?

Household burning of solid fuels is a major health-risk factor in China. The Global Burden of Disease Study 2010 estimates that each year about 1.04 million premature deaths in China can be attributed to HAP linked to smoke emitted from solid cooking fuels (Lim et al. 2012). The use of solid fuels for cooking and heating is linked to an increased risk of cardiovascular disease, acute respiratory infections, chronic obstructive pulmonary disease, cancer, and cataracts. Among all risk factors of ill health estimated globally, it ranks fourth, surpassed only by high blood pressure, tobacco use, and alcohol use (Lim et al. 2012).

The combustion of locally-produced coal with high fluoride and arsenic content is a major cause of endemic fluorosis and arseniasis. In 2000, 201 counties, representing approximately 33.678 million people, were affected by coal-burning endemic fluorosis, with Guizhou and Shanxi provinces hardest hit. That same year, 8 counties, with some 330,000 residents, were affected by coal-burning endemic arseniasis (Jia 2011).

Source: Lim et al. 2012; Zhang and Wu 2012.

The pervasive use of solid fuels in China has significant negative impacts on health, gender equality, poverty reduction, and the local ecology and global environment. Each year more than a million premature deaths in China are attributed to household air pollution (HAP) from cooking with solid fuels (Lim et al. 2012). The poor, women, and young children are disproportionately affected; that is, the poor rely heavily on solid fuels for cooking and heating, women devote much of their day to household fuel collection and cooking, and young children spend many hours indoors close to their mothers while they are cooking (box 1.1). Solid fuel use is also closely intertwined with poverty. Time allocated to the collection and inefficient utilization of biomass energy deprives household members, particularly women, of the opportunity for education, income generation, leisure, and other productive activities. Furthermore, extensive fuelwood collection for use with traditional biomass cookstoves is often linked to local deforestation, and the household combustion of solid fuels using traditional technologies is a major source of black carbon emissions, which have a comparatively large impact on global warming (USAID 2010).

Now is an opportune time for the Government of China to take action. Recently, China raised its rural poverty line from RMB 1,196 to RMB 2,300, meaning that those who earn less than RMB 2,300 (US\$368) per year—about 128 million rural people—are now classified as poor, compared to only 26.9 million previously. Scaling up access to clean and efficient stoves would be an important step in reducing poverty and is consistent with China's strategy to promote energy conservation and reduced carbon

emissions, as well as green energy in villages. Internationally, achieving universal access to modern energy services by 2030 is the goal set by the United Nations, which declared 2012 as the Year of Sustainable Energy for All. With its large population lacking access to modern energy services, China will have an important role to play in achieving this global goal.

China Clean Stove Initiative

Against this backdrop, the World Bank, in collaboration with the Ministry of Agriculture's Department of Science, Technology, and Education, launched the China Clean Stove Initiative (CSI) in early 2012. As part of the East Asia and Pacific (EAP) Clean Stove Initiative, the China CSI aims to scale up access to clean and efficient cooking and heating solutions in China through capacity building, policy development, and support of selected government action plans (box 1.2).

The China CSI comprises four program phases. The first phase centers on initial stocktaking, which is critical for developing an effective strategy, designing subsequent program phases, and establishing policy dialogue with the country's institutional focal point. The second phase focuses on the institutional strengthening and capacity building required for implementing the strategy and pilot programs. The third phase scales up implementation of the clean stoves program, while the fourth focuses on program evaluation and dissemination of lessons learned.

BOX 1.2 EAP CLEAN STOVE INITIATIVE

The East Asia and Pacific (EAP) Clean Stove Initiative is a follow-up regional program to the energy flagship report, *One Goal, Two Paths: Achieving Universal Access to Modern Energy in East Asia and the Pacific*. It focuses on achieving access to modern cooking and heating solutions in the EAP region, particularly scaled-up access to advanced cooking and heating stoves for poor, primarily rural households, who are likely to continue relying on solid fuels to meet most of their cooking and heating needs beyond 2030.

With funding support from the Australian Agency for International Development (AusAID), the EAP CSI comprises four country-specific programs (China, Indonesia, Laos, and Mongolia) and a regional forum to promote regional collaboration, learning, and knowledge-sharing on access to modern energy at the household level. The initiative takes a three-pronged approach, focusing on (1) strengthening institutional capacity and creating an enabling policy and regulatory environment for scaling up access to advanced stoves, (2) supporting supply-side market and business development, and (3) stimulating demand for clean and efficient stoves.

Sources: World Bank 2011a, 2011b.

Study Purpose and Objectives

This study is the key activity under the first phase of the China CSI. Its broad aim is to help households reliant on solid fuel use to achieve clean cooking and heating solutions by 2030. Specific objectives are to gain a better understanding of the challenges facing China's household cooking and heating technologies and markets, review the existing policy and institutional framework for cooking and heating fuels, and identify lessons from successful programs that can be applied to future programs promoting clean cooking and heating solutions.

Methodology

Because household use of cooking and heating stoves in China is specific to each region's unique level of development, climate, fuel availability, cooking customs, and

socioeconomic conditions, the study conducted in-depth assessments of the existing stove market and review of the sector's institutions, policies, and key stakeholders. To obtain the required inputs from all key stakeholders for development of the strategy, two major activities were designed: (1) stocktaking review, including a stove supply survey and (2) stakeholder consultations, including two national consultation workshops. Clarification of the terminology used in this report is provided below (box 1.3).

The stocktaking review used both primary and secondary data sources. Primary data was collected through a survey of the biomass stove supply chain, including producers, wholesalers, and retailers throughout the country (Annex B). Conducted by the China Alliance for Clean Stoves (CACs) and China Stoves Website, the survey's aim was to better understand the current status of China's stove market. Questionnaires were sent to both

BOX 1.3 TERMINOLOGY CLARIFICATION

Unless otherwise noted, the definitions used in this report are as follows:

- *Traditional stove* refers to a rudimentary baseline stove (either open fire or constructed by artisans or household members) that is energy-inefficient with poor combustion features.
- *Clean stove* refers to a stove that is either built in situ or mass produced that, with the benefit of laboratory research, performs better in fuel efficiency, emissions, durability, and safety than open fires or rudimentary traditional cookstoves. While in-situ built clean stoves include improved in-situ stoves and improved Kangs (heating beds commonly used in northern China), mass-produced clean stoves, referred to as manufactured clean stoves, can be further grouped by use into cooking, heating, and combined cooking and heating (i.e., comprising both cooking and heating and cooking and water heating).

(In this report, the term *clean stove* is broadly used; it is recommended that the stove standards/testing/certification system be strengthened to more clearly define the term.)

- *Improved stove* refers to stoves installed in legacy programs and represents the lower segment of clean stoves.
- *Advanced stove* refers to a higher segment of clean stoves with superior performance and often using processed biomass or coal if solid fuels are used.
- *Solid fuels* refer to coal, charcoal, wood-based biomass fuels, agricultural residues, and dung.
- *Modern energy* is used to distinguish ways of using energy rather than types of fuel; thus, *modern or clean cooking and heating solutions* refer to cooking or heating with modern fuels (e.g., electricity, natural gas, LPG, and biogas) or solid fuels used with clean and efficient stoves.

Source: Authors.

manufacturers and dealers nationwide. Additional information was collected through subsequent field trips, which included visits with selected stove manufacturers. Statistical yearbooks provided the main source of secondary data.

As part of stakeholder consultations, two national workshops brought together key stakeholders from China's central and provincial governments, nongovernmental organizations (NGOs), universities, and the private sector. The first workshop, held on April 24, 2012, launched the CSI during China's 6th Clean Stove Expo and International Forum in Gaobeidian city, Hebei province. At that event, more than 100 stove manufacturers exhibited their products, while international and national experts exchanged ideas and information on recent policy and technology developments. At the workshop, the team presented the study structure and initial findings and gathered comments and input toward improving results of the findings. The second workshop, held July 20, 2012 in Beijing, discussed the final stocktaking results and the proposed CSI program strategy and also generated ideas for the second program phase.

Structure of This Report

This report is organized into five chapters. Chapter 2 presents an overview of household cooking and heating fuels used in rural China and recommends stove types suitable for various regions, based on identified drivers of household fuel selection. Chapter 3 suggests how the supply sector can overcome barriers to market development based on analyses of four stove market segments. Chapter 4 analyzes the current policy environment for clean stoves development, identifying program and institutional gaps that future intervention programs will need to fill. Finally, chapter 5 presents the proposed CSI strategy, including an innovative financing approach, and the proposed next steps in helping China scale up access to clean cooking and heating solutions.

Household Cooking and Heating Demand

The rapid growth of China's rural economy in recent years has changed rural households' concept of consumption and quality of life. By 2010, household energy consumption had reached 346 million tce,¹ with cooking and heating accounting for about 90 percent of all rural household energy use (CACS 2012). As living standards have improved, rural households have begun diversifying the types of fuels they rely on to meet daily cooking and heating needs.

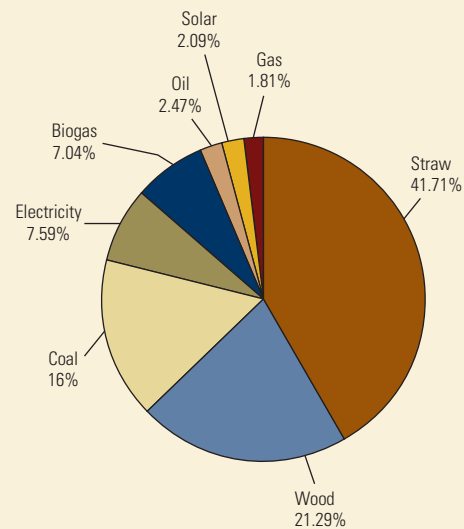
This chapter analyzes the energy used by China's rural households for cooking and heating. The next section offers an overview of the main types of cooking and heating fuels used by rural households. This is followed by analyses of the distribution of cooking and heating fuels across regions and a discussion of the key drivers of rural households' fuel selection. Based on these factors, broadly classified stove types are recommended as suitable for use in these various regions.

Overview of Rural Household Energy

In 2010, traditional, non-commercial biomass dominated the structure of China's rural household energy; also evident was the rapid growth of other renewable energy sources, along with a significant role for modern fuels

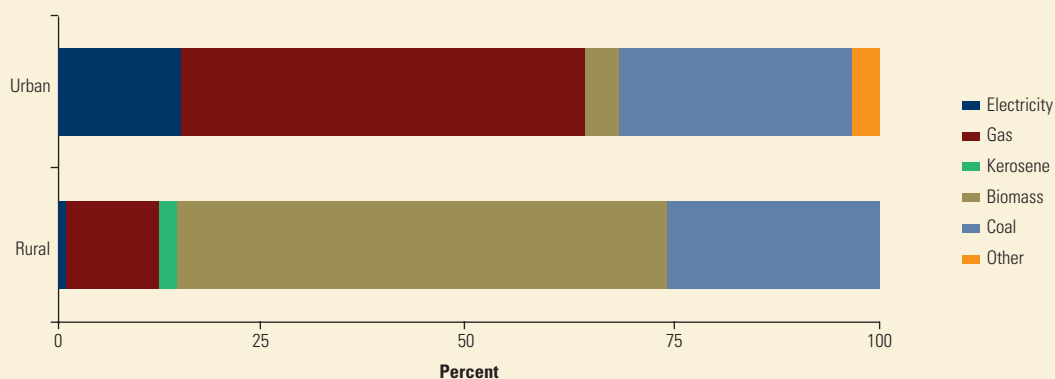
(figure 2.1). Traditional biomass (straw and wood) comprised 63 percent of the total; while commercial energy (coal, electricity, oil, and gas) contributed 28 percent, and other renewable sources (biogas and solar) accounted for the remaining 9 percent.

FIGURE 2.1 STRUCTURE OF CHINA'S RURAL HOUSEHOLD ENERGY, 2010



Sources: China Agriculture Statistical Yearbook 2010; China Energy Statistical Yearbook 2011.

1. According to China's National Bureau of Statistics, household energy use accounted for 10.65 percent of the country's total energy consumption (i.e., 3.25 billion tce) in 2010 (http://www.stats.gov.cn/tjgb/ndtjgb/qgndtjgb/t20110228_402705692.htm).

FIGURE 2.2 PRIMARY HOUSEHOLD COOKING ENERGY IN URBAN AND RURAL AREAS, 2006

Sources: National Bureau of Statistics 2008; Carolina Population Center 2008.

Mapping Rural Household Energy for Cooking

China's household energy structure for cooking varies significantly between rural and urban areas. In rural China, households rely heavily on solid fuels for cooking. More than 133 million rural households—over three-fifths of all rural households—depend on wood and agricultural residues to meet their cooking demand; by contrast, only 4.3 percent of urban households use wood as their primary cooking fuel. Conversely, modern fuels (i.e., gas and electricity) comprise 64.3 percent of total household cooking energy in urban areas, compared to only 12.7 percent in rural areas. However, more than one-quarter of households in both rural and urban areas depend on coal to meet their daily cooking needs (figure 2.2).

China's broad variance in rural households' use of cooking fuels and energy-consumption levels reflects the country's large variations in population density, energy resources, economic development, living habits, climate, and housing structures. For example, in agricultural areas, biomass straw is the primary cooking fuel, while dung predominates in pastureland and wood in mountainous regions. Nationwide, biomass (wood and straw) comprises more than 60 percent of rural household energy for cooking, and more than 88 percent in the Northeast, where the use of electricity is a meager 0.3 percent, 0.5 percentage points less than the national average (table 2.1).

After biomass, coal is the second most widely used cooking fuel, having been adopted by 57.6 million rural households. In Central China, coal accounts for more

than 38 percent of household cooking energy, surpassed only by biomass. Some 26.4 million rural households rely on liquefied petroleum gas (LPG) and natural gas; the East exhibits the greatest household use, at 27.2 percent. Finally, about 1.45 million rural households rely on biogas and another 0.59 million on other forms of cooking energy. The West exhibits the largest share of biogas and electricity use, at 1.3 percent each (table 2.1).

Solid Fuel Use

Eighty-six percent of China's rural households—located mainly in provinces of Central and East China—use solid fuels (in the form of biomass or coal) as their primary cooking energy. In six provinces—Henan, Hunan, and Anhui (Central China); Hebei and Shandong (East China); and Sichuan (West China)—the vast majority of rural households rely on biomass and coal for cooking, with Henan and Hunan exhibiting the highest proportions, at 97 percent each (20 million and 15 million households, respectively). In terms of number of households, Sichuan exhibits the highest reliance on biomass, at 15 million households, while the greatest reliance on coal is found in Henan, at 10 million households (table 2.2). The least reliance on solid fuels for household cooking is found in the more developed municipalities, including Shanghai, Tianjin, and Beijing.

In 22 provinces, reliance on solid fuels for household cooking exceeds 90 percent. Even in the sparsely populated provinces of Northwest China, solid fuels are widely used for cooking, while a relatively lower utilization rate is found in southeastern coastal provinces.

TABLE 2.1 RURAL HOUSEHOLDS' PRIMARY COOKING FUEL USE, BY ECONOMIC REGION
Percent households

Energy type	East	Central	West	Northeast	Nationwide
Biomass (wood and straw)	53.1	56.9	66.2	88.2	60.2
Coal	18.5	38.4	27.1	7.4	26.1
LPG and natural gas	27.2	3.8	3.2	4.0	11.9
Biogas	0.2	0.7	1.3	0.1	0.7
Electricity	1.0	0.2	1.3	0.3	0.8

Source: National Bureau of Statistics 2008.

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

Biomass

The use of biomass to meet rural households' cooking needs varies widely by province (map 2.1a). The least dependence on biomass cooking energy is generally found in the East; in the municipality of Beijing, for example, only 15 percent of households rely on biomass to meet their cooking needs, compared to 93 percent in Jilin. In the Northeast, the vast majority of households rely on biomass. In addition, the western province of Sichuan, the eastern province of Shandong, and the central province of Henan have significant numbers of rural households that depend mainly on biomass for cooking.

Coal

As previously mentioned, coal is rural China's second most common cooking fuel, used by more than one-quarter of households, with the highest adoption rate for coal stoves (38.4 percent) found in Central China. More than half of rural households in the central provinces of Shanxi and Hunan and the western provinces of Ningxia

and Guizhou rely on coal as their primary source of cooking energy. In the western province of Shaanxi, approximately 5.6 million households—more than four-fifths of rural households—use coal as their main cooking fuel. The lowest adoption rate for coal stoves (7.4 percent) is found in the Northeast, where biomass use predominates (map 2.1b).

Biogas

China's application of household biogas is continuously ranked first in the world and has the widest scope and most extensive impacts. In addition, the state has strongly supported the construction of biogas units using agricultural waste, which has accelerated development and led to a new direction in system construction. According to the Ministry of Agriculture, total production in 2010 was 13.08 billion m³. That year witnessed 40.27 million biogas users, including 38.51 million households and 1.76 million centralized users, with one-third of all

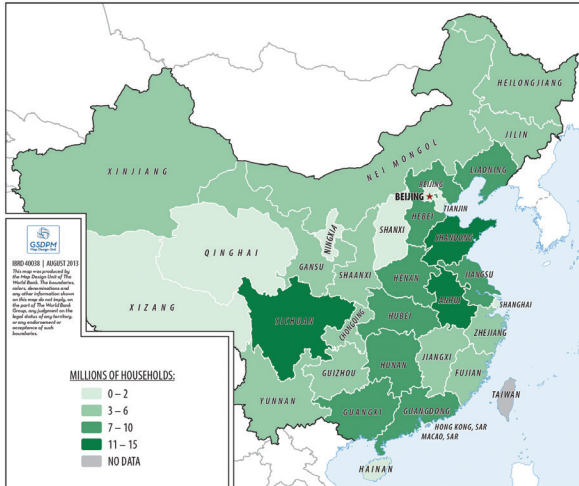
TABLE 2.2 TOP SIX PROVINCES EXHIBITING RELIANCE ON SOLID FUELS FOR RURAL HOUSEHOLD COOKING

Province	Region	Biomass		Coal		Solid fuel use	
		Households (million)	%	Households (million)	%	Households (million)	%
Henan	Central	10	47	10	50	20	97
Hunan	Central	7	46	8	51	15	97
Sichuan	West	15	73	4	21	19	94
Anhui	Central	11	80	2	13	13	93
Hebei	Central	7	49	7	44	14	93
Shandong	East	14	65	5	24	19	89

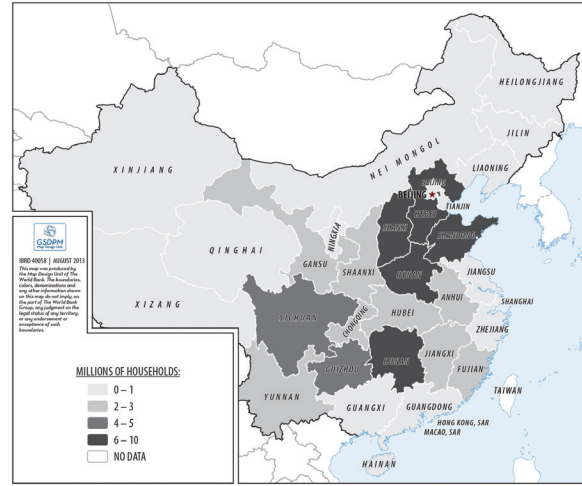
Source: National Bureau of Statistics 2008.

MAP 2.1 DISTRIBUTION OF RURAL HOUSEHOLDS USING SOLID FUELS AS PRIMARY COOKING ENERGY

a. Biomass



b. Coal

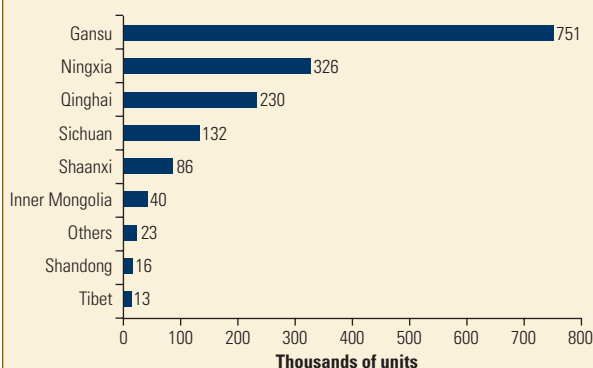


Source: National Bureau of Statistics 2008.

farming households for whom biodigester installations would be suitable represented (map 2.2).

At the provincial level, the number of households with biodigester systems ranges widely, from under 1,000 units in Shanghai to more than 5 million in Sichuan.² The western province of Guangxi has more than 3.5 million biogas-using households, as does the central province of Henan; in 2010, each of these provinces produced approximately 1.2 billion m³. Regions with the least numbers of biogas users (i.e., fewer than 50,000) include the municipalities of Beijing, Shanghai, and Tianjin.

FIGURE 2.3 PROVINCIAL DISTRIBUTION OF SOLAR COOKERS AMONG RURAL HOUSEHOLDS, 2010



Source: China Agricultural Statistical Yearbook 2010.

Solar Cookers

By the end of 2010, the national stock of solar cookers in China had reached more than 1.6 million units, concentrated mainly in the West. Gansu alone accounted for nearly half of the solar cooker inventory that year, with 751,000 units. Ningxia followed with 326,000 units, less than half that of Gansu. In Northeast China, a limited number of households relied on solar energy for cooking, but at a lesser magnitude (figure 2.3).

Household Heating Demand

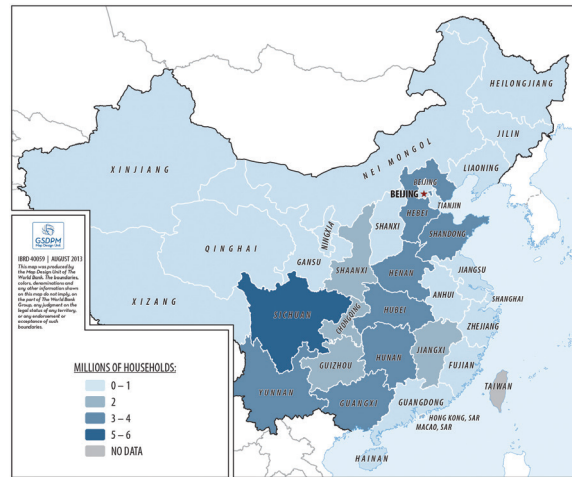
In addition to demand for household cooking energy, household heating energy constitutes a substantial portion of China's total energy consumption, especially in colder climates. It is estimated that more than one-third of rural energy consumption is for heating (CACS 2012). Approximately half of China's area requires winter heating, particularly in northern-latitude regions, where temperatures typically fall below the freezing point during the colder season (October–March).

District Heating

In the 1960s, working units first introduced urban areas to district heating as part of an urban welfare effort; a decade later, district heating was widely used. After the 1990s, working units changed the urban welfare heating model to a social commodity one; and multi-energy, regional heating and new models gradually developed.

2. Sichuan accounted for 14 percent of total production in 2010.

MAP 2.2 DISTRIBUTION OF BIOGAS-USING RURAL HOUSEHOLDS, 2010



Source: China Agriculture Statistical Yearbook 2010.

More recently, with further quality-of-life improvements, district heating has rapidly developed into the primary heating method in urban areas. Out of the total 668 cities in China, 286 have built district heating systems, mainly in the north (Xu et al. 2004).

Options Outside District Heating Areas

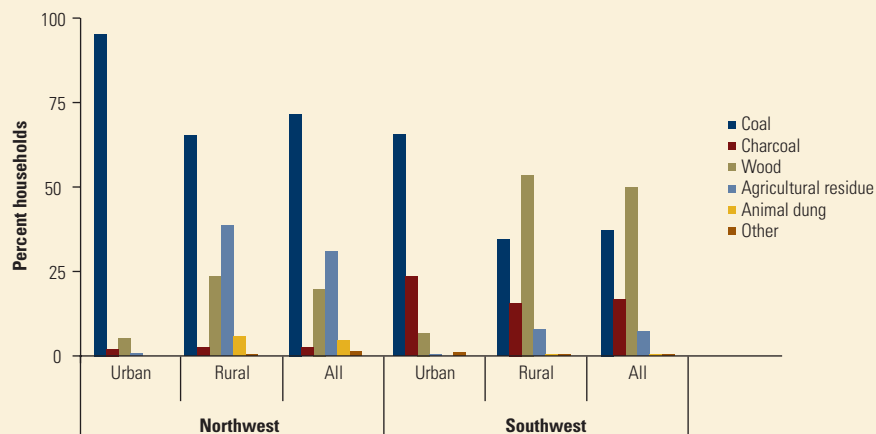
While demand for heating is increasing, households living south of the Huai River lack access to winter district

heating due to the political delineation between North and South. Their heating demand grows gradually with improving living standards and request for more comfort. Although rural households have a diversified fuel mix for heating (e.g., coal, agricultural residues, wood, gas, LPG, and biogas), wood and coal remain their primary heating fuels. The promotion of coal briquettes in rural areas has resulted in the adoption of a variety of coal stove models. In mid- and small-sized towns, coal is used for heating in villages and non-central areas, especially those north of the Yangtze River, which previously had not relied on coal for heating.

A large survey conducted by the National Research Center for Science and Technology for Development (NRCSTD) and the Fafo Institute for Applied International Studies (IAIS) in 2004–05 examined the heating and cooking fuels used by households in 11 western provinces of China. The findings showed that coal and wood are the respective dominant heating fuels in areas of the Northwest and Southwest that lack access to district heating or electric heating facilities (e.g., electric heater and air conditioner). In the Northwest, more than 70 percent of such households rely mainly on coal for heating, while about 30 percent depend on agricultural residues. In the Southwest, by contrast, about half of such households rely on wood, while 34 percent use coal (figure 2.4).

Among households that rely on primitive solid fuels for heating, both the Northwest and Southwest exhibit urban-rural disparities, with the Southwest having the

FIGURE 2.4 HEATING FUEL USE BY URBAN AND RURAL HOUSEHOLDS IN NORTHWEST AND SOUTHWEST CHINA



Source: NRCSTD and Fafo IAIS 2006.

Note: At the time of the survey, all of the various fuels used were classified as primary fuels and more than one primary fuel was used; thus, the total proportion may exceed 100 percent.

Northwest = Inner Mongolia, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang; Southwest = Yunnan, Guangxi, Chongqing, Sichuan, Guizhou.

largest differences. In the Northwest, where urban households in particular, as well as rural ones, rely heavily on coal, an appreciable portion of rural households also depends on wood and agricultural residues. By contrast, in the Southwest, wood is the most common heating fuel among rural households, while urban residents depend primarily on coal. Rural households in the Southwest rely less on agricultural residues than do their Northwest counterparts, instead using more coal and charcoal.

Drivers of Household Fuel and Stove Selection

Households' selection of cooking and heating fuels depends on the interdependent factors of the availability, accessibility, and affordability of energy resources and their cultural acceptability. First, the availability of fuels in any specific area is a primary consideration for fuel and stove selection. Second, households must select their fuels from those accessible. Households might be prevented from collecting fuelwood or agricultural residues owing to natural physical limitations (e.g., difficult terrain or topography) or environmental and other policies and regulations (e.g., protected nature reserve) that restrict households' access to available fuels. Third, fuel affordability depends on both household budgets and fuel and stove costs. Finally, fuels must be culturally acceptable, meaning that they must meet households' preferences for food taste and must fit local cooking habits, cultural traditions, and climatic conditions. The subsections below discuss these key determining factors in more detail.

Resource Availability and Accessibility

China has an abundant variety of widely distributed and produced fuel resources. Biomass resources mainly include agricultural and forest residues, firewood, and animal dung. Agricultural and forestry resources (straw and wood) provide a wealth of raw materials for the development and use of biomass and biomass stoves. Coal resources are abundant, particularly in less developed provinces, and the country's vast territory is quite rich in solar energy resources. The subsections below discuss the availability and accessibility of these resources.

Straw

Since straw is a natural byproduct of harvesting or processing crops (e.g., food, oil, cotton, hemp, and sugar), its removal poses no threat to food security. As an organic resource, straw has multiple uses, such as agricultural fertilizer, animal feed, and raw material for making paper, as well as providing a fuel source. Based on

China's major agricultural production for 2010, the total straw output from crops that year was 834.65 million tons (map 2.3a). Straw resources are distributed throughout the central and northeastern agricultural regions, as well as some southwestern provinces and cities. Five provinces particularly rich in straw resources—Henan, Heilongjiang, Shandong, Hebei, and Jilin—accounted for more than two-fifths of the national total. The two major types of straw were from main food crops (e.g., rice, corn stalk, and wheat) and oil crops, which together comprised about 90 percent of the national total.

The types and quantities of residues in various areas are largely determined by the types of crops produced in these locales, which are ultimately determined by natural climatic and socioeconomic conditions, local customs, and culture. For example, rice straw is especially abundant in South and Southwest China because rice is the main staple in these regions; however, wheat straw and corn stalk are more typical of Northeast and North China.

Provinces with large amounts of straw resources also exhibit high demand for biomass stoves. Henan, Shandong, Sichuan, and Anhui each has more than 10 million households that rely on biomass for cooking; these four provinces are also richly endowed with straw resources, each having had more than 40 million tons in 2010. Interestingly, municipalities with quite limited agricultural residue (e.g., Shanghai, Beijing, and Tianjin) also exhibit low demand for biomass and biomass stoves.

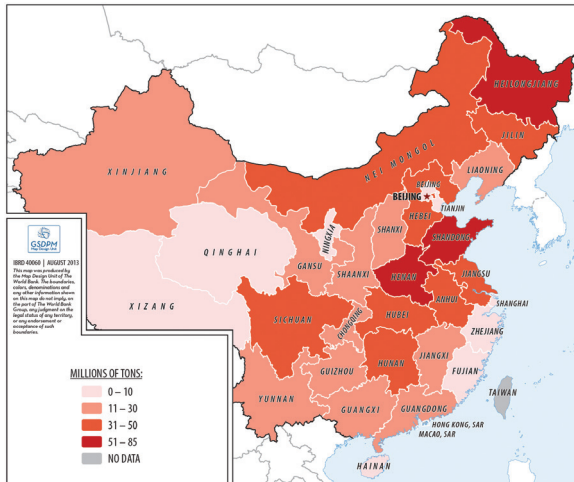
Firewood

From time immemorial, firewood has served as an energy source, with major applications for cooking, heating, and industry. Firewood resources include forest cutting wood and processing residues, pruning of fuel forest, timber forest, shelter forest, shrubbery, open forest, and "four-side tree." In 2005, the Sixth National Inventory of Forest Resources and Deforestation indicated that national firewood resources totaled 104.758 million tons. These are distributed mainly in forested regions of Heilongjiang, Sichuan, Yunnan, Hunan, and Hubei provinces. Northeast China, which is particularly rich in forest resources, has the greatest abundance of firewood resources (map 2.3b).

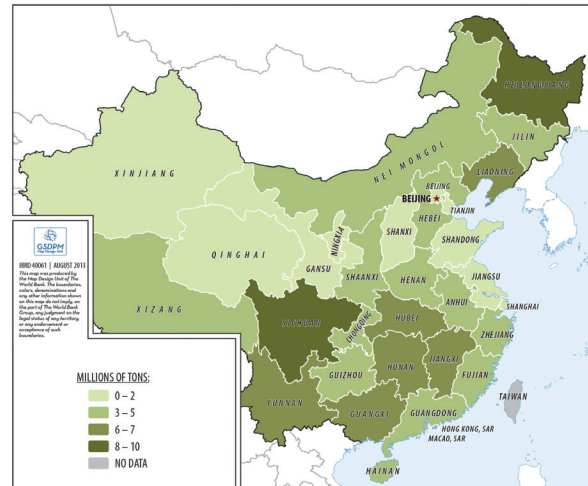
The availability of rich firewood resources in the Northeast has contributed to that region's high demand for biomass and biomass stoves. It has the highest proportion of biomass users, with 90 percent of rural households reliant on biomass to meet their daily cooking needs. Since this region is not as richly endowed with alternative energy sources (e.g., coal, solar, and advanced fuels), the

MAP 2.3 SOLID FUELS DISTRIBUTION

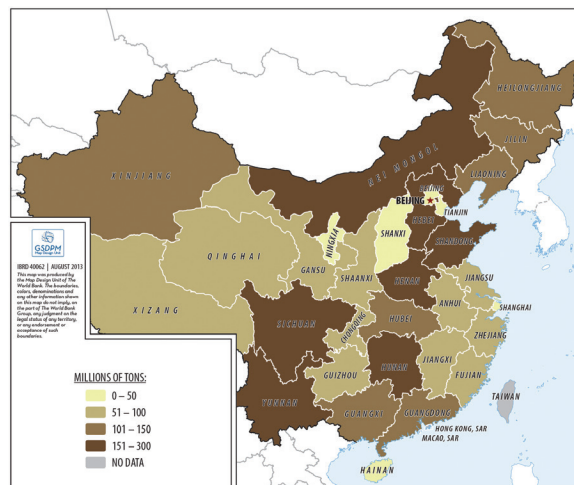
a. Agricultural Residues, 2010



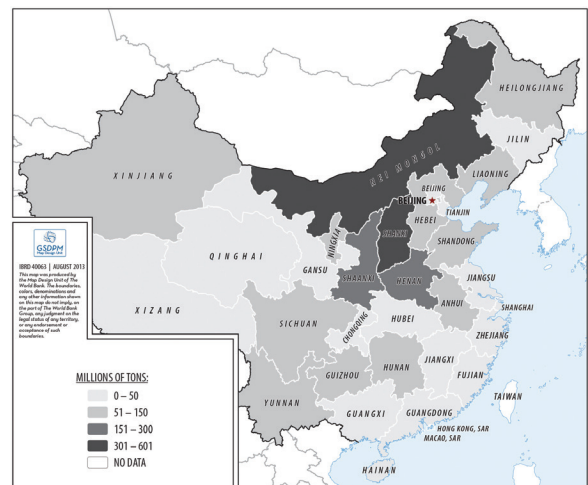
b. Firewood Resources, 2005



c. Animal Dung, 2010



d. Raw Coal Production, 2009



Sources: China Agriculture Statistical Yearbook 2010 (a); State Forestry Bureau 2005 (b); China Livestock Industry Yearbook 2011 (c); China Statistical Yearbook 2011 (d).

comparatively easy access to wood resources accounts, in large part, for the high level of biomass use.

Animal Dung

In certain regions, animal dung is an important biomass resource. It can be combusted directly after drying to provide heating supply and can produce methane and fertilizer through anaerobic digestion. Its production is related to animal species, varieties, gender, and growth period. In 2010, China's production of animal dung resources was estimated at 3.28 billion tons (China Livestock Industry

Yearbook 2011). Dung resources are distributed mainly in the provinces of Henan, Sichuan, Shandong, Inner Mongolia, and Hunan, where stockbreeding and the breeding industry are more developed (map 2.3c). In 2010, these five provinces accounted for 36.08 percent of all animal dung resources. The main types were produced from pigs and cows, which accounted for 44.12 percent and 27.56 percent, respectively, of the total.

As raw materials for household biodigesters, animal dung is closely related to the distribution of biogas. Provinces

TABLE 2.3 CHINA'S SOLAR RESOURCES, BY REGION

Zone	Level	Annual solar radiation (kWh/m ²)	Share of national total (%)	Area
I	Most abundant	≥1,750	17.4	Tibet, South Xinjiang, Qinghai, Gansu, and west Inner Mongolia
II	Very abundant	1,400–1,750	42.7	North Xinjiang, Northeast China, East Inner Mongolia, Hubei, North Jiangsu, Huangtu Plateau, East Qinghai and Gansu, West Sichuan, Hengduan Mountain, Fujian, South Guangdong, and Hainan
III	Abundant	1,050–1,400	36.3	Hill areas in Southeast, Hanshui river basin, and West Guangxi
IV	Normal	< 1,050	3.6	Sichuan and Guizhou

Source: Li and Wang 2007.

more abundant in animal dung resources are more likely to use household biogas systems. For example, Henan and Sichuan provinces, which in 2010 had 297 million and 269 million tons of animal dung resources, respectively, each had more than 3.5 million household users of biogas systems. Perhaps predictably, in municipalities with scant animal dung resources (e.g., Beijing, Shanghai, and Tianjin), the number of households using biodigesters totaled less than 0.05 million.

Coal

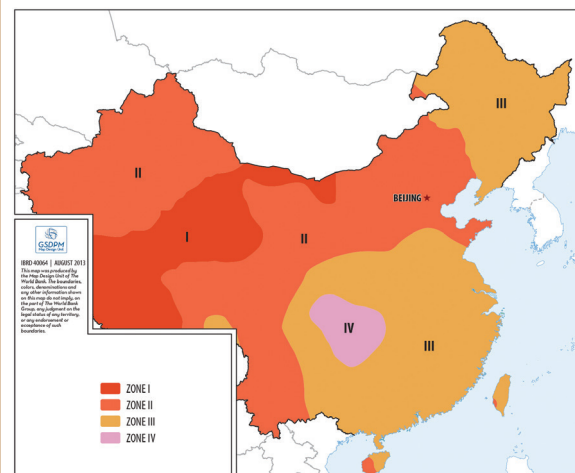
China has abundant, widely distributed coal resources. In 2010, national basic reserves of coal totaled 279.39 billion tons (China Statistical Yearbook 2011). These were concentrated mainly in such less developed provinces as Shanxi, Inner Mongolia, Xinjiang, Guizhou, and Henan. In all provinces, distribution of raw coal production follows the same pattern as that of basic reserves. In 2009, China's coal production, which totaled 2.95 billion tons, was centered in Central China. Shanxi and Inner Mongolia were the largest producers of raw coal, with 600 and 590 million tons, respectively, accounting for more than two-fifths of the national total (map 2.3d).

In Central China, coal is highly accessible, contributing to wide household adoption to meet cooking and heating demand. As the leader in coal production and reserves, Shanxi has approximately 5.6 million households that use coal as their main cooking fuel, representing more than four-fifths of the province's total households. The ease of obtaining coal in Shanxi may explain, in part, its wide use in that province. But unlike biomass fuels, which households can collect from the local environment or use free of charge, coal is a commodity with a market price, suggesting that affordability plays a relatively larger role in household fuel selection.

Solar

China's vast territory is quite rich in solar energy resources. Except for East Sichuan and Guizhou provinces, most areas are abundant in annual solar radiation. The country can be divided into four zones, ranked according to their level of solar resource availability (table 2.3, map 2.4).

The case of solar energy illustrates the importance of availability as a driver of household fuel selection. The large number of solar cookers used in Gansu is due, in large part, to the province's rich solar resources, combined with a severe shortage of biomass and conventional energy sources owing to harsh natural conditions. Over the years, farmers have had to dig up vegetation and roots and cut trees to compensate for the fuel deficit.

MAP 2.4 CHINA'S SOLAR RESOURCE DISTRIBUTION

Source: China Agriculture Statistical Yearbook 2010.

Since the 1980s, solar cookers, which freely utilize abundant solar energy resources, have gained in popularity.

Household Affordability

In rural China, affordability plays a critical role in households' choice of cooking fuels. In only three areas—Beijing, Zhejiang, and Shanghai—do less than half of rural households use solid fuels for cooking. In Beijing, Shanghai, and Tianjin, where rural per capita income exceeds RMB 8,000, the percentage of biomass-reliant households is low and residents are more likely to switch to modern fuels. Shanghai has the lowest percentage of biomass-reliant households at 22 percent, which is attributed to higher incomes and thus affordability levels. By contrast, in western provinces (e.g., Guangxi, Guizhou, Yunnan, Shaanxi, Qinghai, Gansu, Ningxia, Xinjiang, and Tibet), where rural per capita income falls below RMB 4,245—about half that of rural residents in East China and about 30 percent less than the average net rural household income per capita—households are more likely to rely heavily on solid fuels for cooking and are less likely to switch to modern fuels. A simple plot of the percentage of rural households reliant on solid fuels by income level demonstrates the likely negative correlation between the two variables, as evidenced by the nearly horizontal line for most lower-income levels, followed by a sharp decline when income levels rise above RMB 4,369 (figure 2.5).

Far more households in the eastern regions, compared to all other regions, use gas and natural gas. In Shanghai, Zhejiang, Beijing, Tianjin, and Guangdong, the share of modern fuels among rural households exceeds 40 percent, which corresponds to the highest income group. Thus, higher-income households are more likely to switch

to or continue using modern energy fuels, whereas poorer rural households are more inclined to continue using solid fuels, at least in the near term.

Cultural Acceptability

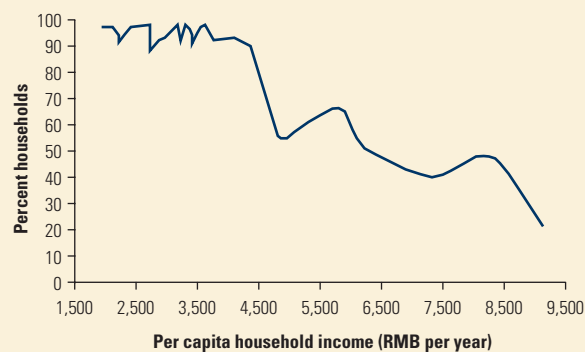
Beyond resource availability, accessibility, and household affordability, cultural acceptability is a key factor in households' selection of cooking fuels and stoves. Acceptability encompasses such considerations as local climate, food preferences, and cooking and heating habits. For example, in Tibet, the widespread use of solar cookers is driven not only by the province's abundant solar energy and shortage of other energy resources, such as coal and biomass. Tibetan farmers and herdsman lead a nomadic way of life and are dispersed across the province. They prefer cooking fuels that are portable and easily obtained. Thus, solar cookers fit well with their lifestyle.

Suitable Biomass Stove Types by Region

Among the four types of stoves and fuels, stoves fueled by biomass and coal exhibit the greatest demand, with coal stoves operating under a commercialized market. Demand is much smaller for biogas stoves and solar cookers; because their use depends more on fuel availability, it is location specific. Biomass stoves are used mainly by relatively poorer rural households, whose options for using advanced fuels and stoves are quite limited. To achieve universal access to modern energy services, meeting the energy needs of these rural households is key. Under conditions of sustainable production and more efficient fuel use, biomass is a renewable resource, suggesting the potential of biomass used for cooking and heating to bring about environmental benefits and generate income from carbon credits. Therefore, this study gives special focus to biomass stoves, while also recognizing the need to remain open to other technology options.

Based on the major factors that drive households to select fuels and stoves, this section broadly classifies those potentially suitable for five regions of China. Clean biomass stoves can either be built in situ or mass-produced. The former include improved in-situ stoves and improved Kangs, while the latter, referred to as manufactured clean stoves, can be further grouped by use into cooking, heating, and combined cooking and heating; combined cooking and heating comprise both cooking and heating and cooking and water heating. Table 2.4 shows key features and potentially suitable clean biomass stoves by region, with illustrative pictures of representative stove models.


FIGURE 2.5 RURAL HOUSEHOLD RELIANCE ON SOLID FUELS BY INCOME LEVEL



Sources: National Bureau of Statistics 2008; China Statistical Yearbook 2007.

TABLE 2.4 SUITABLE CLEAN BIOMASS STOVE TYPES, BY REGION

Region/provinces	Heating months	Fuel situation	Millions of households	Households that use solid fuels for cooking (%)	Suitable stove types
Northwest Shaanxi, Gansu, Inner Mongolia, Ningxia, Qinghai, Xinjiang	4–5	Poor in biomass resources	26.97	97.28	1, 2, and 4
Northeast Liaoning, Jilin, Heilongjiang	> 5	Rich in agricultural and forestry residue	16.43	95.68	1, 2, 4, and 6
North Beijing, Tianjin, Hebei, Shanxi, Shandong, Henan	3–4	Rich in agricultural residue	60.79	90.70	1, 2, 3, 4, and 6
Southwest Yunnan, Guizhou, Sichuan, Chongqing, Guangxi, Tibet	Vary; but Tibet and other high-elevation areas require heating	Rich in agricultural and forestry residue	56.67	92.93	1, 3, and 5
Southeast Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Hunan, Hubei, Guangdong, Hainan	1–3	Rich in agricultural residue	102.99	74.24	3, and 5

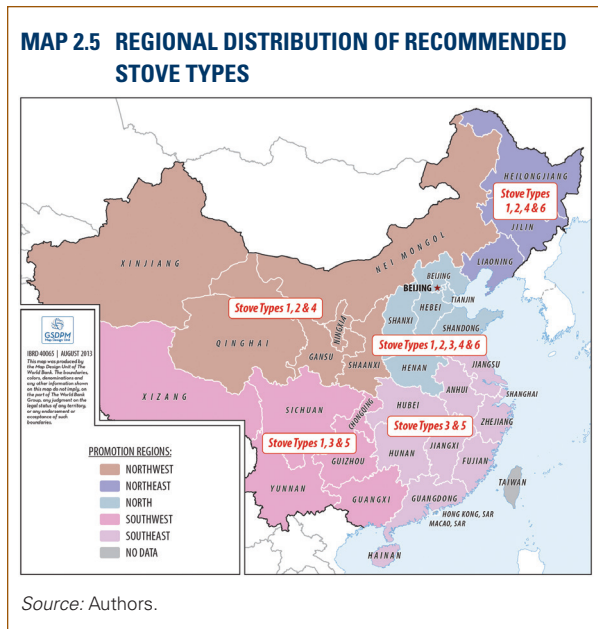
Description	Stove number/type					
	1/Improved In-Situ Stove ^a	2/Improved Kang	3/Clean Cooking Stove	4/Clean Cooking and Water Heating Stove	5/Clean Cooking and Heating Stove	6/Clean Heating Stove
Picture						
Price (RMB)	500–1,000	2,000–2,500	500–800	1,000–2,000	600–1,000	> 2,000
Thermal efficiency (%)	≥30	≥70	≥35	≥65	≥70	≥70

Source: CACS 2012.

a. Dust (mg/m³) = ≤50; SO₂ (mg/m³) = ≤30; NO_x (mg/m³) = ≤150; CO (%) = ≤0.2; Ringelmann black degree = 1.

Northwest and Northeast China, characterized by cold or severely cold winters, require heating more than 4 months out of the year. Residents there have been using Kangs or water heating for decades. Given the climatic conditions, households' affordability, biomass availability, cultural customs, and expert opinions, the types of stoves recommended for these two regions include improved in-situ stoves, improved Kangs, and clean cooking and water heating stoves. In addition, for households in North China, clean cooking stoves, which are sold on the market at a relatively lower cost, are potentially

suitable. Also, considering the higher price, clean heating stoves are more likely to be accepted in North and Northeast China, where rural households' heating demand and affordability are higher. In Southwest and Southeast China, where heating is generally not required and water heating is not commonly practiced by households, clean cooking stoves and clean cooking and heating stoves are more likely to be adopted. In some areas of Southwest China where rural households are accustomed to using Kangs for heating, improved in-situ stoves can also be promoted (map 2.5).



Conclusion

Results from the demand analysis indicate that more than half of China's population still relies on solid fuels for cooking and heating. Most of these households are located in rural areas and will likely continue using solid fuels to meet their cooking and heating needs in the foreseeable future. With the exception of a few provinces in the Southeast, nearly all rural households in each province use solid fuels for cooking, especially residents in West and North China. In terms of number of households using solid fuels for cooking, the most concentrated areas are Central and East China, owing to large population densities and access to solid fuels. The provinces of Henan, Sichuan, Shandong, Hunan, and Hebei feature the most rural households using solid fuels for cooking. In Henan, some 20 million rural households use solid fuels for cooking, while in Sichuan, about 15 million rely on biomass cooking. In addition, coal is the predominant heating fuel for China's households without

central or electric heating; in the Southwest, however, rural households also commonly use wood for heating.

This chapter has demonstrated that heavy reliance on solid fuels for cooking and heating is the result of multiple factors, which can be grouped into four interdependent categories: (1) availability, (2) accessibility, (3) affordability, and (4) acceptability. The urban-rural disparity in fuel and stove usage illustrates how these factors interact. Urban households with higher incomes who have access to modern fuel supplies and service networks can afford and are thus more likely to choose high-efficiency, clean-burning modern fuels and improved stoves. Conversely, low-income rural households without access to affordable modern energy and improved stoves are more likely to collect wood and agricultural residues to meet their daily cooking and heating needs. In addition, the relative abundance of and access to existing local resources play a key role in households' fuel decision-making. The difference between Southwest and Northwest China in terms of households' choice of the most common primitive heating fuel may be attributed to abundance of the respective natural resources in these regions.

It is expected that solid fuels will continue being widely used in rural China in the near future. Such clean modern fuels as natural gas, LPG, and electricity are usually more expensive than solid fuels, require more costly stoves and delivery infrastructure, and are harder for rural households to access. By contrast, rural households traditionally collect many forms of biomass on a non-commercial basis. Therefore, fuel switching on a large scale will not occur in rural areas unless rural economies become substantially more developed. By 2030, an estimated 280 million people in China will still rely on solid fuels for cooking and heating (IEA 2010). Thus, mitigating the negative health effects of HAP and reducing the poverty of this segment of the national population require developing effective strategies for scaling up the dissemination of clean-burning, fuel-efficient stoves that rural households are willing to adopt.

Analysis of Household Stoves Supply

Given rural China's heavy reliance on solid fuels and the key factors that drive household fuel selection, discussed in the previous chapter, what are the major challenges and opportunities for the stove supply sector? To answer this question, this chapter examines four stove market segments—biomass, coal, biogas, and solar—from a variety of perspectives (e.g., production, distribution, sales, and cost) and, based on these analyses, suggests ways to overcome barriers to market development.

Biomass Stoves

China has one of the largest biomass stove industries in the world, with a substantial supply of improved stoves currently in use. As of 2007, more than two-thirds of the 828 million people in developing countries with access to improved cookstoves using solid fuels resided in China (WHO and UNDP 2009). However, the biomass stove market is not sufficiently commercialized to thrive without government support. Also, problems remain in such areas as quality, technology, and standardization, all of which impede the scale-up of more advanced biomass stoves. The subsections that follow examine China's biomass stove industry and results of a large-scale survey conducted among stove manufacturers to better understand current market conditions.

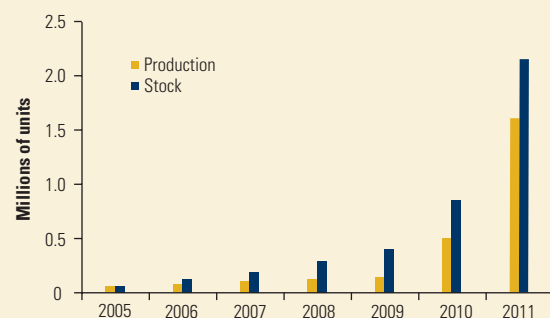
Industry Overview

Both the production and stock of high-efficiency, low-emission biomass stoves, also called clean biomass stoves, have increased rapidly since 2005. Despite this late starting point, biomass stove production increased eightfold within five years, reaching 0.5 million by the end of 2010. Similarly, the national stock of clean

biomass stoves reached 0.85 million in 2010, 11 times greater than in 2005. The production of clean biomass stoves is becoming industrialized and commercialized, particularly in poorer areas of the countryside with abundant biomass resources (e.g., Sichuan, Guizhou, and Chongqing). By 2011, more than 300 biomass stove manufacturers were producing 1.6 million stoves each year (figure 3.1). This sharp increase can be attributed to the government's substantial efforts to invest in the industry, along with the rise in fossil-fuel prices and technology improvements observed in recent years.

The rapid growth in China's biomass stove industry is largely attributed to the government's strong support and stove promotion programs. As early as the 1980s, "Stoves Revolution and Energy Conservation" was codified in China's Sixth Five-Year Plan. The National Improved Stoves Program (NISP), which by the late 1990s had installed some 180 million improved stoves in rural households,

FIGURE 3.1 GROWTH IN PRODUCTION AND STOCK OF CLEAN BIOMASS STOVES, 2005–11



Sources: CAREI 2011a; China CSI survey data.

TABLE 3.1 PERFORMANCE INDICATORS OF CLEAN BIOMASS STOVES

Indicator	Cooking	Cooking and water heating	Cooking and heating	Heating
Thermal efficiency (%)	≥35	≥65	≥70	≥70
Average PM emissions (mg/m ³)	≤50	≤50	≤50	≤50
Average CO concentration (mg/m ³)	≤0.2	≤0.2	≤0.2	≤0.2

Source: CACS 2012.

is the world's most successful national improved stoves program. Since 2005, the biomass stove industry has entered a fast-growth stage under the global advocacy of energy savings and emissions reduction.

Both biomass stove technologies and product quality have greatly improved as a result of continuous research and development (R&D) efforts. Stove manufacturers, particularly coal stoves companies, have been dedicated to developing clean biomass stoves, with substantial support from the government, and developing countries have recognized this technology as a leader. In addition, industrial organizations have played an important role in developing China's biomass stove industry. For example, in 2010, the China Association of Rural Energy Industry (CAREI) launched a voluntary activity that labels high-efficiency, low-emissions stove products or small and atmospheric pressure hot-water boilers of premium quality with after-sales service as "double commitment" products. Currently, 22 enterprises nationwide are producing 40 types of products labeled as double commitment.

Prior to the NISP, the thermal efficiency of cooking stoves was only about 10 percent and that of improved stoves promoted in the mid-1990s was about 25 percent. Today, however, thermal efficiency can exceed 35 percent, with significant reductions in particulate matter (PM) and carbon monoxide (CO) emissions (table 3.1).

Technology improvements, in turn, have led to stove enterprises designing and developing a more diversified line of stove products that target a broad range of customer needs, geographic and socioeconomic conditions, fuel structures, and living/cooking habits. These products include multi-functional ones (e.g., cooking and heating or cooking, heating, and water heating) with high, medium, and low pricing (table 2.4).

The prices of biomass stoves vary greatly by type, ranging from RMB 500–800 for a clean cooking stove to RMB 2,000–2,500 for an improved Kang. Stoves that include a heating function fall into a higher price category, with

water heating stoves selling at RMB 1,000–2,000 and cooking and heating stoves at RMB 600–1,000. The price difference is largely attributable to the stove size and function, transport distance, and distribution approach.

Survey Results

To understand the current status of China's biomass stove market, the first-ever large-scale survey of the biomass stove industry, combined with field visits, was conducted in March–May 2012. Respondents included 89 biomass stove manufacturers throughout the country, who together accounted for 72 percent of total production in 2011 (i.e., 1.15 million stoves). The stoves covered by the survey were mostly mass-produced, referred to as clean biomass stoves (box 1.3).

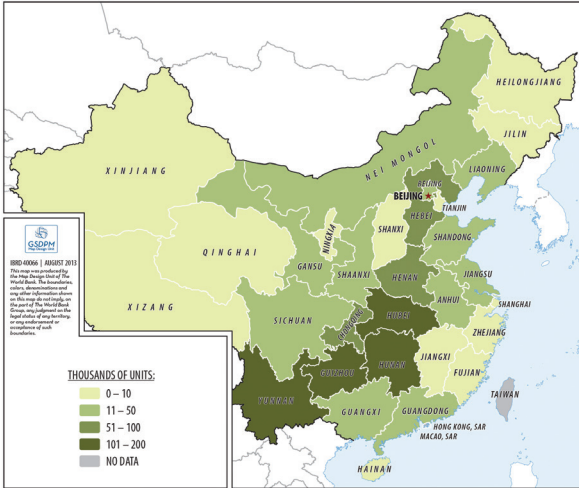
Production and Enterprise Distribution

Provinces with larger stove production levels are distributed throughout the south (especially South Central China). Guizhou and Hunan provinces have the highest levels, each producing more than 181,000 units each year, followed by Yunnan. The large stove output in these poorer provinces, with the exception of Hunan, is linked to preferable government policies that include large subsidies. In 2011, the Guizhou government disseminated at least 120,000 biomass cooking and heating stoves as part of China's Grain for Green Program, while the Yunnan provincial government disseminates at least 100,000 fuel-saving stoves each year. In addition, the Hubei government has included biomass stoves in its Agricultural Machinery Subsidy List (map 3.1a).

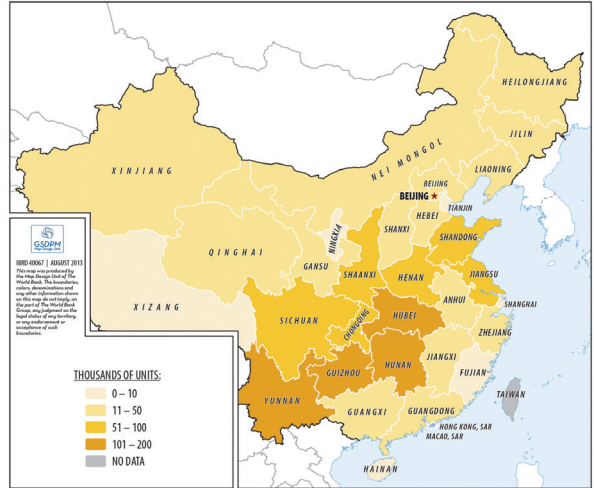
Clean stove enterprises are located mainly in East China, with the largest number found in Hebei province, followed by Beijing and Shandong. Hebei tops the number of biomass stove enterprises among all provinces. By contrast, the western provinces of Xinjiang, Xizang, and Qinghai and such municipalities as Shanghai and Tianjin have no biomass stove enterprises. China's smallest-sized clean stove enterprises are located mainly in the North and Northeast, while mid-sized ones (i.e.,

MAP 3.1 DISTRIBUTION OF BIOMASS STOVE PRODUCTION AND SALES, 2011

a. Production



b. Sales



Source: China CSI survey.

producing 5,000–15,000 units in 2011) are found mostly in the North. Although more enterprises are found in the North, the largest ones, and thus most production, are centered in the Southwest and Southeast (figure 3.2a).

Stove Sales

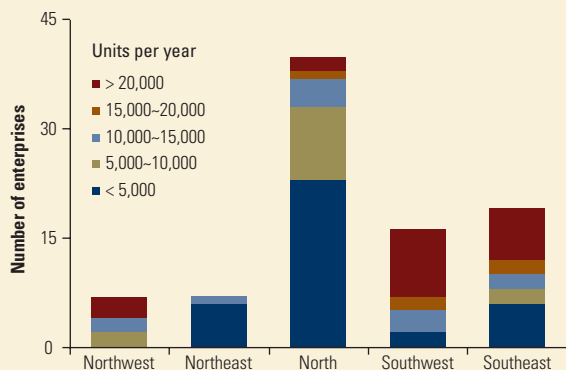
Stove enterprises' inventory is generally low, reflecting a sales level comparable to production. For nearly half of enterprises, more than 99 percent of production is sold the same year, while only about 1 percent sells less than 60 percent of its products (figure 3.2b). Such low inventory can be attributed, in large part, to the planned stove

market, whereby the decision to produce stoves is based on government purchase orders.

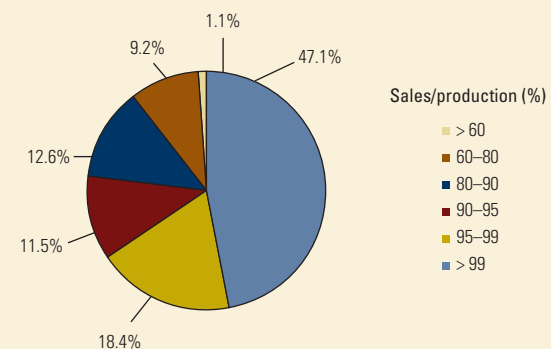
Sales of cooking and heating stoves vary widely by province, with 1.34 million and 0.26 million, respectively, sold in 2011. Combining data from the China CSI survey with statistical information obtained from local government agencies, sales of biomass stoves for 2011 were estimated by region. Consistent with the geographic distribution of production, it was found that most products were sold to the Southwest and Southeast (map 3.1b).

FIGURE 3.2 BIOMASS STOVE ENTERPRISES AND INVENTORY

a. Regional Distribution of Enterprises, by Production Scale

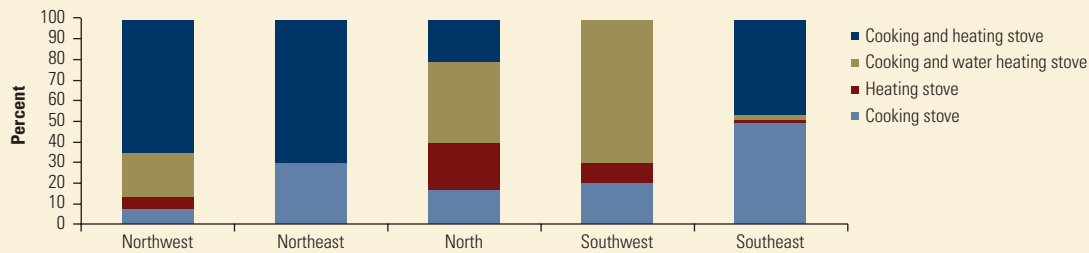


b. Sales-to-Production Proportion as Percentage of Surveyed Enterprises



Source: China CSI survey.

FIGURE 3.3 CLEAN BIOMASS STOVE TYPES PREFERRED BY PRODUCERS, BY REGION



Source: China CSI survey.

Furthermore, the types of clean biomass stoves preferred by producers differ by region (figure 3.3). In the Northeast and Northwest, cooking and heating stoves are the major stove types produced. In the North and Southwest, manufacturing focuses primarily on cooking and water heating stoves. Cooking stoves are more popular among producers in the Southeast and Northeast, while heating stoves are mainly produced in North China.

Production Cost and Sales Price

Generally, profit margin is low for producers in that production cost comprises about 70–90 percent of the sales price that stove companies charge for all types of manufactured, clean biomass stoves. The four types of biomass stoves are quite similar in terms of the cost share in the sales price, whereas cooking and water heating stoves and heating-only stoves have a wider range of cost share. However, the sales price can differ from the purchase price by end users for subsidized stoves sold to poor regions supported by the government.

To further illustrate, we use three stove companies (A, B, and C) as examples (figure 3.4). Companies A and B, which sell cooking and heating stoves, have a slightly higher sales price for their stoves, compared to Company

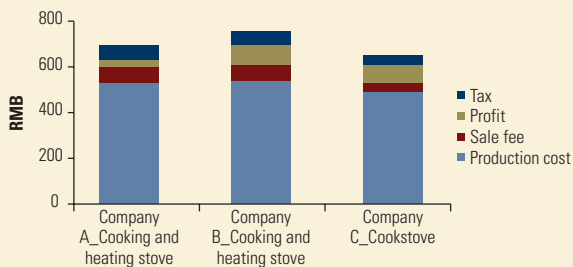
C, which sells cookstoves at RMB 650 per stove. While the share of cost components varies by company, production cost constitutes the largest portion of the price and profit comprises 10–15 percent of the stove price, followed by marketing expenses and tax.

Sales Models and Market Barriers

As previously mentioned, the region of concentrated stove production overlaps heavily with the sales region owing to producers’ customary practice of limiting sales to within or just outside their respective provinces. The exceptions are a few large-scale producers who serve multiple provinces or even the entire country.

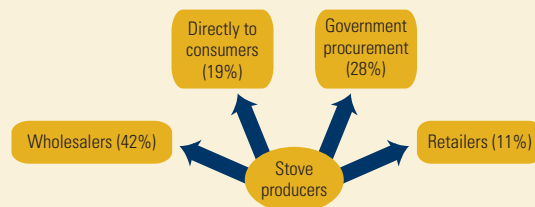
Stove producers can reach end users through wholesalers, government procurement, their own sales network, or retailers. Wholesalers account for 42 percent of producer sales. Government procurement—the model that uses subsidies, with enterprises directly participating in government tenders—accounts for 28 percent, own sales network comprises 19 percent, and retailers only 11 percent. It should be noted that most sales to wholesalers and using own sales network also fall under the government procurement program, meaning that public procurement, whether direct or indirect, accounts for more than 80 percent of all producer sales (figure 3.5).

FIGURE 3.4 TYPICAL COST COMPOSITIONS FOR BIOMASS STOVES

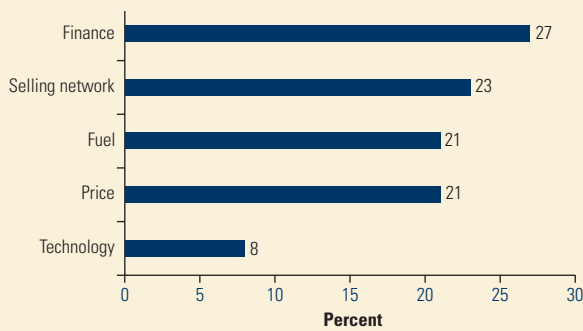


Source: China CSI survey.

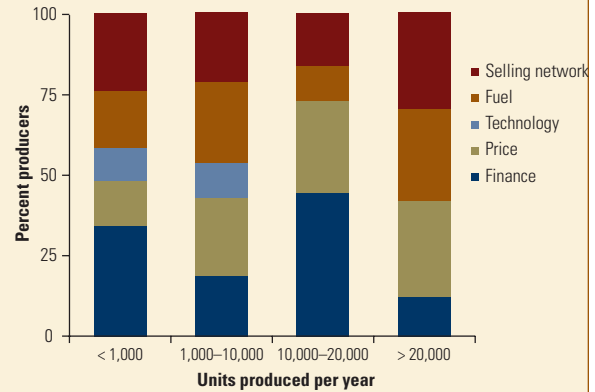
FIGURE 3.5 MAIN STOVE SALES MODELS



Source: China CSI survey.

FIGURE 3.6 MAIN PRODUCTION AND SALES CONCERNS OF SURVEYED CLEAN BIOMASS STOVE ENTERPRISES**a. Obstacle: Finance > Selling Network > Fuel > Price > Technology**

Source: China CSI survey.

b. Main Obstacles by Production Scale

Under the government procurement scheme, there are three subsidy levels. For extremely poor regions, which account for about one-third of cases, nearly 100 percent of the sales price is subsidized by the government. For relatively poorer regions, which represent another one-third of cases, 50–80 percent of the sales price is subsidized. Finally, other poor regions receive a 50 percent subsidy. In addition, the source of subsidies varies, with a 2:3 average ratio of central government to other levels of government.

The enterprises surveyed considered access to financing as their main market barrier, closely followed by sales network, availability of fuel biomass briquette, and stove price. Due to the low technology and high price of biomass briquette, no supply chain for briquettes has been established. Only 8 percent of respondents considered producers' low technological level a major barrier (figure 3.6a). Furthermore, enterprises at different scales vary significantly in their main production and sales concerns (figure 3.6b).

Small-scale enterprises, which account for 62 percent of the enterprises surveyed, pay more attention to accessing financing and building or expanding their sales network. However, enterprises with production levels above 10,000 units focus mainly on expanding the scale of financing and tackling stove pricing, rather than dealing with technical issues. For large-scale enterprises with annual production above 20,000 units, financing pressure is small and technical issues have been resolved; thus, they are more concerned about expanding their sales network and cutting prices, as well as ensuring fuel availability.

Funding Source

Nearly all stove enterprises in China are privately owned. When the enterprises were set up, capital investment depended solely on their own assets, and obtaining business loans from banks was difficult. For small- and medium-sized enterprises, access to financing has been a major bottleneck to scaling up and making technological advancements. However, in recent years, some progress has been made owing to rapid sector development. According to the CSI survey results, 26 out of 120 enterprises have received small loans from banks, which is undoubtedly a good start for the biomass stove industry.

Overcoming Barriers to Market Development

China's biomass stove industry is growing rapidly, and many enterprises prioritize the development of new types of biomass stoves, leading to great progress in stove production and sales, as well as product quality. Nevertheless, various issues remain unresolved. First, there is little commercialization and heavy reliance on government subsidies, with some procurement programs having paid more attention to stove pricing than quality. Delayed setting of product standards has meant that some stove products, such as the heating stove or Tibetan Stove, have been on the market for several years without having national or industry standards. Resolving this issue will require setting up product standards and a testing system, improving the performance of government-supported stove programs, and introducing a market-based approach. More detailed recommendations are presented in chapter 5.

Second, the quality and performance of biomass stoves on the market vary significantly, pirating of quality brand names is not uncommon, and there is insufficient after-sales service and technical training. Furthermore, many small enterprises lack technological innovation, and some stove designs are inferior. Therefore, the priority for the enterprise is to improve the stove's quality and level through investing in technology innovation and technical training.

Third, the lack of a biomass briquette supply chain due to high cost and a low technology level is a main concern among producers. Resolving this issue requires cooperation and coordination among various players in the supply chain. Large biomass enterprises can also consider securing a reliable fuel supply or collecting and processing biomass themselves to receive a subsidy.

Coal-Burning Stoves

China has abundant coal resources and a large coal stove market for heating and other household uses. Households north of the Yangtze River utilize coal stoves mainly for cooking and water heating, while those in the south use them for heating. The coal stove industry started early and developed fast due to the large market potential. However, product quality is patchy, performance may vary considerably, and household demand can be widely dispersed. This section characterizes China's coal stove industry, identifies market barriers, and suggests ways in which to promote the industry's sustainable development. The data presented here are based on survey samples, visits, discussions, telephone interviews, and expert consultations with producers nationwide.

Stove Development

There are four major types of coal stoves: (1) cooking, (2) cooking and water heating, (3) cooking and heating, and (4) heating (figure 3.7). Cooking coal stoves are installed with or without chimneys and mainly use coal briquettes for fuel. Most cooking and water heating coal stoves are installed with chimneys and mainly use lump coal and briquettes as fuel; these stoves can be connected to heating pipes, heated Kangs, or hot walls. They are primarily used for water heating and secondarily for cooking. Cooking and heating coal stoves mainly use lump coal and briquettes as fuel, and are utilized primarily to provide heat, with cooking a secondary use. Finally, heating coal stoves, whose primary purpose is for winter heating, are installed with chimneys; they mainly use lump coal for fuel and can be connected to heating pipes.

FIGURE 3.7 MAIN TYPES OF HOUSEHOLD COAL STOVES



Source: China Stoves Website.

Coal-burning stove types vary significantly by region. North of the Yangtze River, households mainly use cooking and water heating or heating stoves during the cold winter months. Stoves with combined cooking and heating purposes are mainly used in the Southwest, Northeast, alpine cold region, and pastoral areas.

The performance of improved coal stoves has improved in terms of thermal efficiency and emissions. Currently, there are no national standards for nitrogen oxides (NO_x) or carbon monoxide (CO) emissions from coal stoves, but new regulations are under way. It can be observed that each type of advanced stove has a thermal efficiency at least 5 percentage points better than that of common stoves. In fact, advanced heating stoves can reach a thermal efficiency of up to 70 percent. For all types of advanced stoves, the level of released smoke is below 80 mg per m³ and the level of sulfur dioxide (SO₂) is within 500 mg per m³, compared to 120 mg per m³ and 900 mg per m³, respectively, for common stoves (table 3.2).

Production and Sales

In 2011, some 1,500 enterprises produced 20 million honeycomb coal cooking stoves, of which 16 million were sold, while another 800 enterprises produced 2.6 million clean coal heating stoves, of which 2.2 million were sold (CAREI 2011a). Of the 18.2 million coal stoves promoted that year, Hubei led (2.4 million), followed by Hunan (2.0 million) and Jiangsu (1.53 million). Production and stock of coal heating stoves were fairly stable over the 2005–10 period, with production declining slightly in 2006–08 and subsequently rising (figure 3.8). Over the five-year period, production grew by 21 percent, while stock rose by just 12 percent.

Prices and sales differ by stove type. Similar to biomass stoves, coal stove prices range from hundreds to

TABLE 3.2 COMPARISON OF PRODUCT PERFORMANCE INDICATORS

Indicator	Cooking stove		Cooking and heating stove ^c		Heating stove ^d	
	Common ^a	Advanced ^b	Common ^a	Advanced ^b	Common ^a	Advanced ^b
Efficiency	≥35	≥45	≥60	≥65	≥60	≥70
Released smoke (mg/m ³)	≤120	≤80	≤120	≤80	≤120	≤80
SO ₂ (mg/m ³)	≤900	≤500	≤900	≤500	≤900	≤500
Ringelmann shade (level)	1	1	1	1	1	1

Source: CACS 2012.

Note: The coal fuel used is in the form of briquettes.

a. Common stove types meet GB16154 technical specifications and GB13271 emission standards.

b. Advanced stove types represent the leading stoves in the clean and efficient stove industry.

c. Cooking and heating stoves comprise both cooking and heating and cooking and water heating uses.

d. All heating stoves are of the water heating type.

thousands of RMB per stove. In addition, sales of coal stoves are completely market based, with no national or local supportive policies. Thus, the stove industry has been largely commercialized, and the market is stable to a certain extent. However, most production is from microenterprises operating under rudimentary conditions. Nationwide, only 40 enterprises, all of which are located in Hebei, Shandong, and Guizhou provinces, have an annual production exceeding 10,000 stoves. Thus, production and sales usually occur locally or within the respective provinces. One exception is Hebei, which has the largest number of stove manufacturing companies and established infrastructure, exporting 70 percent of its products outside the province. At the other extreme is the Northeast, which lacks sizeable stove enterprises and imports 60 percent of its stoves from provinces in other regions.

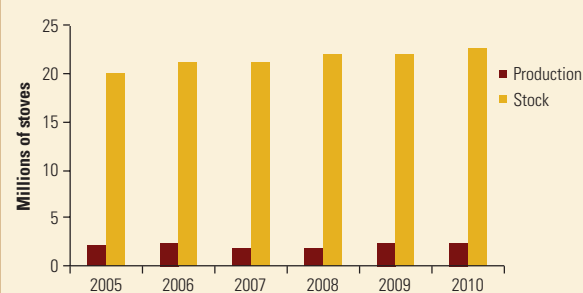
Overcoming Barriers to Market Development

Unlike biomass stoves, which rely heavily on government support, China's coal stove market is highly commercialized without substantial government support, which accounts for the stable supply in past years. In addition, some improvements have been made in stove performance. Owing to the small production capacity of most enterprises, their business model, with few exceptions, focuses on producing and selling within their respective provinces.

Beyond volatility in weather, coal prices, and the cost of materials and labor, China's coal stove market faces

a number of barriers that have hindered the promotion and sale of high-quality stoves. For example, four-fifths of the coal stoves in most regions are obsolete. In addition, since relatively poorer families prioritize stove price over concerns of safety, efficiency, and pollution, their demand is met with low-quality, low-priced products. Furthermore, the market is insufficiently regulated and thus is flooded with shoddy imitation products.

To enhance market stability, the government should strengthen its efforts to phase out low-quality, traditional coal stoves. In addition, relevant national law enforcement agencies should step up their supervision of the stoves market and crack down on infringements, including counterfeit products and cheap dumping practices, to ensure product quality and safe use.

FIGURE 3.8 PRODUCTION AND STOCK OF COAL HEATING STOVES, 2005–10

Source: CAREI 2011a.

Biogas

In rural China, biogas plays a key role in household energy, accounting for 7.04 percent of rural household energy consumption in 2010. Over the past decade (2000–10), the number of farming households using biogas systems increased sharply—from 8.5 million to 38.51 million—owing, in large part, to government-supported efforts. This section examines the history and current status of China's biogas industry and suggests ways to overcome barriers to further scale-up.

Promotion of Household Biodigesters

Large-scale construction of household biogas systems in rural China began in the late 1950s, but fell off quickly due to lack of technology, low income levels, and lack of training and after-sales service. It took several decades for construction to return to peak levels. The 1980s to the year 2000 marked a period of stable development. Since 2000, owing to substantial government support, the industry has entered a new phase of rapid development.

By the end of 2010, biogas users (both household and centralized levels) exceeded 40.27 million, representing one-third of all potential users nationwide. Energy savings are estimated at more than 24 million tons of standard coal each year, with annual reductions in emissions and chemical oxygen demand (COD) amounting to 50 million tons of carbon dioxide equivalent (tCO₂e) and 0.76 million tons, respectively. In 2010, the various types of biogas and sewage biogas projects numbered 72,700 and 191,600, respectively, reflecting a 20 percent increase from 2005, benefiting 0.15 billion people. Currently, a new biogas growth pattern has been established for household, medium- and large-scale projects, and sewage purification projects being developed concurrently (CAREI 2011b).

The rapid growth in China's rural household biogas industry since 2001 is attributable, in large part, to the government's continuous and generous support. According to incomplete statistics, the Ministry of Agriculture invested RMB 8.62 billion in rural energy construction during 2001–07 (CACS 2012). Of this amount, RMB 270 million came from a special finance fund, RMB 350 million from a construction fund, and RMB 8 billion from a government bond fund. Of the 8.62 billion invested, 8.3 billion was allocated to household biodigester systems and 125 million directed to medium- and large-scale biogas projects. As the result of strong government support, the development of China's household biogas construction

made a leap forward. From 2008 to 2011, both the central and local governments continued to increase support of biogas construction, with a total of RMB 26.96 billion invested, further accelerating the industry's growth.

Technology Trend

Currently, most of rural China's household biodigesters are made of brick and concrete and are constructed on site. Over the years, construction materials and technology and system structure have gradually improved. However, certain problems remain (e.g., the time required for system construction and higher technology requirements). Even so, the commercial biogas industry—featuring new technologies, materials, and techniques, known as the “three news”—has made significant progress. With support from all levels of government, commercial household biogas has made important strides; by the end of 2010, nearly 1 million units had been installed, accounting for 2.5 percent of all rural household biodigesters.

The “three news” mainly include glass-fiber reinforced plastic (GRP), other plastics, and software, all of which are lightweight, using chemicals as raw input. Such materials have structural advantages over conventional ones and thus are more economical, durable, and adaptable to local conditions. Currently, hundreds of enterprises are engaged in production and research on the “three news” products, having scaled up innovation, quality reliability, and after-sales service to medium- and large-sized enterprises.

Service System Development

In recent years, China has begun to strengthen construction of the household biogas service system. Through state funding, 6 provincial training bases, 536 country-level service stations, and 64,756 rural service networks have been built. Also, basic service models have been created for county building centers, township building stations, and village building service points. Existing service modes include production worker contracts, rural biogas associations, and biogas cooperatives. The number of staff working on biodigester construction, installation, and follow-up services totals more than 0.3 million. The entire supply system has been established, with thousands of sector enterprises, including some large ones that can achieve sales revenue exceeding RMB 100 million.

Overcoming Barriers to Market Development

Despite the impressive development of rural China's household biogas industry, some obstacles must be overcome to further scale up biogas supply. The substantial changes in rural socioeconomic conditions in recent decades present new challenges, with new lessons to be learned along the way. The foremost issue is rural households' low utilization rate and thus lack of enthusiasm for using or constructing the biogas systems. The reasons for their reluctance are multifaceted, including lack of a service system, decreased individual cultivation of livestock, large upfront investment and insufficient subsidy level, and slow technological progress.

Specifically, the service system has lagged far behind the needs of biogas users, thus restricting household utilization. Although China has invested more than RMB 1.4 billion in the past two years to fund the rural biogas and service system and has actively explored service models for local development, many service outlets face difficulties due to a lack of running costs and fee sources. In areas without effective service systems, low utilization of biodigesters has become a common problem, especially among families lacking raw materials and labor.

In addition, with the structural change in rural production in recent years, the livestock and poultry industry has become more industrialized, leading to a decline in individual cultivation of livestock. Reduced household cultivation of livestock, in turn, has led to a decline in the raw materials used for generating biogas and thus the number of qualifying farming households for biogas system installation.

Furthermore, owing to higher prices for materials, accessories, and labor, the subsidy level is insufficient to compensate for the increased cost of system construction. Also, due to tight local budgets, county-level matching funds for rural biogas projects are difficult to obtain, leading to project delays and farmers' unwillingness to invest more in construction.

Moreover, lack of investment in R&D activities has restricted biogas industry innovation; over the past decade, such investment has been minimal. Many research institutes and production enterprises are reluctant to engage in biogas-related R&D due to lack of funding from all sources. Most of the technology and products remain the same as years ago. The slow progress in technology and frequently required repairs and maintenance can further reduce farmers' enthusiasm for utilizing biodigesters.

Tackling these problems is vital to increasing biodigester use among qualified rural farming households and their full realization of the benefits of biogas systems. For example, the byproducts of biogas fermentation have high nutrient value and can be used as a fertilizer. Once the above-mentioned barriers are removed, households' motivation to use biogas more efficiently and effectively will increase as their awareness of the many benefits of biogas grows.

One suggested recommendation is to focus on continued government support for improving or reforming current supporting mechanisms to motivate households in biogas use. It is possible to subsidize biogas equipment, as done under the agricultural equipment subsidy policy, to alleviate the burden on equipment enterprises and users alike. Germany's successful biogas experience, which expands the subsidy to various stages along the supply chain from enterprise input to output, could be adapted to China's situation. Or perhaps new policies and approaches based on rewards rather than subsidies could be introduced, leading to a more efficient and effective use of public funds for improved biogas utilization.

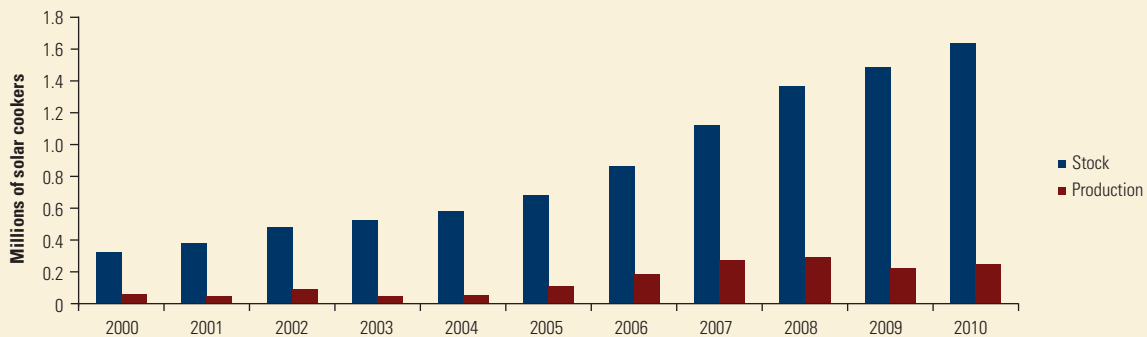
Finally, piloting and demonstrating commercial biodigesters should be implemented to accelerate industrialization. In addition, various types of public-awareness campaigns are needed on the co-benefits of biogas and best practices, especially related to energy conservation, to raise farmers' enthusiasm for using biogas systems.

Solar Cookers

Over the past several decades, China has made great progress in solar cooker research and promotion and now has the largest stock of solar cookers in the world. The solar cooker industry has made significant strides in commercial production and sales, including after-sales service. This section examines the history and current status of solar cooker production, identifies areas suitable for promotion, and characterizes suppliers. It then suggests how to overcome identified barriers in order to accelerate industry development.

Production Scale

During the early 1980s, China's government invested considerably in solar cooker development, which led to a rapid rate of growth. However, in 1985, subsidies were substantially reduced, causing development to slow, and the industry started to explore commercialized

FIGURE 3.9 PRODUCTION AND STOCK OF SOLAR COOKERS, 2000–10

Source: China Agriculture Statistical Yearbook 2010.

production. In recent years, with the government's emphasis on energy conservation, the industry has regained significant support for developing and promoting solar cookers, especially in poorer regions.

Over the 2000–10 period, solar cooker stock increased more than fourfold, while production experienced ups and downs (figure 3.9). By 2010, stock totaled 1.6 million units. In 2003, production dipped to only 54,500 units, but soon bounced back, peaking at 0.30 million units in 2008. Since then, annual production levels have remained above 0.20 million units.

China's solar cooker manufacturers generally take two forms: specialized and local. Specialized manufacturers refer to the industrial production of certain manufacturers with technical strength and equipment. These are located mainly in Jiangsu, Shandong, Gansu, and Beijing. Most products are made of cast iron, glass-fiber reinforced concrete (GRC), GRP, and composite material and are sold over a wide geographic area. The price range is RMB 400–500 per cooker. Local manufacturers are located mainly in Gansu, Ningxia, and Qinghai; their products generally consist of thick cement shell stoves with a waste glass lens as reflective material. These products are popular among local residents due to their lower production cost and sales price (about RMB 200–300 per cooker) and emphasis on quality and reputation, which are key to small business models.

Stove Types and Suitable Areas

Suitable promotion areas for solar cookers are mainly concentrated in Gansu, Qinghai, Ningxia, Tibet, Sichuan, and Yunnan Tibetan areas, where solar energy resources are rich and biomass is scarce, as discussed in chapter

2. China uses three main types of solar cookers: (1) heat box, (2) box focusing, and (3) focusing (figure 3.10). Heat box solar cookers are easy to produce, with materials easy to obtain at low cost. However, disadvantages include low temperature, low heat capacity, and limited cooking functions, leading to a low development level. The box focusing solar cooker is more compact and can be folded into a box for convenience of carrying, which can prolong the life of the reflective material. But due to its complex structure, inconvenient maintenance, and higher cost, it is not widely used. The focusing solar cooker is the most popular type. It is simple in structure and easy to operate, and has reliable performance, low cost, and multiple functions.

Suppliers

Currently, China has more than 20 enterprises that produce solar cookers distributed throughout Gansu, Ningxia, Qinghai, Sichuan, Jiangsu, and Shandong. The first four provinces are noted for their high levels of solar cooker stock. In addition, most companies are either private or joint-ownership types, with annual sales of more than 200,000 units.

FIGURE 3.10 VARIOUS TYPES OF SOLAR COOKERS

Source: CACS 2012.

Despite large production, sales rely mainly on government procurement and subsidies. The market accounts for less than one-fifth of sales because demand is centered in poorer regions, where profitability is low. Thus, government support will continue to play a major role in promotion. The quality of solar cookers varies greatly, suggesting a strong need for better production technology and greater capacity in standardizing product performance.

Overcoming Barriers to Market Development

The application of solar cookers can ease China's energy shortage and improve the ecological environment in some regions. To effectively promote solar cookers, various strategies should be used. For example, in low-income regions, it is advisable to integrate the promotion of solar cookers with poverty-reduction planning and continue to provide subsidies, given the difficulty of commercialization due to households' low affordability and producers' low profitability. One might consider financial and material resources and tax relief for qualified producers and users. However, households in middle-income regions rich in solar resources should be encouraged to purchase solar cookers through diversified sales methods with improved after-sales services, such as consignment and installment. At the same time, public-awareness campaigns should be conducted to publicize the benefits of solar cookers. However, in most high-income regions, use of solar cookers is rare unless there is an extreme lack of conventional energy.

To improve existing technology, R&D activities should be conducted by a highly qualified team with sufficient research funding. Special focus should center on developing stable and durable reflective material, a tracking system that enables solar cookers to adjust automatically to the sun, and lightweight box-type cookers that are environmentally friendly.

To guarantee stove quality, it is essential to standardize solar cooker products through a unified, consistent system. A testing center should be established to test and monitor the quality and performance of solar cookers under the same standards. Also, technical cooperation, technical exchanges, and product trade should be established among countries, especially developing countries that face similar fuel challenges, which call for strengthened coordination among relevant departments.

Conclusion

Among the four market segments considered in this chapter, biomass stoves have the largest demand, especially in poorer rural areas, but supply relies on government procurement. The coal stove market has reached a certain level of commercialization and currently does not require government support; but most suppliers' production capacity is small and, with few exceptions, businesses are limited to the respective provinces. Biogas faces the challenge of low household utilization and lack of farmer enthusiasm. Although China has the world's largest stock of solar cookers and its commercial market is under way, it still relies on government subsidy.

For market segments that rely heavily on government support, it is necessary to continue such support while exploring the possibility of creating market incentives for households to use stoves and suppliers to produce them based on market signals. All four market segments require increased access to financing and standardization of stove products against technical specifications with strengthened institutions. Annex A further examines these market segments, characterizing the interactions of stove supply, demand, and market policies in specific local contexts. Valuable lessons from these four cases can be applied to designing and implementing future stove promotion programs.

Policies, Programs, and Institutional Players

This chapter reviews China's policies, programs, and major institutional players that promote clean household energy solutions. Specifically, it explores the extent to which China's policies have been engaged in the household energy solution, identifies program and institutional gaps that future interventions will need to fill, and offers lessons and insights from past and current policies and programs that can be applied to future efforts to ensure their sustainability.

The chapter begins with an overview of the current structure of China's stoves policies, including their administration, the projects and programs implemented, and the responsibilities of the various ministries involved. Next, it illustrates how these institutions are coordinated within China's clean stove promotion mechanism, followed by a review of recent national policies and regulations related to clean stoves. The chapter then turns to China's standardization system for clean stoves, presenting the results of a gap analysis on policies, programs, and standards. Finally, suggestions are offered for more effective interventions.

Structure of Current Programs

Since the early 1980s, China's government has been involved at various levels (i.e., national, provincial, and local) in issuing policies and implementing programs related to clean stoves. These policies and programs have covered a wide array of topics, ranging from renewable

energy development, utilization of crop residues, rural energy development, and poverty reduction to improving rural households' quality of life and health and preventing deforestation.

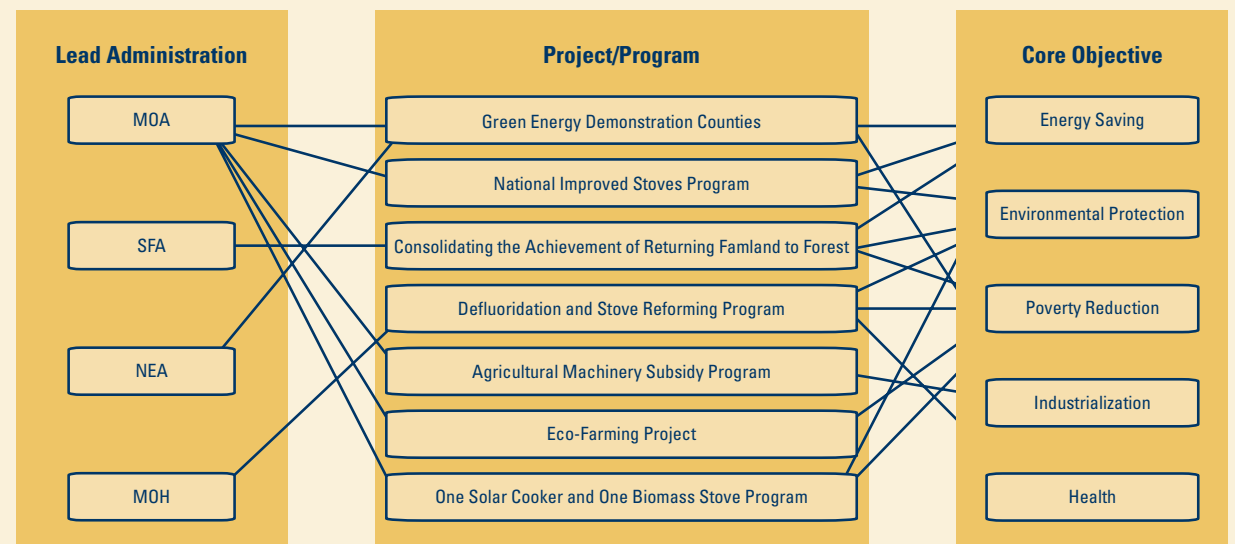
For example, in 2007, the General Office of the State Council released a guidance document for ministries and local government on the central government's views on modernizing agriculture as part of its push for the new rural construction of socialism.³ The next year, the Council issued its views on accelerating the comprehensive utilization of crop straw in order to reduce open field burning of crop residues.⁴ This document encouraged the accelerated utilization of biomass with biogas, pyrolysis gasification, briquetting, and carbonization technologies, and called for providing financial support to apply these technologies and loan credits to enterprises and agricultural machinery service organizations to spur capital investment.

Various ministries have invested in such efforts, with each project/program having its core objectives. Figure 4.1 provides examples of major projects/programs, for which, in addition to the lead implementing ministries, the National Development and Reform Commission (NDRC), successor to the State Planning Commission, and the Ministry of Finance (MOF) assume overall coordination and financing.

3. Detailed information is available at www.gov.cn/gongbao/content/2007/content_548921.htm.

4. General Office of the State Council opinion (2008, No.105) (http://code.fabao365.com/law_16716.html).

FIGURE 4.1 CHINA'S CLEAN STOVE PROGRAMS STRUCTURE



Source: Authors.

Ministry of Agriculture

As administrator for rural production and living, China's Ministry of Agriculture (MOA) has previously introduced numerous policies related to clean stoves. For example, in the 1980s, it initiated the National Improved Stoves Program (NISIP), with the dual objectives of energy conservation and environmental protection. The NISIP developed pilot counties for fuel-saving stoves and incorporated upgraded stoves and wood savings into the Sixth Five-Year Plan, marking a new wave of stove promotion (box 4.1).

The MOA also initiated the One Solar Cooker and One Biomass Stove Program in 2007, targeting energy conservation and poverty reduction in the Tibet Autonomous Region and neighboring provinces. The program has succeeded in improving the quality of herdsmen's lives, protecting the local ecology, and promoting construction of the new countryside (box 4.2).

The Eco-Farming Project, another MOA initiative, has poverty reduction as its core objective. The MOA implements the project under its strategy to promote sustainable agricultural development, as set forth in its national ecological farming and livelihood improvement plan. In early 2000, the project launched 10 eco-farming demonstration villages in 7 western provinces.

During the Eleventh Five-Year Plan (2006–10), the MOA created the National Program for Rural Biogas, whose main objectives are to optimize the structure of rural energy, increase farmers' income, and improve the ecological environment. The program uses a county-based, multi-level approach to implementation.

In 2004, the MOA initiated the Agricultural Machinery Subsidy Program, which aims to strengthen financial support for agricultural development. The program responds to the central government's incorporation of the agricultural machinery purchase subsidy into its national policy of three subsidies and two exemptions.⁵ In 2011, the government further increased the subsidy level to RMB 17.5 billion for agricultural machinery purchases (including both biomass stoves and biomass briquetting machines) to promote rural industrialization of the agriculture sector.

State Forestry Administration

In 2002, the State Forestry Administration (SFA) initiated Consolidating the Achievement of Returning Farmland to Forest, a program whose threefold goal was conserving energy, protecting the environment, and alleviating poverty. With thermal efficiencies of stoves as low as 10–12 percent, the continued use of traditional stoves

5. More information is available at http://www.gov.cn/test/2006-02/22/content_207406.htm.

BOX 4.1 NATIONAL IMPROVED STOVES PROGRAM

China's National Improved Stoves Program (NISP), the world's largest such program, was initiated by the Ministry of Agriculture and the National Development and Reform Commission in the 1980s. At that time, the General Office of the State Council had begun to promote fuel-saving stove technology to reduce rural energy shortages and inefficiencies and address related ecological and economic concerns. The Sixth Five-Year Plan incorporated the work of the State Council, and soon the program of promoting wood- and coal-saving stoves was launched.

Achievements. The NISP successfully promoted some 180 million improved stoves by the end of 1990s, benefiting more than 500 million farmers. The thermal efficiency of improved stoves is 15 percentage points higher than that of traditional stoves, resulting in fuel savings of 33–50 percent on average. It is estimated that annual energy savings could reach 73 million tons of standard coal, thus contributing to solving rural energy shortage and security problems.

Lessons in success. Four major principles contributed to the success of the NISP. First, China's government was firmly committed to stoves promotion, having incorporated it into its Sixth Five-Year Plan and listed it on the government's agenda. Second, national stoves competitions were organized and unified standards and testing methods were adopted. Third, the program was integrated into rural development planning, which led to more effective and appropriate program design. Finally, related departments and research institutes invested in the research and development (R&D) of stove technology and formation of a specialized technical team.

Challenges. Despite the NISP's success, a number of problems remain. The low technology level of stove products has resulted in a low level of commercialization and durability. In addition, more than 70 percent of the stoves promoted have been damaged or broken due to a lack of repair and maintenance services. Furthermore, 20 percent of farmers are still using traditional stoves. Moreover, lack of funding has impeded further promotion. Finally, management cannot keep pace with program implementation.

Looking ahead. Work on promoting improved and advanced stoves and Kangs to improve indoor air quality and quality of life for rural households has been included as key components of the Twelfth Five-Year Plan's outline of national economic and social development and action plan for implementing energy conservation and emissions reduction.^{a,b} Under the regulatory framework, this work will further contribute to improving rural energy efficiency, health, emissions reduction, and quality of life as plans move forward to launch the second national improved stoves program.

Source: CACS 2012.

a. Details on the outline of national economic and social development are available at www.gov.cn/2011/11/content_1825838.htm.

b. Details on the action plan for implementing energy conservation and emissions reduction are available at www.gov.cn/zwqk/2012-02/07/content_2059923.htm.

led to a significant waste in biomass resources and even deforestation in fuel-shortage regions. Thus, many local governments procured improved stoves and promoted subsidized ones in regions with reclaimed forestland from agriculture. The program significantly reduced energy consumption and enhanced the achievement of returning farmland to forest.

National Energy Administration

The National Energy Administration (NEA), along with the MOF and the MOA, implements the Green Energy Demonstration Counties program, whose dual objectives are energy conservation and industrialization (box 4.3).

BOX 4.2 ONE SOLAR COOKER AND ONE BIOMASS STOVE PROGRAM

China's One Solar Cooker and One Biomass Stove Program, initiated by the Ministry of Agriculture (MOA) in 2007, is designed to solve the household energy problems of herdsmen and farmers living in the Tibet Autonomous Region and neighboring provinces of Sichuan, Qinghai, Gansu, and Yunnan. Under the program, rural households in targeted areas receive one energy-efficient (clean) biomass stove and one solar cooker.

Implementation. Stove products are entered into a unified bidding process and are purchased from the stove enterprises by the provinces. The MOA's agricultural engineering construction center tenders the contracts. The stove enterprises transport their products to the counties and provide technical assistance on installation. Specific responsibilities are assigned at all levels of government. At the provincial and county levels, committees are set up to manage projects. The provincial-level government handles product procurement and quality control. At the prefecture level, the agriculture department is responsible for project coordination and inspection. The county-level government receives products and organizes transport and installation, while the village-level government conducts public-awareness campaigns and ensures households' timely use of the products.

Achievements. In just four years, the program successfully promoted 79,833 biomass stoves and 244,474 solar cookers. Tibetans have welcomed the clean biomass stoves and solar cookers since the products are of good quality and perform well. As a result, rural sanitary conditions have improved, the incomes of herdsmen and farmers have risen, and overall quality of life for ethnic minorities is improving, helping to build a more stable and prosperous region.

Lessons in success. Multiple factors have accounted for the program's success. Local conditions, energy consumption, and lifestyle were carefully integrated into the program design, following consultations with local business departments, experts, and enterprises. These groups provided counties technical assistance to ensure high-quality and timely project implementation. The provincial agricultural department sent representatives to monitor enterprises to strengthen quality control, while the rural energy office invited experts from the China Association of Rural Energy Industry (CAREI) and stove professional committee to provide county technicians training. In addition, by raising households' awareness of stove performance levels, public-awareness campaigns ensured project implementation. Bilingual manuals and pamphlets on the installation and safe use of biomass stoves were distributed to all targeted rural households. Finally, stove enterprises set up an after-sales service network in the project counties to encourage product maintenance and thus ensure safe and sustainable use.

Source: CACS 2012.

Ministry of Health

The De-fluoridation and Stove Reforming Program was implemented nationwide in the mid-1980s to prevent and control coal-related endemic fluorosis, as well as protect the environment and alleviate poverty. Great efforts were invested in upgrading stoves to reduce the use of poisonous coal, especially in the Three Gorges mountainous region (box 4.4).

In addition to these line ministries-led programs, the NDRC and the MOF also issue the supporting policies to provide sector guidance and financing incentives. For example, in 2007, the NDRC released the Medium- and Long-Term Renewable Energy Development Plan,⁶

which outlined the industrial development of biomass briquette. The plan aims to meet basic rural energy needs, upgrade the structure of energy consumption, and promote biomass pellets demonstration sites. The annual consumption target is 5 million tons of biomass pellets, substituting 3 million tons of coal. During the Eleventh Five-Year Plan (2006–10), the government invested significantly to promote biomass utilization technologies nationwide.

In 2008, the MOF formulated the Subsidies Management Provisional Measures for Straw Energy Utilization (2008, No. 735) to accelerate use of agricultural residues and develop a market for biomass products.⁷ The

6. Details are available at www.gov.cn/zwggk/2007-09/05/content_738243.htm.

7. Additional information is available at www.ccgp.gov.cn/site13/gysh/qltb/zcfg/765150.shtml.

BOX 4.3 GREEN ENERGY DEMONSTRATION COUNTIES

Since 2000, the National Energy Administration (NEA), together with the Ministry of Finance (MOF) and the Ministry of Agriculture (MOA), has implemented the Green Energy Demonstration Counties program, which works to solve or mitigate rural household energy problems using green energy. The range of renewable energy sources includes biomass, solar, wind, geothermal, and hydropower.

Implementation. Biomass energy is applied through three projects: (1) biomass briquetting, (2) centralized biogas, and (3) biomass gasification. Biomass briquettes, made of agricultural and forest residues—annual production for each product can reach or exceed 5,000 tons—can meet the cooking and heating demands of more than 1,000 rural households, as well as the heating needs for public buildings (e.g., hospitals, schools, government offices, and nursing homes). Subsidies are used to support the purchase of biomass stoves and reconstruct biomass boilers, Kangs, and stoves.

Under the centralized biogas project, livestock manure and crop straw are used to generate biogas. The fermentation pit of each unit has a capacity of more than 350 m³, with an annual output of more than 100,000 m³—enough to provide energy to at least 150 households. Subsidies support the construction of biogas purification treatment facilities, gas storage, and the transport pipeline and network.

Under the biomass gasification project, gas produced from agricultural and processing residues and forest waste is used to generate carbon products and electricity. Each application is designed to meet the energy demands of at least 200 households. Like the centralized biogas project, subsidies target the construction of purification treatment facilities, gas storage, and the transport pipeline and network.

Subsidy eligibility and approach. Qualification criteria include a green-energy production capacity of more than 50,000 tce and more than 20,000 newly added household users. The energy utilization rate of livestock manure and agricultural and forestry residues should be increased by at least 10 percentage points, while the comprehensive utilization rate of crop straw resources should exceed 80 percent. The central government subsidizes demonstration counties through direct subsidies, rewards, and low-interest loans, while local government arranges matching funds for strengthened program sustainability and scaled-up impact.

Achievement and long-term goal. In November 2011, the first group of 26 green energy demonstration counties each received RMB 25 million in subsidies. By 2015, 200 such counties are to be established.

Source: CACS 2012.

measures specify the eligibility and subsidy criteria for fuel-producing enterprises in the straw business of briquetting, gasification, and dry distillation. To qualify, enterprises must consume more than 10,000 tons of straw per year, with more than RMB 10 million in registered capital. The subsidy level, currently RMB 140 per ton of straw, depends on the type and quantity of straw consumed, estimated by the enterprise's sale of biomass products.

Provincial and Local Programs

In addition to centralized stove-related policies and programs, less comprehensive ones are implemented at

provincial, city, and county levels, accompanied by a corresponding series of supporting policies in accordance with those of the central government. The most representative programs include the biomass stove promotion program in Shanxi province, Enshi city's exploration of a new path for rural development, and Anshun city's utilization and reduction in open-field burning of agricultural residues. The provincial-level Bureau of Finance funds the Shanxi program, while the Anshun program draws on a specialized fund under the Consolidating the Achievement of Returning Farmland to Forest program. The Enshi program is subsidized under both the Returning Farmland to Forest and Agricultural Machinery Subsidy programs.

BOX 4.4 DE-FLUORIDATION AND STOVE REFORMING PROGRAM

By the mid-1980s, coal-related fluorosis had become a serious health issue in 13 provinces of China, affecting more than 40 million people in 90 counties. In response, the Ministry of Health (MOH), together with the State Development Planning Commission, MOF, MOA, SFA, and Ministry of Water Resources, took comprehensive measures to reduce fluorine nationwide, with a focus on upgrading stoves.

Achievements. Over the years, 15 types of stoves suited to various altitudes, coal types, and end uses were developed and promoted, which resulted in significant prevention of fluorine-related diseases. In the Three Gorges pilot project area, for example, where more than 100,000 rural households upgraded their stoves, more than 600,000 residents avoided endemic fluorosis.

Lessons learned. Owing to the low incomes of the targeted rural households, many upgraded stoves were not replaced when they fell into disrepair or broke, and a number of households reverted to using conventional coal stoves. This outcome highlights the importance of designing programs that target long-term sustainability.

Source: CACS 2012.

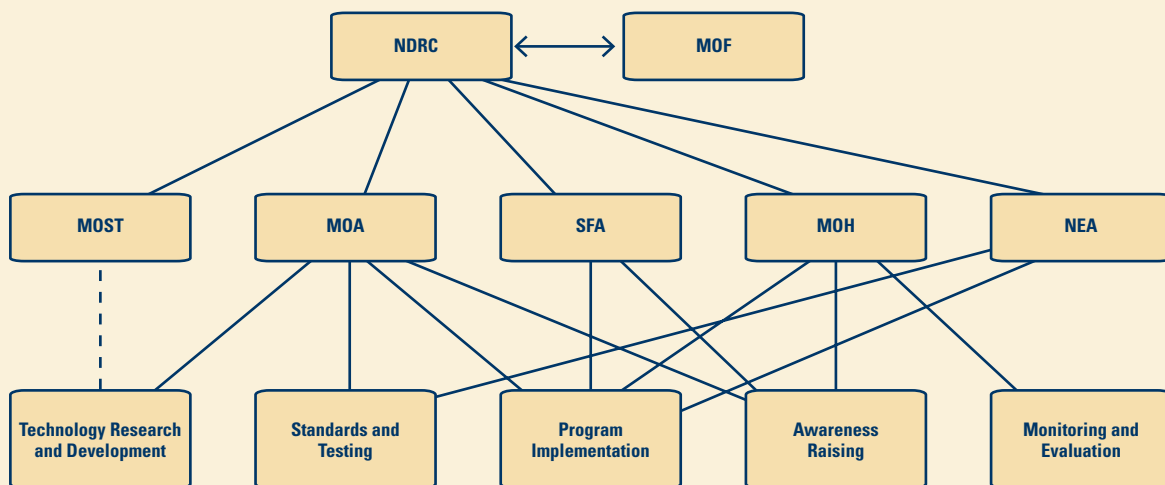
Institutional Arrangements

In the previously described programs and projects, various ministries and departments are responsible for key functions that can affect program/project processes, progress, and sustainability, such as technology research and development, standards testing, program implementation, awareness raising, and monitoring and evaluation (figure 4.2).

Technology Research and Development

Currently, the development of clean biomass stove technology relies heavily on research and development (R&D) conducted independently by enterprises. Few if any special funds are available to support research on stoves-emissions testing and equipment or the impacts on pollutant emissions, health, and climate change. However, following the Fourth China-U.S. Strategic Economic Dialogue, held May 3, 2012, and China's official announcement to join the Global Alliance for Clean Cookstoves (GACC), the Ministry of Science and Technology

FIGURE 4.2 INSTITUTIONAL COORDINATION MECHANISM FOR CLEAN STOVES PROMOTION



Source: Authors.

TABLE 4.1 CLEAN STOVE POLICIES AND REGULATIONS THAT CAME INTO EFFECT IN 2011

Institution	Policy/regulatory document	Description
General Office of the State Council	Twelfth Five-Year Plan (2011–15)	Main areas of focus are promoting biogas and agricultural straw and forestry residue; utilizing biomass, solar, and wind energy; and upgrading fuel-saving stoves.
NDRC, MOA, and MOF	Notification of implementing multipurpose use of agricultural straw, Twelfth Five-Year Plan (NDRC [2011] 2615)	Household program includes promotion of high-efficiency, low-emission biomass stoves.
MOF, NEA, and MOA	Interim Measures for Administration of Subsidy Funding for Construction of Green Energy Demonstration County ([2011] 113)	Support is provided for the purchase of biomass cooking and heating stoves and upgrading of biomass boilers and stoves.
General Office of the State Council	Notice of comprehensive work on energy conservation and emissions reduction, Twelfth Five-Year Plan (State Council [2011] 26).	Promotion of clean stoves is included under the rural energy conservation plan.
NDRC and 17 ministries	Notice of implementing action plan for energy conservation and emissions reduction.	CAREI supports implementation of the action plan for rural areas. Main activities include upgrading stoves, promoting efficient stoves, and improving rural indoor air quality and rural people's quality of life.

Source: CACS 2012.

(MOST) plans to build an Alliance Research Platform to promote R&D and international cooperation.

Standards and Testing

The MOA and the NEA have approved a number of general technical conditions and testing standards related to clean stoves. Also, there are testing centers for agricultural machinery and environmental protection products at various locations. However, these are not specialized in national-level stove testing and thus lack authority and reliability.⁸

Program Implementation

The MOA, SFA, NEA, and MOH are experienced in implementing clean stove promotion programs. The approach is a direct subsidy mechanism, whereby the government tenders and procures stoves before promotion and then disseminates the subsidized stoves to pilot regions.

Awareness Raising

All ministries, as part of their programs/projects, have conducted public-awareness activities, including training and dissemination of manuals and information handouts. Yet people's awareness of clean stoves has not

been substantially raised, suggesting the need to better design and implement awareness campaigns that have impacts of greater breadth and depth.

Monitoring and Evaluation

In the programs implemented by the MOA, MOH, and SFA, the number of promoted stoves were evaluated and verified; however, monitoring and evaluation (M&E) was missing for households' use of the stoves and was incomplete for the program implementation process. The biomass stove promotion project in Shanxi province has adopted an internationally accepted verification method under the carbon trade program, but the method has not been applied to any other project owing to the high cost and complexity of M&E and verification.

Recent National Policies

In addition to the above-mentioned policies and programs implemented in the past, a series of related policies and regulations were issued in 2011 (table 4.1).

A review of these policies confirmed that laws are in place at the national level to promote and upgrade stoves for rural households, especially improved biomass stoves, as well as biogas and other clean rural energy. Moreover, these regulations have started to emphasize the benefits of improved indoor air quality, low carbon emissions, and

8. At the time of this writing, China had no national-level specialized center for clean stoves testing.

better quality of life from using clean stoves, along with the fuel savings and rural energy solutions recognized in the past.

Stove Standards and Testing Protocols

To control product quality and guide development of the stove industry, clean stove standards have been issued and applied at various scales by the corresponding authorities. Stove standards can be grouped into four levels: national, industry, regional, and enterprise. Associated with stove standards are testing protocols that specify how the testing should be conducted to evaluate stove performance. Stoves entering the market or public bidding above the provincial level are required to be tested at legitimate testing centers to certify that they meet certain standards. Those that fail the tests are considered inferior products and are denied market entry.

Any government agency, industry association, enterprise, or individual can propose the development of standards. After receiving such a proposal, the standardization technical committee audits and submits it to the departments in charge of national or industry standards for approval.⁹ Once approval is received, the technical committee organizes the drafting and validating of the standards.

China's existing household stove standards and testing protocols, which encompass a broad array of stove types and technologies, form the foundation for clean stove R&D, production, promotion, and utilization (table 4.2). These standards and protocols are the government's technical means for guiding and regulating the household stove industry; yet they are not systematic, requiring improvements in both methodology and coverage. In addition, they lag in relation to technology improvements and the emergence of new products. A number of required standards and testing protocols are not yet in place. For example, emission standards, design and safety guidelines, and the rating of thermal efficiency and emissions levels for both biomass and coal stoves are missing at every level of the standards system. Furthermore, standards are seldom implemented or enforced

strictly, meaning that some inferior stoves may enter the market or government-supported programs, hindering development of the stoves sector and program implementation.

Thus, the goal toward which progress is being made is to improve the current standards, testing, and certification system in terms of methodology, scope, implementation, and enforcement. As the formulation of international stove standards and testing protocols progresses, China needs to actively participate in the process and consider the compatibility of its national standards with the international framework so that certified national clean stoves can be recognized internationally.

Addressing Key Challenges

China's stove dissemination and household energy policies have achieved a number of positive results, yet issues remain that impede the potential for larger-scale success and longer-term sustainability. Below are suggested ways that future programs can meet these key challenges.

Systematic programs with a firm policy commitment to achieving sustainable development of the stove market are needed.

Too often past intervention policies were one-off and fragmented. While some programs successfully disseminated the expected number of stoves, little effort was made to ensure their long-term utilization. Rural households' low income levels, high maintenance and repair costs, lack of after-sales service and training, and difficulty in obtaining fuel have all contributed to low household utilization rates and poor durability of products. Thus, future programs should target the sustainable use of improved and advanced stoves.

Clean cooking solutions involve cross-cutting issues, requiring strengthened cooperation and collaboration among relevant departments at all levels.

Clean cooking solutions encompass the themes of energy access, energy efficiency, renewable energy, rural development, biomass utilization, and public health. The core objectives of past programs that focused on these respective areas sometimes overlapped at the project or regional level, which led to inefficiencies and ineffectiveness. Moreover, responsibility for M&E, testing, and technology R&D were not specified or assigned. By enhancing the cooperation and collaboration among key departments at all levels, stove projects can be designed and implemented as an integrated program to achieve benefits in all associated fields. Thus, synergies among programs/

9. Relevant administrations under the General Office of the State Council, together with the industry association authorized by the State Council, are responsible for the management of standardization in the corresponding departments and industries. At the provincial level (including provinces, autonomous regions, and municipalities), management is centralized in the provincial standardization administration, with respective management duties shared by the provincial People's Government. The standardization administration manages standards at the corresponding city and county levels, in keeping with the duties specified by the People's Government.

TABLE 4.2 CHINA'S HOUSEHOLD STOVE STANDARDS AND TESTING PROTOCOLS

Standard number	Standard name	Type	Proposing institution	Issuing institution
GB6412-2009	Testing protocol for domestic coal use and household stove	National	China National Coal Association	SAC
GB16154-2005	General technical specification for household water heating coal stove	National	MOA	SAC
GB/T16155-2005	Testing protocol for heating performance of household heating coal stove	National	MOA	SAC
NY/T1001-2006	Technical specification for household improved stove and Kang	Industry	MOA	MOA
NY/T8-2006	Testing protocol for thermal performance of firewood stove	Industry	MOA	MOA
NY/T1703-2009	Specification for installation and acceptance of water heating stove of heating system	Industry	MOA	MOA
NB/T34006-2011	General specifications for household densified biofuel heating stove	Industry	CAREI	NEA
NB/T34005-2011	Testing protocol for household densified biofuel heating stove	Industry	CAREI	NEA
NB/T34007-2012	General specification for biomass cooking and heating stoves	Industry	CAREI	NEA
NB/T34008-2012	Testing protocol for biomass cooking and heating stoves	Industry	CAREI	NEA
NB/T34009-2012	General specification for biomass cooking and radiant heating stoves	Industry	CAREI	NEA
NB/T34010-2012	Testing protocol for biomass cooking and radiant heating stoves	Industry	CAREI	NEA
To be approved	General technical specification for household biofuel cookstove	Industry	MOA	MOA
To be approved	Testing protocol for household biomass cookstove	Industry	MOA	MOA
DB11/T540-2008	General technical specification for household biomass stove	Regional (Beijing)	Beijing Bureau of Quality and Technical Supervision	Beijing Bureau of Quality and Technical Supervision

Source: CACS 2012.

Note: GB = national standards, NY = agricultural industry standards, NB = energy industry standards, DB = regional standards.

projects should be explored to increase efficiency and effectiveness.

More flexible subsidy schemes that incorporate monitoring and evaluation (M&E) are needed to directly link program results to subsidy disbursement. Currently, most stove programs lack flexible, diverse subsidy systems. The subsidy is not directly linked to performance or results, and its level does not differentiate by region or stove type. An alternative, results-based scheme could be more effective. Also, past programs failed to conduct M&E during project implementation and after project closure. It

is essential to set up M&E to assess program results, which can be used to trigger the subsidy disbursement.

Strengthened public-awareness campaigns, particularly those that center on the benefits of clean stoves, are vital to changing household behavior and developing product demand. To date, intervention policies and programs have focused on informing households about the economic subsidies rather than the benefits of better stoves and the negative impacts of conventional ones, which have resulted in households' lack of willingness to use the stoves. Increasing the likelihood that households adopt

improved and advanced stoves requires public-awareness campaigns that inform household members of the stoves' multiple benefits (i.e., health, cost reduction, time savings, and environmental quality).

Research is needed to obtain better market data on the supply chain, stove market segments, and stove technology. Due to a lack of in-depth research on stove supply and demand, little attention has been paid to household energy demand in various regions and suppliers' economic profit. In addition, a lack of coordination between upstream and downstream supply-chain players often increases production and operating costs and hinders scaled-up production. Along with insufficient investment in R&D, stove producers and others along the supply chain often lack interest in stove production, dissemination, and innovation. Designing better programs requires that the government and market players conduct further studies to gain a better understanding of the market.

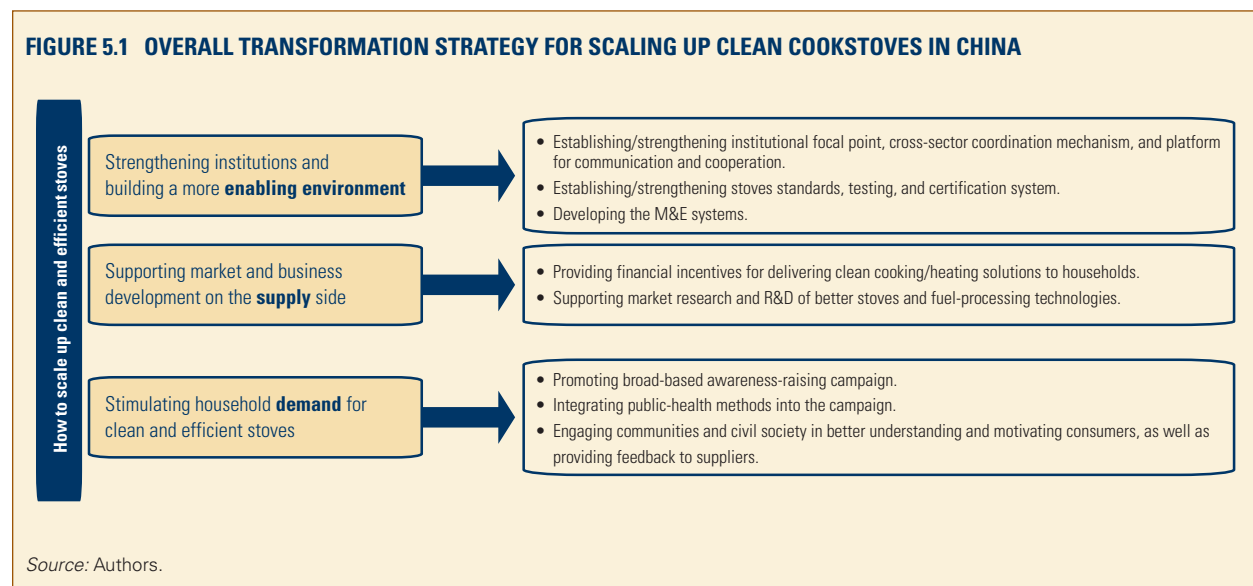
Conclusion

This chapter's review of China's stove-related policies, programs, and institutional arrangements demonstrates the significant strides that have been made at national and regional levels in promoting clean rural-energy solutions. At the same time, most such programs are not sustainable; in some cases, households have reverted to using conventional stoves once funding for programs ended. Although various national, industrial, and regional standards for stove products exist, the system lags behind the rapidly developing stove industry and lacks an integrated system. The institutional setup of past programs did not specify stove testing centers, stove R&D, or M&E during and after programs, which has led to inefficiencies in program implementation. Thus, it is strongly recommended that strategies for future government programs target sustainable development using a results-based approach with an improved standards and rating system and strengthened institutional capacity, supported by awareness-raising campaigns and market research. The next chapter elaborates on how such a program might be designed.

Key Policy Recommendations

Since the National Improved Stoves Program (NISIP) ended in the late 1990s, the various government-supported stoves programs that have been implemented have tended to be fragmented and lacking in coordination, as previously discussed. More recently, however, China has begun taking proactive steps, having joined the Global Alliance for Clean Cookstoves (GACC) and having integrated clean stoves promotion into its action plan for energy conservation and emissions reduction as part of its Twelfth Five-Year Plan. Now there is a window of opportunity for China to build on these efforts to develop a comprehensive intervention strategy to promote clean cooking and heating solutions, primarily for the rural households that are likely to continue using solid fuels for cooking and heating beyond 2030.

This chapter presents recommended actions for China to accelerate the progress toward universal access to clean cooking and heating solutions, building on results from the China CSI stocktaking review, as well as the two national consultation workshops with key stakeholders from central government, provincial governments, stove enterprises, nongovernmental organizations (NGOs), and academia. The sections that follow provide the overall CSI program strategy and details on its three priority areas; an innovative financing approach that integrates the identified priorities and focuses on delivery of results; and the CSI's proposed next steps in preparing for scaled-up access to clean cooking and heating solutions.



Overall Program Strategy

The proposed CSI program strategy comprises three main components: (1) strengthening institutional capacity and creating an enabling policy and regulatory environment for scaling up access to advanced stoves, (2) supporting supply-side market and business development, and (3) stimulating household demand for clean and efficient stoves (figure 5.1). This strategy builds on and is consistent with the sector transformation strategy developed by the GACC and the World Bank's "one goal, two paths" approach to achieving universal access to modern energy in the East Asia and Pacific region (World Bank 2011a).

Strengthening Institutions and Building a More Enabling Environment

Overcoming the fragmented nature of current stoves programs and policies calls for strengthening institutions. In addition, an enabling policy and regulatory environment requires establishing and strengthening stove standards, testing, and certification, as well as developing a systematic approach for project planning, assessment, implementation, and monitoring and evaluation (M&E).

Institutional Strengthening

Several key actions are suggested for strengthening institutions. First, an institutional champion and focal point are needed. Given that the Ministry of Agriculture (MOA) has been a long-time champion of the stoves issue and has served as the main implementing institution for the NISP and other past stoves promotion programs, it is recommended that the MOA continue as institutional champion and focal point. Further support will be needed to strengthen its technical and implementation capacity, particularly with regard to its role as lead implementing agency for the second national clean stoves program currently being planned.

Second, given that the clean stoves agenda involves issues that cut across multiple sectors, a cross-sectoral coordination mechanism is needed. It is recommended that the National Development and Reform Committee (NDRC) establish and co-chair with the MOA a national clean stoves development steering committee comprising the Ministry of Finance, Ministry of Science and Technology, Ministry of Health, National Energy Administration (NEA), State Forestry Administration, and other relevant ministries and commissions. Such a steering committee will coordinate various sectors and provide strategic direction for their development.

BOX 5.1 CHINA ASSOCIATION OF RURAL ENERGY INDUSTRY

The China Association of Rural Energy Industry (CAREI), also known as the China Alliance for Clean Stoves (CACS), which it initiated, has played a critical role in developing China's stove industry. Founded in 1992 when the country's national stoves program was under way, CAREI is the country's only national-level organization focused on the rural energy industry. Affiliated with the Ministry of Agriculture, CAREI has 1,076 members, representing enterprises, research institutes, universities, and societies engaged in technology R&D, manufacturing and processing, construction, and marketing and sales. In addition to an editorial office that publishes news and reports, the association has six specialized committees across various rural energy-related fields, including solar thermal utilization, energy-saving stoves, biogas, bioenergy conversion technology, small-scale electricity power, and novel liquid fuels and associated burners.

CAREI's main functions are to safeguard the legitimate rights and common interests of its members, reflect the aspirations and demands of enterprises, implement national policies and regulations, play a bridging role between government departments and its members, and assist the government in carrying out industry management. Through advancing industrial technology, improving product quality, and strengthening technical and economic cooperation domestically and internationally, the association comprehensively improves the quality and economic benefits of the entire industry; realizes rural energy services with a focus on energy conservation, renewable energy development, and comprehensive utilization of resources; improves the ecological environment; and promotes the country's sustainable development.

Sources: CAREI 2012; CAREI Platform 2012.

Third, a platform for communication, learning, and cooperation is needed. The China Association of Rural Energy Industry (CAREI), also known as the China Alliance for Clean Stoves (CACS), has played an instrumental role in stove industry development, having provided a communication platform for key stakeholders, including the government, users, producers, the research community, and international partners (box 5.1). Thus, it is recommended that CAREI's role be expanded as a platform for communication, learning, and cooperation, including the bridging of public and private sectors.

Enabling Policy and Regulatory Environment

Creating an enabling policy and regulatory environment for clean stoves promotion requires establishing and strengthening sound stove standards and testing protocols, testing centers, and a certification system. In addition, a systematic approach is needed for project planning, assessment, implementation, and monitoring and evaluation (M&E).

As discussed in chapter 4, China's current stove standards and testing protocols lag behind the rapidly developing stove industry and lack an integrated system. International stove standards and testing protocols are currently in the process of being formulated. For example, the International Workshop Agreement issued in June 2012 provides an intermediate rating framework, which includes four performance indicators (efficiency, indoor emissions, emissions, and safety) and five tiers (0–4). China needs to actively participate in formulating the international standards and consider the compatibility of its national standards with the international framework so that certified national clean stoves can be recognized internationally. It is recommended that the Standardization Administration of the People's Republic of China (SAC) work with the MOA and NEA to improve national standards and testing protocols and actively participate in discussion and formulation of international standards.

Establishing testing centers will be necessary for evaluating stove performance and providing recommendations for making continuous improvements. Testing centers can be hosted by research centers or universities with multiple functions (e.g., testing, education, research and development [R&D], and advisory service for design development). Competitions can be organized to identify top-performance stoves. Currently, China has a small number of testing centers for agricultural machinery and environmental products hosted by universities

or companies, but they lack authority and are not specialized in stove testing. Therefore, improving capacity, cross-learning, and coordination among the testing centers will be important priorities.

To ensure stove quality, an open, fair, and transparent certification system needs to be established. Testing centers qualified to conduct stove certification need to be accredited, and the accreditation process should be open, fair, and transparent. This will be particularly important when stove certification is linked with government incentives.

As discussed in chapter 4, a comprehensive system to promote clean stoves calls for an integrated program and thus a systematic approach from project outset through project closure and beyond to ensure efficiency and effectiveness. A review of completed and ongoing intervention programs reveals that most have lacked systematic M&E, which is required for making adjustments, as needed, to design and implementation and providing important implementation feedback. Systematic M&E is also critical for designing follow-up and scale-up activities. Thus, future intervention programs should develop and institutionalize such a system.

Supporting Market and Business Development

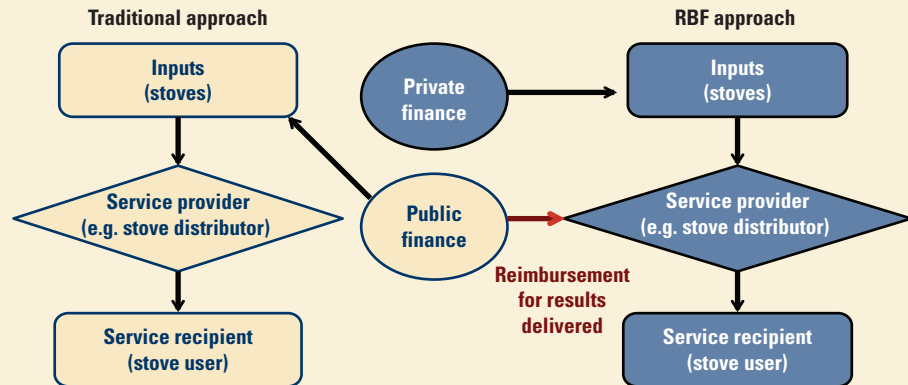
On the supply side, two main challenges are (1) ensuring the delivery of clean cooking and heating solutions to primarily poor households in rural areas, where the stove business is not profitable and may not be fully commercialized and (2) supporting market research and R&D for better stoves and fuel-processing technologies.

Financial Incentives for Delivery of Better Stoves

As discussed in chapter 3, about four-fifths of biomass stoves are subsidized by government funding; however, as mentioned in chapter 4, the traditional government procurement process on which the subsidy scheme is based has a number of problems. It is suggested that more innovative subsidy schemes be piloted in order to increase the efficiency and effectiveness of government funding support. One such scheme is Results-Based Financing (RBF), which disburses public resources against demonstrated, independently verified outputs or outcomes instead of project inputs. This distinguishing feature can mean more effective and efficient use of public funds and improved support of market interventions (box 5.2).

BOX 5.2 WHAT IS RESULTS-BASED FINANCING?

Results-Based Financing (RBF) is a concept comprising a range of public policy instruments, whereby incentives, rewards, or subsidies are linked to the verified delivery of pre-defined results. RBF is often used to enhance access to and delivery of basic infrastructure and social services, such as improved access to water and sanitation, energy, and health care. In most cases, the funding entity—typically a government, development agency, or other agent—deals directly with the service provider (e.g., private firm, public utility, civil society organization, or financial institution). Some of the better-known RBF approaches include output-based aid (OBA), conditional cash transfers, carbon finance, and advance market commitments.

Distinguishing RBF from Traditional Public Procurement

Unlike traditional public procurement, which uses public resources to purchase the inputs and contract service providers to deliver them to users, the RBF approach uses private-sector resources to finance the inputs and service delivery and public resources to reimburse the service provider upon delivery of the pre-defined results. This key difference gives RBF the potential to improve the efficiency and effectiveness of disbursing public resources and support of market-based interventions (see figure above).

Source: Zhang and Knight 2012.

Market Research and R&D Support

Promoting clean cooking and heating solutions should understand market segmentation, adapt to local conditions, and be consistent with and adjust to long-term development patterns. Market research should be supported to better understand market needs, which can be used to design government-supported programs and help stove suppliers adjust their products.

China's clean stoves research groups are limited in number, dispersed, and generally lacking in funding support. In addition, stove manufacturers are not motivated to invest in innovation as new designs are often copied. Furthermore, biomass fuel processing still faces technological barriers. Thus, it is recommended that R&D funding be provided for better stoves and fuel-processing technologies. Since stove performance relates to cross-cutting factors covering multiple fields (i.e., environmental science, mechanical manufacturing, biomass energy, and social science), a multidisciplinary team may be needed. Internationally, there is growing interest in this area. It is recommended that an international clean

stoves research center be established to provide a platform for research and innovation, as well as knowledge exchange with international experts. Since China has large and diverse demand for various stoves and a high R&D capacity, such a center should aim to be a first-class leader in innovation.

Stimulating Household Demand

In the long run, any market-based clean stoves intervention will only be sustainable if consumer demand can come to permanently influence better stoves supply in the market. As previously discussed, various factors account for households' lack of enthusiasm in investing in and using clean stoves, including limited funds, low product quality and durability, and lack of an after-sales service system. Propelling growth in market demand requires raising households' awareness of the health risks of household air pollution (HAP) and the benefits of clean stoves. The clean stove delivery mechanism should also include user training and after-sales maintenance

service. At the same time, communities and civil society should be engaged in broad outreach activities that feed users' requests and comments back to suppliers.

Comprehensive Awareness-Raising Campaign

As previously discussed, survey results and past programs reveal inadequate public knowledge about the damaging health effects of indoor use of fuel-inefficient stoves, how clean cooking/heating technology can combat these health hazards, and the multiple benefits of clean stoves. Given the current low level of public awareness, a campaign promoting clean stoves must be a far-reaching, comprehensive effort involving multiple sectors. Such methods as road shows and public campaigns released through various media channels can draw consumer awareness to the existence of clean cooking/heating technologies and the many advantages of clean stoves over traditional methods. Such a campaign would be further enhanced by increased R&D on new clean stove designs and standardization.

One key component of educating the public about clean cooking/heating technology is emphasizing the consistent use of quality stoves. If the public can be convinced of the beneficial features of using modern, high-quality stoves over inefficient traditional technologies, they can be influenced to demand quality stoves from their suppliers. In turn, this will create public control over quality, which will help to solidify the presence of quality clean stoves in the national stoves market.

Integrating Public-Health Methods

Awareness-raising campaigns on clean cooking technology should integrate public-health methods that educate households about the risks of inefficient fuel technologies on family health, and thus help influence them to reject dangerous traditional cooking/heating methods in favor of modern, cleaner options. A public-health campaign on this scale will require cooperation among community and civil-society officials and representatives. Possible venues for a public-health intervention include local health clinics, with the participation of physicians and other medical authorities who play a daily role in the public health of their communities. Also, training should be designed in the local communities' language or dialect at the appropriate literacy level. Furthermore, women's groups, the primary users of household cooking technology, should be involved or targeted since they often influence the types of technology used. Any public campaign should be aware of the gender implications of its messages in order to maximize the effects on users' behavioral change.

A New Approach to Promoting Clean Stoves: Results-Based Financing

Past stoves programs have followed public procurement procedures, meaning that public entities have been responsible for making stove technical specifications and identifying eligible service providers, delivery methods, and end users to receive subsidized stoves. Payments have been made against the stoves purchased and associated delivery service. By contrast, using the RBF approach, public entities specify the intended results, verification methods, and associated subsidies; while payments are made to the service provider against verified delivery of the stoves and their operational performance.

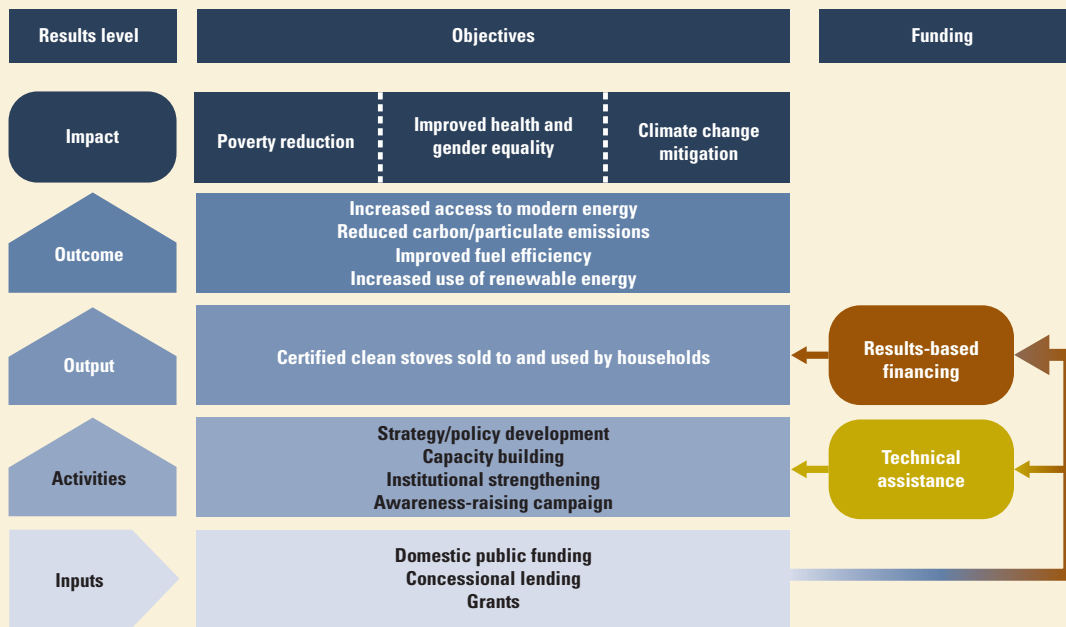
The RBF approach focuses on results that the public sector cares about and rewards private-sector suppliers who can deliver them. Investment and performance risks shift from the public to the private sector. In turn, private-sector suppliers have the flexibility to innovate in designing, producing, and selling defined clean stoves that are eligible for targeted incentives. This flexibility is vital to stoves market development since stoves must fit local conditions, including customary cooking practices, affordability, and availability of local resources and after-sales service. The success of stove suppliers depends on understanding such local conditions.

Chain of Results

Promoting clean stoves can contribute to the broader development objectives of reducing poverty, improving health and gender equality, and mitigating climate change (figure 5.2). Replacing fuel-inefficient, polluting stoves with those that have better energy-combustion properties can help poor households climb out of poverty by reducing their fuel expenses. The health of family members who spend long hours in the household cooking environment—primarily women and their young children—benefit from reduced HAP. Women's freed-up time from collecting fuelwood and preparing meals with traditional cookstoves can be spent on more productive activities. The local ecosystem and global environment also benefit as a result of reduced carbon emissions and less black carbon due to the burning of solid fuels.

To achieve these impacts, the RBF incentive would be linked to the verifiable output: certified clean stoves sold to and used by households. Also critical to success would be technical assistance activities for strategy and policy development, capacity building, institutional strengthening, and awareness-raising campaigns (figure 5.2).

FIGURE 5.2 SAMPLE RESULTS CHAIN FOR CLEAN STOVES PROMOTION PROGRAM



Source: Authors.

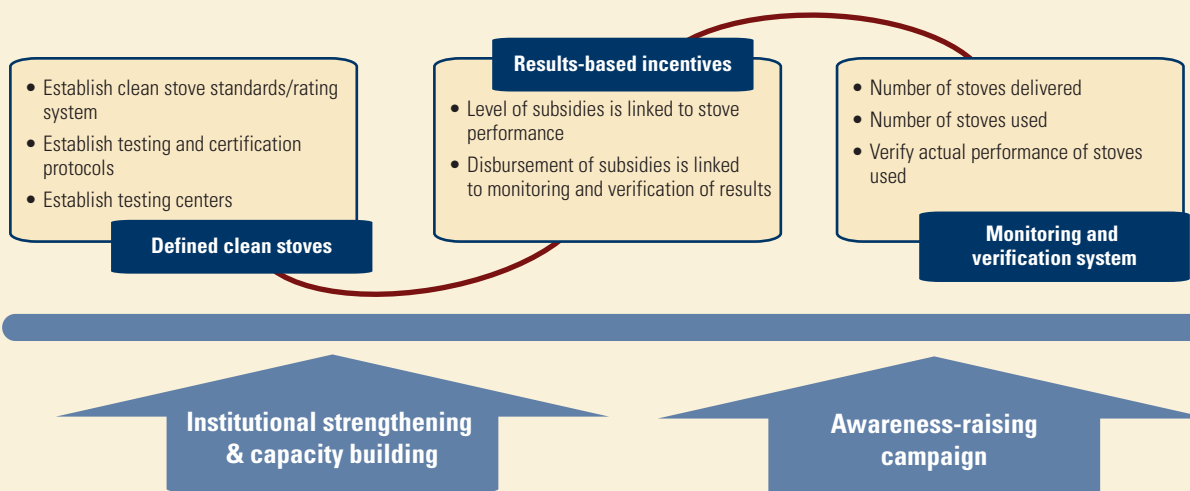
RBF Framework

The conceptual framework for using RBF in programs to promote clean stoves could include three key building blocks—(1) defined clean stoves, (2) results-based incentives, and (3) a monitoring and verification (M&V) system—supported by two pillars—(1) institutional strengthening and capacity building and (2) awareness-raising campaigns (figure 5.3).

Building Blocks

Defined clean stoves. Defining a clean stove requires establishing a standards/rating system, testing and certification protocols, and testing centers. The standards/rating system should consider its compatibility with the rating framework provided by the International Workshop Agreement, which includes four performance indicators (efficiency, indoor emissions, emissions, and safety) and five tiers

FIGURE 5.3 RBF FRAMEWORK WITH THREE BUILDING BLOCKS AND TWO SUPPORTING PILLARS



Source: Authors.

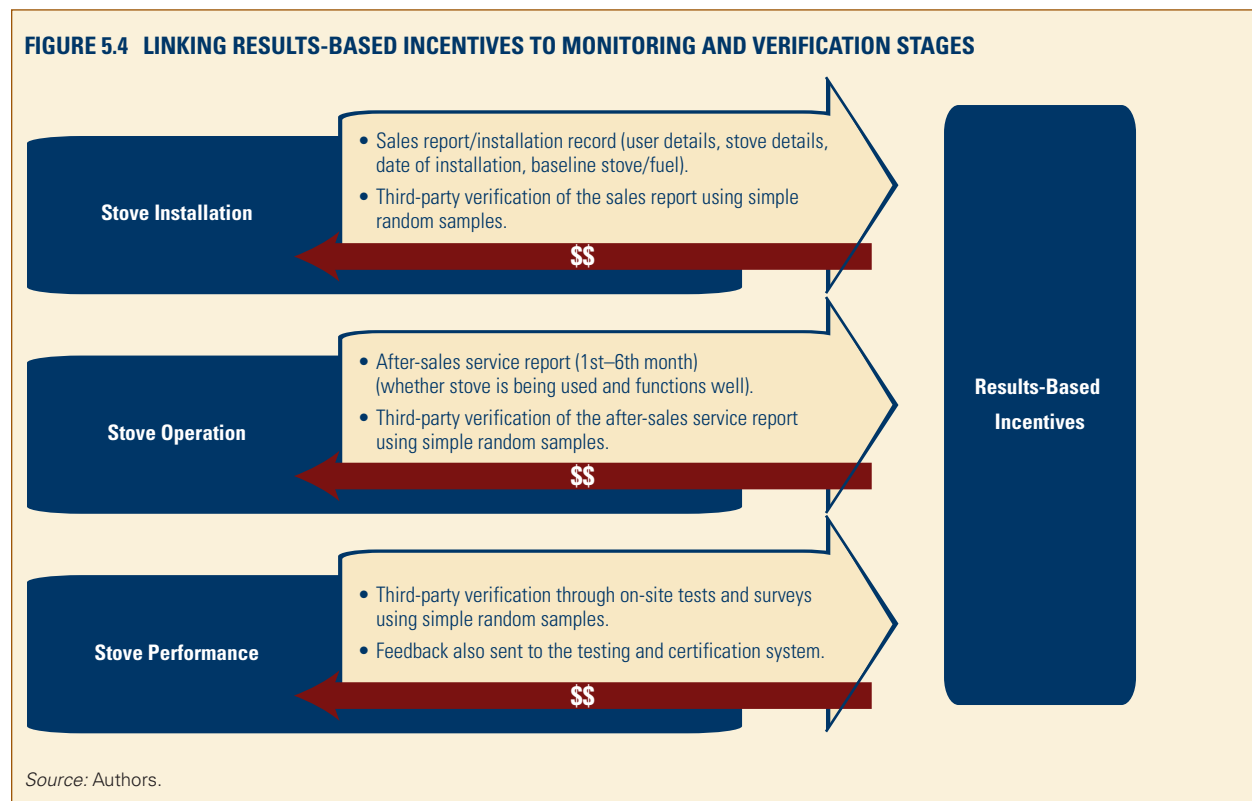
(0–4). Laboratory and field testing might be included, and the certification process should be open, fair, and transparent. A research center or university with multiple functions (e.g., testing, education, R&D, and advisory service for design development) could host the testing centers to ensure their sustainability. Competitions could also be organized to identify top-performance stoves.

Results-based incentives. The level of incentive (subsidy) should be linked to stove performance and its disbursement to monitoring and verification of results. Eligibility criteria should be clearly outlined and the amount adjusted according to the level of stove performance and geographic preferences. Those who apply for incentives (the market aggregators) are those willing to take investment and performance risks. These may include producers, wholesalers, retailers, and project sponsors. To receive payment, they must produce stoves that can be certified as “clean,” design according to customer preferences, and convince customers to buy and use the stoves.

Design of an incentive payment system requires a thorough understanding of the cost structure and profit margin (supply side) and consumers’ willingness to pay (demand side), as well as the economic benefits of the

incentive provided. Advance disbursements could be designed to help finance stove suppliers. The incentives could be implemented through a financial institution to leverage the existing network and traditional financing instruments.

Monitoring and verification system. A critical part of the RBF design is monitoring and verification (M&V), which triggers payments. The M&V system could combine self-reporting and third-party verification, using sampling methods to balance the trade-offs between accuracy and costs. To incentivize efforts to achieve sustainable clean cooking, results-based incentives could be linked to specific stages of M&V results, including stove installation, operation, and performance (figure 5.4). The detailed design of the M&V system could also incorporate lessons learned from the carbon finance methodology for clean stoves projects. China has been particularly successful in developing carbon finance projects to promote clean stoves dissemination (box 5.3). However, since carbon finance focuses exclusively on carbon emission reductions while clean stoves are linked to other benefits (figure 5.2), the RBF can be designed more flexibly to fit program objectives.



BOX 5.3 BIOMASS STOVE CARBON FINANCE PROJECT

In 2009, the China Association of Rural Energy Industry (CAREI), Beijing University of Chemical Technology (BUCT), Impact Carbon and Jinqilin Energy Technology Company, Ltd. together developed the Biomass Stove Carbon Project. Two years later, the project was validated and issued by the Gold Standard Foundation, the first issuance of which was 49,308 tCO₂e. The enterprises used most of the credit to promote biomass stoves. The project used the earlier government subsidy, combined with later carbon credit funds, to sustain the dissemination of clean biomass stoves. From March 2009 to September 2010, the Yangquan government subsidized 13,403 stoves; by the end of 2011, Jinqilin had sold 3,577 stoves with the carbon funds. Even without the government subsidy, it is expected that the project could continue subsidizing farmers using the carbon credit fund, thereby achieving large-scale, sustainable dissemination of biomass stoves.

The project monitors rural households' stove use by administering the kitchen and test-kitchen performance surveys, which cover farmers' basic family situation, comparison of old and new stoves, service life of stoves, and the baseline change and fuel consumption. According to the Gold Standard Baseline and the Monitoring Methodology for Improved Cook-Stoves and Kitchen Regimes V.02-08/02/2010, the project needs to conduct continuous, quarterly, and biennial monitoring for the following variables.

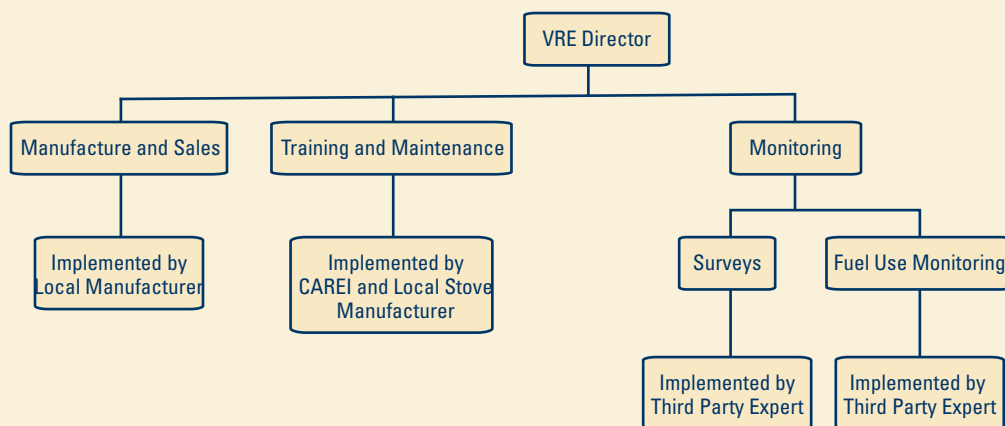
Continuous monitoring. Variables are total sales record (date of sale, location, model, number sold, and contact information [as complete as possible]); a detailed customer database that records results of the monitoring surveys; and a project database that calculates emission reductions based on total sales and results of the monitoring surveys, including adjustments for clusters and other influencing factors.

Quarterly monitoring. To reassess kitchen regimes, a kitchen survey is conducted each quarter; 25 households are randomly selected from the relevant period, not less than half of which are contacted in their homes. The data collected includes contact information, seasonal stove/fuel combinations used for cooking, domestic versus institutional use, number of people cooked for, and number of meals cooked per day.

Biennial monitoring. Twice a year, the kitchen performance of older stoves and new stove models is tested. For older stoves, fuel-reduction performance and other factors related to successive years of aging are measured; for new stove models, fuel consumption is measured. The utilization rate is surveyed to establish the drop-off rates in stove usage from year-1 sales, and is applied to each relevant stove vintage in the project databases.

A monitoring team is established to ensure that the monitoring of project activities is in accordance with GS VER Methodology guidelines (see figure below).

Organizational Structure of the Monitoring Process



Supporting Pillars

Institutional strengthening and capacity building. Institutionalizing clean stoves would be an important step toward providing an enabling environment. Key elements could include an institutional champion; a cross-sector coordination mechanism; and a platform for communication, learning, and cooperation. Technical assistance in capacity building is also needed to improve the performance of all market players, ranging from designers and producers to market aggregators, financiers/investors, testing professionals, and M&V specialists.

Awareness-raising campaigns. To motivate both supply and demand, awareness-raising campaigns should be conducted at all relevant levels. Campaigns could focus on informing the public about the program and the availability of results-based subsidies and other associated program benefits and raising awareness about the negative health impacts of HAP linked to biomass cooking smoke. Using a celebrity ambassador could be an effective way to raise such public awareness.

The RBF framework can not only integrate all of the identified priorities described under the overall intervention strategy. More importantly, it can help to clarify the roles of the government and private sector in delivering the results. That is, the government plays a facilitating role to provide policy support and financial incentives to motivate market development, while the private sector responds to the incentives and delivers the results.

It should be noted that, under certain circumstances, the RBF approach may not be the most effective or efficient way to achieve results. For example, in more remote and poorer areas, which cannot attract the private sector owing to scant market activities, high delivery costs, and low affordability, traditional government procurement is probably a better approach. It has the advantages of easy demand aggregation and fast implementation, and can be integrated into poverty alleviation, social programs, and post-disaster relief programs. If this approach is selected, it is recommended that bidding documents and contract arrangements be carefully designed in terms of technology selection, delivery method, and post-delivery service. It is also important to keep options and approaches open. Promoting clean cooking and heating solutions should understand market segmentation, be able to adapt to local conditions, and be consistent with and adjust to long-term development patterns.

Next Steps

The overall intervention strategy and the RBF implementation approach were discussed at the second national consultation workshop held in Beijing in July 2012. The public and private sectors agreed with the strategy and also expressed great interest in the RBF approach, which they agreed to pilot in selected areas. Under phase II of the China CSI, four major areas of activity are proposed for supporting strategy implementation to scale up access to clean stoves: (1) improving stove standards, testing, and verification system; (2) strengthening institutions and building the capacity of key market players; (3) supporting pilot activities; and (4) supporting preparation of the second national clean stoves program and provincial activities.

Since defining “clean stoves” is a priority for promoting them, a thorough review of China’s current system and international experience in this area will be conducted to identify gaps and opportunities for improvement. In addition, coordination with the GACC, which currently supports the establishment of regional testing and knowledge centers, will be strengthened to ensure China’s participation in the process, help it build a regionally recognized stove-testing center, and contribute to regional knowledge-sharing. Furthermore, as international standards for clean stoves are being formulated, efforts will be made to encourage China to actively participate in the process and consider the compatibility of its national standards with the international framework so that certified national clean stoves can be recognized internationally.

China has already established a good institutional setup, having selected the MOA as the institutional focal point, with the NDRC taking the lead on cross-sectoral coordination and the CAREI (CACS) serving as a platform for communication, learning, and cooperation. The next step is to further strengthen these institutional arrangements. As the RBF approach relies on market players to deliver the results, training activities will be provided to build the capacity of key market players through the CAREI (CACS) platform. In addition, activities for international knowledge exchange and learning will be planned.

The CSI will identify areas that are representative and scalable for piloting the RBF approach to promote clean stoves. All of the key elements discussed under the RBF approach will be included in the pilot program. Preparations are under way to identify pilot areas and develop the program’s implementation plan.

Finally, the second national clean stoves program, currently being planned, represents a significant step toward achieving universal access to clean cooking and heating solutions. The China CSI will work closely with the MOA, the lead agency, to provide needed support. In addition, Hebei province, which is preparing a large-scale rural

energy project that will provide rural households clean cooking and heating solutions, has requested US\$100 million in IBRD loan support. The CSI will support preparation activities and provide a learning platform for provincial rural energy projects that target increased access to clean cooking and heating solutions.

Case Studies of Key Market Segments

Learning from the successful experiences of past stove dissemination programs across key market segments in various provinces can inform the design and implementation of future programs. This chapter presents four such cases that characterize the stoves supply, demand, and policy interactions in the biomass, coal, biogas, and solar cookers markets in specific local contexts. Each case begins by introducing the study site, followed by a description of program design, implementation, and achievements, as well as lessons learned.

Biomass Stoves in Shanxi Province

Located in central China, Shanxi province has a population of more than 337 million, more than three-fifths of whom reside in agricultural areas. The province relies heavily on coal, especially for heating, which accounts for three-fifths of household energy consumption in rural areas. Furthermore, during the characteristically cold winter months (i.e., five months per year), coal is the dominant fuel used for household heating. Each year, the average rural household consumes 2–4 tons of coal for winter heating and cooking throughout the year, with total rural coal consumption amounting to 18–20 million tons.

Shanxi boasts China's largest coal reserve and is among the country's leaders in coal production. Such a high level of availability contributes greatly to the resource's widespread use for heating. However, for low-income rural households, with a monthly expenditure range of RMB 1,800–2,400 (2011 figures), the per-ton price of coal, RMB 600–800, is not so affordable. Beyond coal, Shanxi is abundant in agricultural and forest residues, although

forest resources are limited. An estimated 20 million tons of residue resources, derived from crop straw, pruning of fruit trees, and forest waste, remain untapped each year.

The province has two common winter heating options in rural households: (1) smaller consumption of coal (2 tons per year on average) to heat a limited area with heating stoves and (2) larger consumption of coal (4 tons per year on average) to heat a larger area with water heating stoves. The first option entails a hygiene problem and the likelihood of gas poisoning. Using the second option heats a larger space, but most farmers cannot afford the high cost, and the ash contaminates the environment.

Stoves Promotion Pilot Program

To address the heating needs of poorer rural households, a promotional pilot program was designed to provide such customers alternative heating-energy solutions using clean biomass stoves. The aim of the pilot program was to demonstrate that such stoves could offer rural households a suitable heating alternative during the winter months. In 2007, Shanxi province's finance and agriculture departments selected 15 representative villages in 11 cities to participate in program implementation. Each village has 200 pilot users, each of whom receives a subsidy of RMB 1,000 from the provincial government.

The pilot program promotes three types of biomass stoves: (1) combined cooking and heating, (2) heating, and (3) cooking. The combined cooking and heating stoves are used for both heating and cooking purposes in winter, and the available models of cooking and water heating stoves can heat an area 60–120 m² in size while those of cooking and heating stoves heat a smaller area

TABLE A.1 BIOMASS STOVE PERFORMANCE

Stove type	Cooking thermal power (kW)	Heating thermal power (kW)	Combined thermal efficiency (%)	Dust (mg/m ³)	SO ₂ (mg/m ³)	NO _x (mg/m ³)	CO (%)	Ringelmann black degree
CNK-80 Cooking and water heating	2.1	9.8	79.9	9	0	132	0.06	1
CK-II Cooking and heating	3.1	-	88.6	29	13	138	0.09	1

Source: CACS 2012.

Note: SO₂ = sulfur dioxide; NO_x = nitrogen oxides; CO = carbon monoxide.

(10 m²). With a higher thermal efficiency and price, various heating stove models can heat an area 150–300 m² in size. Most stoves, identified as “double commitment” products by the China Association of Rural Energy Industry (CAREI), are procured from two main manufacturers in Shanxi province. These stoves are mainly fueled by agricultural and forest residues (e.g., crop stalks and tree branches from harvesting, trimming, pruning, and processing) (table A.1).

Implementation Arrangements

The biomass pilot program is implemented by the agriculture department at all levels, with distinct responsibilities for each. At the county level, the department is in charge of project proposal submission and implementation at the grassroots level; at the city level, it is mainly responsible for monitoring implementation through field surveys and other measures. The provincial-level government selects pilot locations and designs implementation plans, based on information gathered from county- and city-level offices.

Procurement follows local government regulations and must be approved by the finance department at the county or district level. In addition, manufacturers are responsible for equipment installation and testing, training farmers in use of the technology, and after-sales service. After the equipment installation, the county-level department verifies the equipment performance based on testing results and keeps track of inventory in a standard way. At the provincial level, the department regularly organizes the supervisory field visits of technical experts to make inspections, ensuring sound program implementation.

Achievements and Outcomes

The pilot program, which now is expanding its scale, demonstrates that high-efficiency, low-emissions biomass stoves can offer rural households a suitable option for winter heating. Since the program was initiated in 2007, 100 model villages have been established, with nearly 20,000 farmers using the stoves. Also, farmers have become more aware of the program’s benefits and thus are now more willing to participate. For example, in Xiqi village, which features 120 households with 4 fruit trees per household, 100 households adopted the improved stoves in 2008, and obtained three branch-cutting machines that year. A year later, all 120 households were using clean cooking and heating stoves that burn biomass.

In addition, the pilot program has demonstrated the broader benefits of energy savings, cost savings, environmental protection, and improving rural households’ quality of life. The consumption of agricultural and forestry waste as fuel can save each household 2–4 tons of coal each year on average. Also, given the rise in coal prices, the cost savings from replacing coal for heating and cooking becomes larger, estimated at more than RMB 1,500 per household per year. The utilization of waste meets rural households’ demand for water heating, cooking, and space heating, thereby improving their quality of life.

What Was Learned

The pilot biomass promotion program has achieved the objective of providing a suitable and sustainable heating solution for targeted rural households in Shanxi province. Although certain issues still must be resolved before program scale-up, the program offers valuable lessons in success that can be applied to future stove programs.

First, programs must be designed to cater to customer needs and local conditions. Compared to agricultural residues, fruit-tree residues can be processed at a much lower cost due to their higher density. In this pilot program, the processing cost can run less than RMB 10 per ton, versus RMB 200 per ton for crop straw. Thus, it makes more economic sense to promote high-efficiency, low-emissions biomass stoves in fruit-tree growing regions for easier fuel collection and simpler, lower-cost processing.

Second, it is advisable to combine the use of clean biomass stoves together with other rural energy technologies. In accordance with local conditions, various combinations can be applied, such as stove and solar energy, stove and hanging Kang, or stove and biogas. With a focus on demonstration, households can begin to recognize and appreciate the convenience and benefits that available energy sources bring to their lives. As the program outcome demonstrates, broader utilization of clean energy types, such as solar and biogas, occurred in the targeted area.

Third, technology must be improved to cut production cost. Although the participating villages have rich corn straws, the straw briquetting technology has not improved much. Along with the rising cost of electricity and labor, a top priority is to have a strong R&D input to advance technology, thereby reducing production cost and, in turn, making the supply of high-quality biomass more affordable and sustainable.

The high upfront costs faced by users and producers require continued government support and public-awareness campaigns to stimulate demand and willingness to pay. Even with the subsidy, the village and each household still need to raise RMB 100,000 and RMB 2,000, respectively. Public-awareness campaigns that help households realize the benefits of biomass stoves and thus increase their willingness to pay for the stoves and fuel are key to sustainable utilization of improved stoves.

Coal Stoves in Hebei Province

Located in North China, Hebei province has a population of more than 68 million. Coal is a main heating fuel for rural households; however, the province has scant coal resources, and shortages exacerbate during the winter months, along with coal price increases. Three out of a total of 11 cities have no coal resources, while 5 have some low-quality coal resources and 3 have small- and

medium-sized resources. Supplies are especially inadequate during the winter, when households in small towns and rural areas, typically without central heating, burn coal for heating. The annual household consumption of coal for both cooking and heating purposes can reach 1.8 tons for coal briquettes and 2.5 tons for lump coal.

With the increasing price of coal, ranging from RMB 800 to 1,600 per ton, households can no longer afford to consume as much coal for winter heating as in the past. Also, households increasingly recognize the negative health effects associated with the smoke emitted from burning coal in traditional stoves. There is an urgent need to conserve coal resources and improve household members' health and quality of life by improving the efficiency of coal stoves. As rural households' incomes and living standards have risen, coal stoves have been re-designed and produced to better suit household needs. Today, under the guidance of national policy, the energy-saving stoves industry exhibits a strongly diversified development trend. Coal stoves burning firewood, biomass briquettes, forestry processing waste, and other multifunction products are being developed to cater to various consumer needs.

Stove Industry

In Hebei province, coal stoves for household use are categorized according to end use. These include heating stove or boiler and cooking and heating stove. Also, three models of briquette stoves are promoted to meet rural households' various cooking and heating demands. Priced at about RMB 700–800, small-sized stoves can provide a family of two cooking and heating of a 20–60 m² area, while saving coal and reducing emissions. Mid-sized coal stoves, which can serve a family of 3–5, covering an area of 80–180 m², are widely adopted due to the common household size. Large stoves for heating areas 200 m² in size, priced at RMB 2,200–2,600, are suitable for multi-generational households (e.g., three generations living together), which are not uncommon in China. Stoves that heat spaces larger than 300 m² are appropriate for villas.

Hebei province features one of the country's largest coal stove manufacturing industries. The province has about 500 coal stove enterprises, with production totaling more than 1.5 million units per year. Since the economy recovered in 2009, sales have revived, having reached more than 1.5 million units.

The business models for small-, medium-, and large-sized enterprises are similar, with the exception of some

small companies. The sales model commonly adopted is a three-level network version, whereby the general manager or sales vice-president takes responsibility for sales at the enterprise level; distributors assume responsibility at the city, county, or district level; and sub-agents, occasionally assisted by the enterprises to establish outlets, at the township level. However, a handful of small enterprises conduct sales horizontally (e.g., at outlets in townships), with the advantages of quick response and flexibility. Moreover, to facilitate knowledge- and experience-sharing, sales staff meetings are usually held once or twice a year.

Although the service model of larger enterprises is similar to that of smaller ones, it features more comprehensive and complete services. Both types are staffed by maintenance personnel and have regulations on after-sales service. Whether the enterprise is large or small, a five-year warranty is common for all products. At the same time, larger enterprises are capable of providing better services, such as on-the-spot technical assistance and follow-up services.

What Was Learned

The coal stove market has reached a certain level of commercialization without the government's support. This lack of favorable policy is likely leading to a lack of motivation among stove enterprises. However, it is possible to regain momentum by integrating the promotion of efficient, clean coal stoves into the broader context of energy conservation and rural energy development under the government's strategic planning. The market has called for product standardization and quality control, accompanied by greater R&D efforts and after-sales service. Despite stable stove production and market sales, quality-related problems are common. Establishing a standard monitoring, inspection, and quality control system is key to a regulated market. In addition, R&D efforts on product innovation and quality improvement, involving both producers and consumers, are desirable. Also, reliable, complete, and timely after-sales service is important to stimulating household demand.

Biogas in Enshi City

Enshi city, the capital of Enshi Tujia and Miao Autonomous Prefecture in Hubei province, has a population of 0.78 million, which is widely dispersed over a mountainous area of 4,000 m². The city consists of 10 towns, 3 townships, and 172 administrative villages.

Supermarket Service System

To standardize and formalize biogas after-sales service in the mountainous area, Enshi city proposed the concept of a "supermarket service system." The overall goal is to provide service to all household customers, while extending the useful life of biodigesters to more than 15 years and that of associated equipment to more than 10 years. The specific objective is to contribute to rural energy development by establishing a standard service system, consisting of town or township service stations connected by a village-level network staffed by local personnel.

The supermarket service system refers to a replicable service module equipped with a service store, a manager in charge of operations and organization, an energy association, a skilled service team, a set of service equipment, and a set of association and service regulations and protocols. The concept applies to both the standard service approach and the standard service station construction.

The standard service approach comprises four integral components: (1) site radiation, (2) association management, (3) supermarket-style operation, and (4) circular economy. Site radiation means that the town-level service station manages village-level service stations within its jurisdiction and provides service to them and other towns not eligible for setting up town-level stations. Association management refers to management of the system by the rural energy association at the city, town, and village levels under guidance of the Enshi State Eco-Energy Bureau. The association management approach provides a platform for coordination between commercial and non-commercial services and motivates farmers to participate. Supermarket-style operation refers to the combination of commercial store, service station, and association office, where non-commercial and commercial services complement each other. Thus, the operational approach leads to sustained economic benefits and material recycling, defined as circular economy.

The construction of service stations is formalized to follow standards for (1) town- or township-level service stations and (2) village-level service stations. For the former, requirements include a comprehensive store, land phone hotline, energy association, carrier vehicle for biogas slurry, water pump, professional operator, skilled service team, set of maintenance tools per person, set of gas-detecting devices, and set of association regulations and protocols. Although the standards for village-level service

stations are relatively lower, they guarantee the capacity to perform maintenance and repair when needed or requested.

Implementation

Under guidance of Enshi city's Eco-Energy Department, town-level service stations are set up based on agricultural service centers, whereas the construction of village-level service stations is based on population density, number of biodigesters, and service radius. Staff at town- or township-level service stations are in charge of operating the network and organizing and managing the service team. All service stations follow a standardized system of delivery, fees, and assessment and management.

Achievements

The supermarket service system model has been highly successful, as indicated by the increasing number of service stations and growing interest among farmers in adopting household biogas systems. Since 2008, Enshi city has set up 163 rural energy follow-up service outlets (1 at the town level, 17 at the township level, and 145 at the village level), based on which a city-township-village service system is also built. By late 2011, there were more than 0.1 million biogas-generating pits, comprising 68 percent of all eligible households. In addition, there were 163 skilled service teams serving biogas users to guarantee normal operation of biodigesters. In 2011, teams received an estimated 8,697 calls for support and 5,105 calls for maintenance, as well as 5,284 calls for on-site repair and 2,084 calls related to mechanical operation.

The supermarket model has also demonstrated economic benefits and is contributing to the sustainable development of biogas. To date, most service departments are operating normally, and the annual economic profit for township- and village-level service departments is about RMB 30,000–50,000 and RMB 3,000–5,000, respectively. The model has successfully met the service demand from more than 0.1 million biogas users in the entire city, which boosts the government's image and farmers' enthusiasm in using biogas and participating in biogas-related jobs. Thus, the model has proven to be an important way to improve the rural environment, energy infrastructure, agricultural growth, and farmers' income.

What Was Learned

The standard supermarket model is an innovative way to solve rural households' energy problems, especially when populations are dispersed. Several key lessons result from this experience. First, after-sales service is critical for biogas promotion and sustainable use. Prior to this program, farmers were not enthusiastic about using biogas, mainly because of inadequate after-sales service and financial support. With the supermarket service system, farmers' requests for maintenance and repair services can be responded to in a timely manner, which motivates farmers to use the biodigesters.

Second, standardization and quality control are key for scaling up. Low-quality construction of biodigester units contributed to farmers' reluctance to invest in and use biogas. Through standardization and quality control, household biogas systems have become more reliable than previously and are thus welcomed by farmers.

Third, a market-based approach provides a feasible pathway to sustainable development of the biogas industry. Currently, the high cost of installing and using biogas systems requires government support; however, a market-based approach should be considered to ensure households' sustainable use of biogas. The supermarket model combines commercial and non-commercial services to enable sustained operation of the service department. Recognizing the economic benefits of biogas beyond meeting rural households' cooking demand, both the government and farming household users have become more incentivized to participate in the biogas industry, thus contributing to its sustainable development.

Solar Cookers in Gansu Province

Gansu province is a typical underdeveloped western province, with an income level below the national average. As of 2011, more than 16 million people lived in rural villages, with a per capita income below RMB 4,000. More than two-thirds of rural energy consumption is dominated by biomass (i.e., straw, dung, wood, and forest residues). Biogas, solar, and other energy sources together comprise only 3 percent of the province's total rural energy. The biomass consumed in mountainous and forest areas is obtained through cutting trees and digging grass roots, which have had a negative impact on local vegetation.

Although Gansu experiences energy shortages, it is endowed with abundant solar resources. The average residential energy consumption in rural Gansu is only 398 kg of standard coal equivalent per person, which is about 165 kg of standard coal equivalent below the national average. However, rural households in some regions suffer energy shortages lasting up to several months.

Gansu's richest solar regions are characterized by low-density populations that are widely scattered and poor transport, resulting in a backward economy. Therefore, there is an urgent need to circumvent conventional energy shortages by utilizing solar energy to meet rural household demand at relatively low cost in a way that fits local households' nomadic lifestyle.

Product Type

The mostly widely adopted solar cookers in Gansu province are the focusing and heat-box types (figure 3.10), using GRC and cement plaster as the main materials. The requirements for technical specifications should be met by all of the solar cookers being promoted (table A.2). Most of the solar cookers currently in use are 1.8–2 m² in size and can boil 5 kg of water in 15–20 minutes at midday.

Policy Support

Legal support for solar cooker promotion was first laid out in the regulations for managing rural energy construction in Gansu province, issued by the Provincial People's Congress in 1998. Related departments in the Provincial People's Congress are in charge of enforcement and inspection to ensure implementation. In addition, in accordance with industry association protocol, the Gansu Rural Energy Industry Association provides

guidance and technical assistance to selected enterprises. Furthermore, the Development and Reform Commission incorporates solar cooker promotion into rural energy construction as part of its long-term provincial rural energy planning. Moreover, the Provincial Poverty Relief Office and Forestry Department consider solar cooker promotion an important component of projects to alleviate poverty and return farmland to forests.

Promotional Approach and Achievements

In recent years, Gansu has adopted three approaches to promoting solar cookers: (1) market sale by producers, (2) procurement through government-supported projects, and (3) Clean Development Mechanism (CDM) projects. Of the three, procurement comprises 65 percent of the annual increase, while market sale contributes just 15 percent. Under government procurement, the solar cooker is priced at RMB 200 per unit, three-quarters of which the government subsidizes. Thus, sales still depend on government support, and the level of commercialization remains quite low.

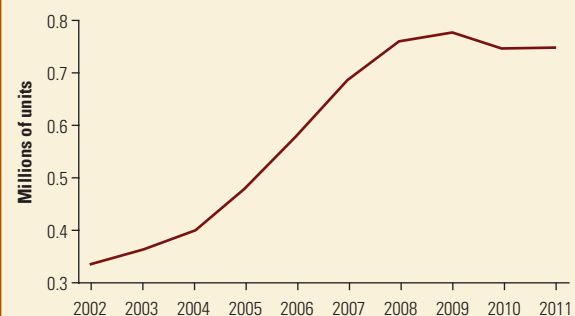
Solar cookers were first introduced to Gansu during the 1970s, with demonstration projects following throughout the 1980s. The 1990s marked the start of the market development stage, while the first decade of the 21st century featured a period of steady growth. Along with national implementation of western development, accompanied by environmental management and the project to return farmland to forests, solar cookers are considered a key measure for protecting the environment. According to the Rural Energy Management Department, 920,000 solar cookers were disseminated in Gansu during 2002–11, equivalent to about 90,000 cookers per year. By late 2011, some 750,000 solar cookers were in use throughout the province (figure A.1).

TABLE A.2 PARAMETER REQUIREMENTS FOR SOLAR COOKER PERFORMANCE IN GANSU

Parameter	Requirement
Intercepting area (m ²)	1.8-2
Power (W/m ²)	> 450
Optical efficiency (%)	> 65
Solar altitude angle (degree)	25~80
Operating height (cm)	110~130
Operating distance (cm)	40~60

Source: CACS 2012.

FIGURE A.1 CUMULATIVE SOLAR COOKER INVENTORY, 2002–11



Source: CACS 2012.

After 20 years of development, solar cooker producers are becoming larger in size. Currently, 12 manufacturers in Gansu have production levels above 10,000 units, employing more than 600 workers. With strict quality control and advanced technology, these enterprises not only meet local demand; they also export a number of cookers to Qinghai and Ningxia provinces. However, the enterprises face various major challenges, including unstable demand, lack of access to financing, low technology level, and increasing production costs.

The promotion of solar cookers has generated tremendous benefits in terms of resource and cost savings, as well as emissions reduction. It is estimated that every solar cooker could replace 1,200 kg of straw or 600 kg of coal, meaning that the 750,000 solar cookers in use at the end of 2011 could save consumption of 450,000 tons of coal (CACS 2012). At an average price of RMB 1,300 per ton of coal, the economic benefit could reach RMB 580 million. Moreover, solar cookers have the potential to reduce annual emissions of carbon dioxide (CO₂) and sulfur dioxide (SO₂) by more than 1 million tons and 10,000 tons, respectively.

What Was Learned

Current industry development relies heavily on government-supported programs that are often one-off and sporadic. The production and sales level is largely determined by government procurement rather than the market, suggesting an unstable industry unlikely to be sustainable.

At this stage, continued government support is required and should be integrated with programs that center on energy conservation, emissions reduction, and poverty alleviation. There is also a need for strategic planning and promotion; currently, this is lacking at all levels of the government agenda, which has no fixed channel for subsidies. The overall benefits of solar cookers—energy savings, emissions reduction, and environmental protection—are not fully realized by the government. Lack of economic incentives, an obstacle experienced by many enterprises, could be overcome by strengthening government support through integrated programs.

Greater efforts in technological improvement and innovation are also needed. Currently, design technology and production processes remain at 1980s levels. Thus, there is ample room for improving solar cooker technology, especially with regard to shell and reflectorized materials and production technology. Scientific research in designing better solar cookers for rural households should be conducted at research institutes, universities, and colleges.

Lessons Learned

The four case studies presented in this chapter—biomass, coal, and biogas stoves, and solar cookers—offer valuable lessons and insights that can be applied to the design and implementation of future stove promotion programs. Although experiences in these four market segments vary, the following general lessons can be drawn.

Stove promotion strategies must be based on local conditions, including fuel availability, climatic conditions, income level, and lifestyle. As discussed in chapter 2, household demand for stoves is determined by four interdependent factors in specific contexts, and thus stove promotion should cater to local demand and culture. For example, the biomass case study found that the cost of obtaining forest residues was much less than that of agricultural residues, making it more appropriate to promote biomass stoves in fruit-tree growing regions. In the solar cooker study, products were designed and made for easy portability and durability to suit herdsmen's customary lifestyle.

A market-based approach should be explored in stove promotion to ensure sustainability. Past programs to promote biomass stoves, solar cookers, and biogas digesters relied heavily on government support, which was often one-off and fragmented. In addition, producers of these stoves experienced difficulty in accessing financing. The supermarket system model for biogas application demonstrates the success of a combined commercial and non-commercial service approach. Receiving an influx of economic benefits, suppliers are motivated to provide continued services, with which users are more willing to install and utilize biogas digesters. For stove programs to achieve sustainability, a market-based approach is a must. Therefore, it is necessary that the design of future programs integrate a market-based approach from the outset.

Product standardization and quality control provide an enabling environment for market development. Lessons from all four market segments show that lack of technical standards and a quality control process impairs market growth. Setting up a standardization system, together with monitoring and verification (M&V), creates a regulatory environment for the stove industry (chapter 4).

Strong government commitment is especially important for any industry that depends on subsidies, but careful design of the subsidy scheme is required for sustainable development. With government support, production and technology in the biomass stove, biogas, and solar cooker industries

have greatly improved over the past several decades; yet commercialization has not been reached. A better designed subsidy scheme that works toward sustainable market development is needed. It should create incentives for the industry to sustain itself, even without continued subsidy (chapter 5).

Stove programs can be integrated into programs that focus on such broad areas as energy efficiency and conservation, environmental protection, emissions reduction, poverty alleviation, and health improvement, along with strengthened awareness-building campaigns. Policy makers and

end users are not fully aware of the overall benefits of improved stoves, as reflected in limited government budgets and sporadic support and lack of enthusiasm among users. Raising the public's awareness of the many benefits of stoves—energy savings, environmental protection, emissions reduction, poverty alleviation, and better health—can stimulate users' interest in high-efficiency, low-emissions stoves. Recognizing these benefits, the government could carry out more coherent, integrated programs that target multiple issues to generate co-benefits.

Survey Method and Questionnaire

To gain a better understanding of the current status of China's stove market, the China Alliance for Clean Stoves and China Stoves Website conducted a survey of the biomass stove supply chain—producers, wholesalers, and retailers throughout the country. Survey questionnaires were sent to both manufacturers and dealers nationwide; valid responses were received from 110 producers in 25 provinces and 123 wholesalers and retailers. Additional information was collected through subsequent field trips, including visits with selected stove manufacturers.

The abbreviations used in the market survey are as follows: C = cooking, CO = carbon monoxide, H = heating, NO_x = nitrogen oxides, PM = particulate matter, SO₂ = sulfur dioxide, and WH = water heating.

炉具行业生产和销售市场调查（生产企业）

Market Survey of Stove Supply Chain (for Producers)

日期 Date: _____ 地点 Address: _____

调查员 Investigators: _____ 受访者签名 Signature: _____

炉具行业生产和销售市场调查表 Market Survey of Stove Supply Chain		
#	问题栏 Question	回答栏 Answer
1	受访者姓名 Name	
2	单位名称 Organization	
3	地址 Location	
4	联系方式 Contact	电话 Tel _____ 传真 Fax _____ 邮箱 Email _____
5	企业注册时间、资本和法人代表 Registered capital and legal representative	_____年Y _____月M _____日D _____元RMB 法人代表 Legal representative _____
6	企业类型 What type of ownership is this stove production?	<input type="checkbox"/> 民营 Private <input type="checkbox"/> 合资 Joint venture <input type="checkbox"/> 国有或其他 State-owned or other

(continued)

7	企业人数 Number of staff	<input type="checkbox"/> 工人 Workers _____ <input type="checkbox"/> 管理人员 Managers _____ <input type="checkbox"/> 技术人员 Technical staff _____
8	占地面积和厂房建筑面积 Floor space and plant area	占地面积 _____ m ² 厂房建筑面积 _____ m ² Floor space Plant area
9	2011年生产及销售量 Stove production and sales in 2011	<input type="checkbox"/> 燃煤炉具 Coal stove Production units Sales units 1. 炊事 Cooking 生产 _____ 台 销售 _____ 台 2. 采暖 Heating 生产 _____ 台 销售 _____ 台 3. 炊事水暖 C+WH 生产 _____ 台 销售 _____ 台 4. 炊事烤火 C+H 生产 _____ 台 销售 _____ 台 <input type="checkbox"/> 生物质炉具 Biomass stove 1. 炊事 Cooking 生产 _____ 台 销售 _____ 台 2. 采暖 Heating 生产 _____ 台 销售 _____ 台 3. 炊事水暖 C+WH 生产 _____ 台 销售 _____ 台 4. 炊事烤火 C+H 生产 _____ 台 销售 _____ 台
10	生产的主要炉具规格 Main product sizes (可多选)	<input type="checkbox"/> < 5 kW <input type="checkbox"/> 5~20 kW <input type="checkbox"/> 20~50 kW <input type="checkbox"/> > 50 kW
11	炉具热效率 Stove efficiency	<input type="checkbox"/> 燃煤炉具 Coal stove 1. 炊事 Cooking _____ % 2. 采暖 Heating _____ % 3. 炊事水暖 C+WH _____ % 4. 炊事烤火 C+H _____ % <input type="checkbox"/> 生物质炉具 Biomass stove 1. 炊事 Cooking _____ % 2. 采暖 Heating _____ % 3. 炊事水暖 C+WH _____ % 4. 炊事烤火 C+H _____ %
12	炉具功率 Stove power	<input type="checkbox"/> 燃煤炉具 Coal stove 1. 炊事 Cooking _____ kW 2. 采暖 Heating _____ kW 3. 炊事水暖 C+WH _____ kW 4. 炊事烤火 C+H _____ kW <input type="checkbox"/> 生物质炉具 Biomass stove 1. 炊事 Cooking _____ kW 2. 采暖 Heating _____ kW 3. 炊事水暖 C+WH _____ kW 4. 炊事烤火 C+H _____ kW
13	炉具烟气污染物排放指标 Primary stove emissions level	<input type="checkbox"/> 燃煤炉具 Coal stove 1. 一氧化碳CO _____ % 2. 二氧化硫 SO ₂ _____ mg/m ³ 3. 烟尘浓度 PM _____ mg/m ³ 4. 氮氧化物 NOx _____ mg/m ³ 5. 烟气林格曼黑度 Ringelmann shade _____ level <input type="checkbox"/> 生物质炉具 Biomass stove 1. 一氧化碳CO _____ % 2. 二氧化硫 SO ₂ _____ mg/m ³ 3. 烟尘浓度 PM _____ mg/m ³ 4. 氮氧化物 NOx _____ mg/m ³ 5. 烟气林格曼黑度 Ringelmann shade _____ level
14	2011年销售价格 (和问题9对应填写) Stove average price (RMB), corresponding to Question 9	<input type="checkbox"/> 燃煤炉具 Coal stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____ <input type="checkbox"/> 生物质炉具 Biomass stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____

(continued)

15	2011年生产成本（和问题9对应填写） Stove average cost (RMB), corresponding Question 9	<input type="checkbox"/> 燃煤炉具 Coal stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____ <input type="checkbox"/> 生物质炉具 Biomass stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____
16	主要销售地区及销售商数量 Sales areas and wholesaler/retailer numbers	主要销售地区 Sales areas _____ 销售商数量 Wholesaler/retailer numbers _____
17	2011 年炉具销售额 Sales revenue in 2011	_____ RMB
18	享受过哪些国家优惠政策和国家项目补贴 Do you have government subsidies?	<input type="checkbox"/> 有Y <input type="checkbox"/> 无N
19	如果生物质炉具有补贴，每台补贴金额（和问题9对应填写） If you have the subsidy, how much (RMB) per stove?	1. _____ 元 2. _____ 元 3. _____ 元 4. _____ 元
20	主要销售方式（可多选） What is/are the sales channel(s)?	<input type="checkbox"/> 自己销售网络直接到用户 Directly to consumers <input type="checkbox"/> 通过批发商//代理商 Through wholesalers/traders <input type="checkbox"/> 通过零售商店 Directly to retail shop <input type="checkbox"/> 政府采购 Government procurement
21	市场开拓的主要障碍（可多选） What is/are the main constraint(s) to expansion?	<input type="checkbox"/> 融资 Finance <input type="checkbox"/> 价格 Price <input type="checkbox"/> 技术 Technology <input type="checkbox"/> 燃料 Fuel <input type="checkbox"/> 销售网络 Selling network
22	企业资金来源（可多选） What is/are the financing source(s) for stoves production?	<input type="checkbox"/> 自有资金 Self finance <input type="checkbox"/> 银行贷款 Bank loans <input type="checkbox"/> 民间融资 Private loans <input type="checkbox"/> 外商投资 Foreign investment <input type="checkbox"/> 其他 Other（如政府、集团公司支持等）
23	质量保证体系和售后服务 What is/are the methods of quality assurance? Is there after-sales service?	质量保证体系 Quality-assurance method _____ 售后服务: After-sales service <input type="checkbox"/> 有Y <input type="checkbox"/> 无N

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炉具行业生产和销售市场调查（批发/零售商）

Market Survey of Stove Supply Chain (for Wholesalers/Retailers)

日期 Date: _____ 地点 Address: _____

调查员 Investigators: _____ 受访者签名 Signature: _____

炉具行业生产和销售市场调查表 Market Survey of Stove Supply Chain		
#	问题栏 Question	回答栏 Answer
1	受访者姓名 Name	
2	单位名称 Organization	
3	地址 Location	
4	所有权性质 Type of ownership	<input type="checkbox"/> 个人 Individual owned <input type="checkbox"/> 企业 Company <input type="checkbox"/> 其它 Other
5	联系方式 Contact	电话 Tel _____ 传真 Fax _____ 邮箱 Email _____
6	2011年销售炉具的类型及销售量 Number and types of stoves sold in 2011	<input type="checkbox"/> 燃煤炉具 Coal stove Production units Sales units 1. 炊事 Cooking 生产 _____ 台 销售 _____ 台 2. 采暖 Heating 生产 _____ 台 销售 _____ 台 3. 炊事水暖 C+WH 生产 _____ 台 销售 _____ 台 4. 炊事烤火 C+H 生产 _____ 台 销售 _____ 台 <input type="checkbox"/> 生物质炉具 Biomass stove 1. 炊事 Cooking 生产 _____ 台 销售 _____ 台 2. 采暖 Heating 生产 _____ 台 销售 _____ 台 3. 炊事水暖 C+WH 生产 _____ 台 销售 _____ 台 4. 炊事烤火 C+H 生产 _____ 台 销售 _____ 台
7	平均销售价格（和问题6对应填写） Stove average price (RMB), corresponding to Question 9.	<input type="checkbox"/> 燃煤炉具 Coal stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____ <input type="checkbox"/> 生物质炉具 Biomass stove (RMB) 1. _____ 2. _____ 3. _____ 4. _____
8	销售的是否为清洁高效炉具 Are there any clean and efficient stoves sold?	<input type="checkbox"/> 有 Yes <input type="checkbox"/> 无 No
9	销售的炉具规格（可多选） Main product sizes	<input type="checkbox"/> < 5 kW <input type="checkbox"/> 5~20 kW <input type="checkbox"/> 20~50 kW <input type="checkbox"/> > 50 kW
10	主要销售地区 Sales areas	
11	销售量最大的炉具类型？（可多选） Which kind of stove sells best?	<input type="checkbox"/> 燃煤炉具 Coal stove <input type="checkbox"/> 炊事 Cooking <input type="checkbox"/> 采暖 Heating <input type="checkbox"/> 炊事水暖 C + WH <input type="checkbox"/> 炊事烤火 C + H <input type="checkbox"/> 生物质炉具 Biomass stove <input type="checkbox"/> 炊事 Cooking <input type="checkbox"/> 采暖 Heating <input type="checkbox"/> 炊事水暖 C + WH <input type="checkbox"/> 炊事烤火 C + H

(continued)

12	采用什么方式销售? (可多选) What is the business model?	<input type="checkbox"/> 批发 Wholesale <input type="checkbox"/> 零售 Retail <input type="checkbox"/> 代理(后付款) On consignment <input type="checkbox"/> 经销(先付款) Pay first
13	运输方式和距离 (可多选) What are the stove delivery method and range?	<input type="checkbox"/> 送货到家 To home <input type="checkbox"/> 用户自己提货 By user self <input type="checkbox"/> < 10 km <input type="checkbox"/> 10~20 km <input type="checkbox"/> > 20 km
14	主要销售品牌及供应商? Who is/are the supplier(s) of stoves to the retail shop?	
15	是否提供炉具配件和维修服务? Are there any parts and/or repair services for stoves?	<input type="checkbox"/> 有 Yes <input type="checkbox"/> 无 No
16	市场销售的主要障碍 (可多选) What are the main constraints to expansion?	<input type="checkbox"/> 融资 Finance <input type="checkbox"/> 价格 Price <input type="checkbox"/> 技术 Technology <input type="checkbox"/> 燃料 Fuel <input type="checkbox"/> 销售网络 Selling network

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