CHINA STOVES AND FUELS MARKET ASSESSMENT

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Foreword Ⅰ

Promoting clean stoves is not only good for the environment, but also for people's life as well. This change in life and production will effectively improve indoor air quality in rural areas, protect ecological environment, and reduce soil erosion. In aspect of people's life, this initiative would help ensure health of women and children, solve the problem of unemployment and poverty for local residents, and drive the development of related industries. Ministry of Agriculture of the People's Republic of China has always regarded this work (promoting clean stoves) as a matter of concern to numerous households, also as an important part of rural energy construction.This initiative supports such aspects as basic research, formulation of standards, industrial development, and experiment and demonstration. By the end of 2015, China has been promoting 115 million units cooking stoves of all kinds that save coal and firewood, popularizing more than 30 million energy-saving furnaces and more than 18 million kangs. This initiative generates a total of 329 related production enterprises serving cleaning stoves for all types of production, employed more than 6500 workers, and produced nearly 1 billion yuan annually. Based on what we have achieved, we can proudly say that China's program to popularize the clean stove and fuel, which involves 150 million rural households and benefits more than 500 million people, is the world's largest energy-saving project ever.

In order to familiarize more people with the technology of energy-saving stoves and kangs, Chinese government has achieved a common agreement with the Global Alliance for Clean Cookstoves, which is to deliver access to clean cooking solutions to 40 million households by 2020 and to crack down all the inefficient stoves and fuels by 2030.This

program in China is also a component of a bigger plan of the Alliance whose goal is "to promote clean stoves and fuels in 100 million households in 2020". To achieve this goal, in 2014, Global Alliance for Clean Cookstoves and Rural Energy & Environment Agency, Ministry of Agriculture, cooperated to launch a market-based research project about coal-saving housing cookstoves and kangs in China. The essence of this project is to find out how typical rural residents use energy and how they apply the stoves and kangs that save fuel and firewood in their life. In this way, we can estimate this program's potential for promotion, and provide scientific evidence for establishing development plans.

The report includes survey data from 3583 typical farmers, 59 stove manufacturers and 75 fuel producers in 6 provinces and cities in China. The data does statistical analysis about the status quo of the application of stoves and fuels in different regions, and about farmers' habits of using energy and their purchasing potential. After assessing China's promotion potential for stoves and kangs that save firewood and fuel, the researchers propose some market-based popularizing approaches. These recommendations will be applied to pilot demonstration and upgrading work in the next step, thereafter it will be replicated in larger areas popularizing the application of Chinese clean stoves and fuel.

As a developing country, China's clean stove technology and products are also suitable for other developing countries. We want to work more closely with other concerned countries and international organizations. In the framework of South-South cooperation especially, we would like to share China's successful experience and practices with the rest of the world, making our contribution for the promotion of clean stoves and the sustainable development for human society.

Wang Jiuchen
2017.9

Foreword Ⅱ

Air pollution is a serious issue impacting China's population, causing an estimated 1 million premature deaths each year. Research shows that household air pollution caused by traditional cooking and heating contributes up to one third of China's total PM2.5 emissions and more than half of China's total black carbon emissions. Rapid scale up of the adoption of cleaner stoves and fuels among China's vast rural market can therefore contribute to significant improvements in public health and environment.

The Global Alliance for Clean Cookstoves is committed to supporting the Government of China in addressing this issue and achieving the Government's ambitious goal of delivering access to clean cooking solutions to 40 million households by 2020 with sustainable, market-based approaches. The Government of China has been an Implementing Partner of the Global Alliance for Clean Cookstoves since 2012, and under the leadership of National Development and Reform Commission (NDRC) and the Ministry of Agriculture, the Chinese government is coordinating multiple agencies to work with the Alliance on distribution, policy planning, standards and testing, research, women's empowerment, climate mitigation, and South-South cooperation.

The Alliance partnered with the Ministry of Agriculture on this in-depth market study to better understand the status of the cookstove and fuel market and identify policy recommendations that could accelerate scale. Following the findings and recommendations, seven pilot projects in representative provinces were launched in 2016 to demonstrate the viability of interventions in shifting to cleaner burning stoves and fuels. The Alliance and the Ministry of Agriculture will continue the pilot effort in 2017—2018 with more focused

and tailored intervention strategies. Findings from the pilots will inform the development of a new national clean stove and fuel program to be incorporated in the new Five-Year Plan.

Cooking and heating are essential and they shouldn't be lethal. The Alliance is committed to working with Chinese government partners and the private sector and our more than 70 partners in China to ensure that China has many more blue sky days and to contribute to President Xi's vision of the Chinese Dream – a beautiful China with healthy environment and low pollution.

Radha Muthiah
2017.9

Abbreviations / Terminology

Abbreviations

Alliance	Global Alliance for Clean Cookstoves
MOA	Ministry of Agriculture, P.R. China
NDRC	National Development and Reform Commission, P.R. China
NISP	National Improved Stoves Program
REEA	Rural Energy & Environment Agency, Ministry of Agriculture
RMB	Renminbi
GDP	Gross Domestic Product
LPG	Liquefied petroleum gas
PM 2.5	Particulate matter with an aerodynamic equivalent diameter of 2.5 micrometres or less
PM 10	Particulate matter with a aerodynamic equivalent diameter of 10 micrometres or less
PIC	Products of incomplete combustion
BaP	Benzo[a]pyrene is a representative polycyclic aromatic hydrocarbon with mutagenic and carcinogenic toxic (IARC Group 1 carcinogen)
IEA	International Energy Agency

Fuel Classification

Solid fuels	Raw unprocessed biomass (agricultural residue, wood, animal dung), biomass pellets, charcoal, raw coal.
Gas, electricity and solar	Either a gaseous fuel (LPG, natural gas, biogas), electricity or solar energy.
Biomass pellets	Pellets produced by compressing raw biomass (agricultural residue, wood, animal dung) under high pressure. Pellets are easier to store and more energy efficient than raw biomass as they have less moisture content and a higher energy density.
Coal briquettes*	Briquettes produced by compressing and extruding raw coal under high pressure. Coal briquettes are easier to store and more energy efficient

than raw coal as they have less moisture content and a higher energy density. Briquettes can also be mixed some biomass such as sawdust, charcoal dust, grass, urban waste wood, and agricultural residues.

Stove Classification

Solid fuel stoves	Stoves that use solid fuels for generating energy for cooking and/or heating.
Gas, electric and solar stoves	Stoves that use either gas, electricity or solar energy.
Built-in stove	Stove that is constructed within rural households and affixed to the wall. These are typically made of clay, stone or tiled on the surface. These stoves were the focus of the National Improved Stoves Program in the 1980s. Almost all of these stoves have a chimney also built-in.
Kang	Stove and a chamber over which a bed can be placed, typically used in the north area and in winter.
Coal stove	Stove that uses raw or processed forms of coal to generate energy for cooking and/or heating.
Biomass stove	Stove that uses raw or processed forms of biomass. This stove is constructed off-site and is easily transportable. It is more efficient than a traditional built-in stove, particularly the gasifier variants.
Biomass/ coal stove	Stove that uses raw or processed forms of biomass or coal. This stove is constructed off-site and is easily transportable. It is more efficient than a traditional built-in stove, particularly the gasifier variants.
Ground stoves	Stove that uses biomass or coal and is placed on the ground. Used to smoke meat or heat areas in winter.
LPG stove	Stove that uses LPG for generating energy for cooking and/or heating.
Coal gas stove	Stove that uses coal gas for generating energy for cooking and/or heating.
Natural gas stove	Stove that uses natural gas for generating energy for cooking and/or heating.
Biogas stove	Stove that uses biogas for generating energy for cooking and/or heating.
Electric stove	Stove that uses electricity for generating energy for cooking and/or heating.
Solar stove	Stove that uses the energy of direct sunlight for generating energy for cooking and/or heating.

Methodological Terms

Stove Hours	A comparative index created in this report to distinguish the relative usage of fuels and stoves based on average hours per day as collected in the GACC Survey 2014. This index is more advantageous than simply looking at "primary use" of stoves and fuels as it accounts for stacking (as it measures relative usage across all fuel/stove combinations), and therefore provides a greater base for comparing and understanding emissions impact and overall consumer behavior.

*Note that briquettes can also be produced from biomass sources such as sawdust, charcoal dust, grass, urban waste wood, and agricultural residues.

Executive Summary

Looking at the stove issue through a new lens

China has made significant progress in reducing the proportion of solid fuel (coal and biomass) dependency as a proportion of rural household energy consumption over the past 30 years. Solid fuel dependency fell from 99% in 1980 to approximately 78% in 2013. This has been driven by successful resource-saving policies (such as the world's largest publicly financed initiative to improve cooking and heating stoves, the National Improved Stove Program (NISP), which distributed close to 200 million energy-efficient built-in stoves during the 1980s and 1990s), coupled with China's urbanization and economic development, which has encouraged increased usage of electricity and gas.

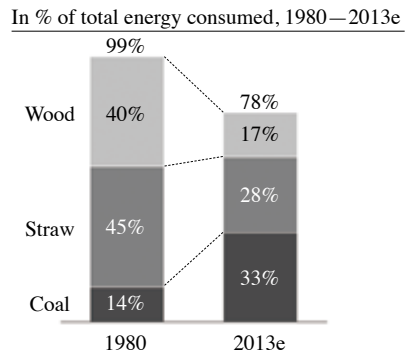

Figure A Reduction in share of household solid fuel consumption in rural China

Despite progress, today's realities create the need for further government investment and for policy actions to be implemented through a new lens.

First, despite China's rapid economic growth and increased living standards, there is still a large market need for improved stoves and fuels for cooking and heating. Around 160 million rural households (approximately 75% of all rural households) are still primarily dependent on solid fuels. And many are likely to continue using solid fuels in the near future; the International Energy Agency (IEA) estimates that 241 million people (or 80 million households) will still use solid fuels in China by 2030.

These estimates indicate that economic growth alone will not be enough to transition rural China's energy mix away from dependency on solid fuels, strong government actions is needed. Analysis confirms that while increased wealth correlates to increased usage of electricity and gas, the rate of change appears limited. There was only an 11% difference in solid fuel usage when comparing a Chinese household that earns less than 20,000 RMB per year to one that earns over 40,000 RMB per year.

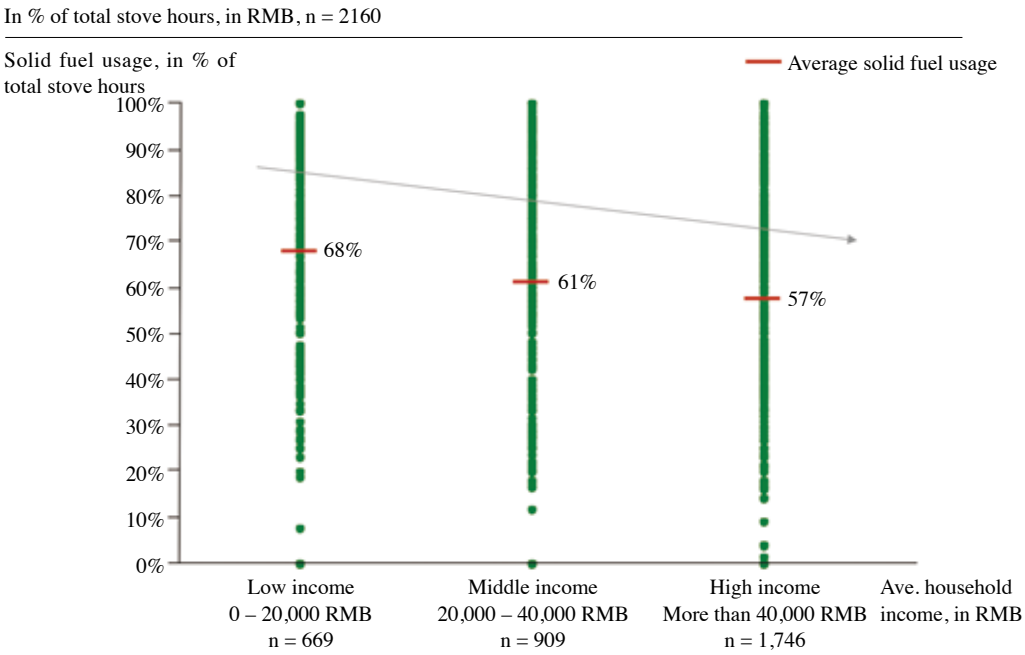

Figure B Proportion of solid fuel usage by income

Therefore, without government intervention, it is estimated that economic growth will drive a 9% increase in electricity and gas usage by 2020. While significant, this still leaves 69% of rural household fuel consumption still dependent on burning solid fuels. As a result, further government investment is needed in parallel to continued economic growth and development.

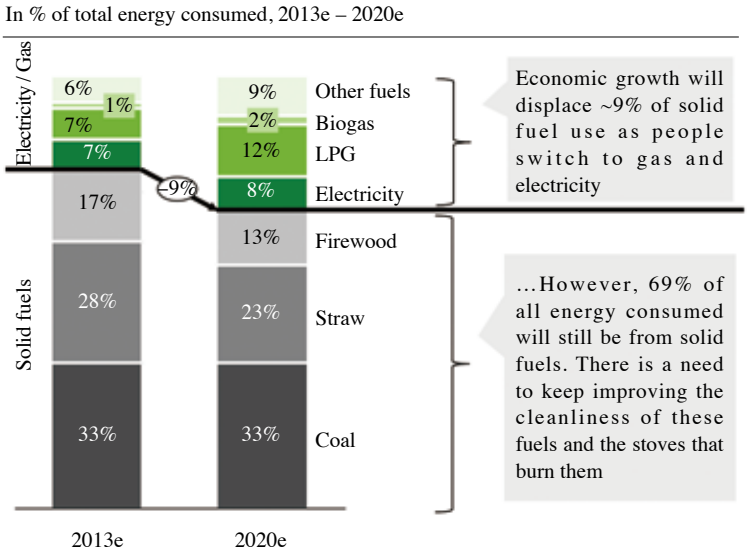

Figure C Estimated impact of continued economic growth on rural China's fuel mix between 2013-2020

Second, addressing the stove and fuel issue in rural China is no longer solely a resource saving concern as it was in the 1980s. It is now well established that solid fuel burning produces harmful emissions that damage the environment and public health, particularly that of women and children. Burning solid fuels releases carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), primary fine and ultrafine particulate matter (PM2.5 and PM1.0) and polycyclic aromatic hydrocarbons (PAHs). In addition, a review of recent studies estimates that residential coal and biomass combustion could account for as much as 33%-47% of China's total PM2.5 emissions annually, 46%-67% of black carbon, 82%-91% of organic carbon and 55%-65% of benzopyrene (BaP)[①].

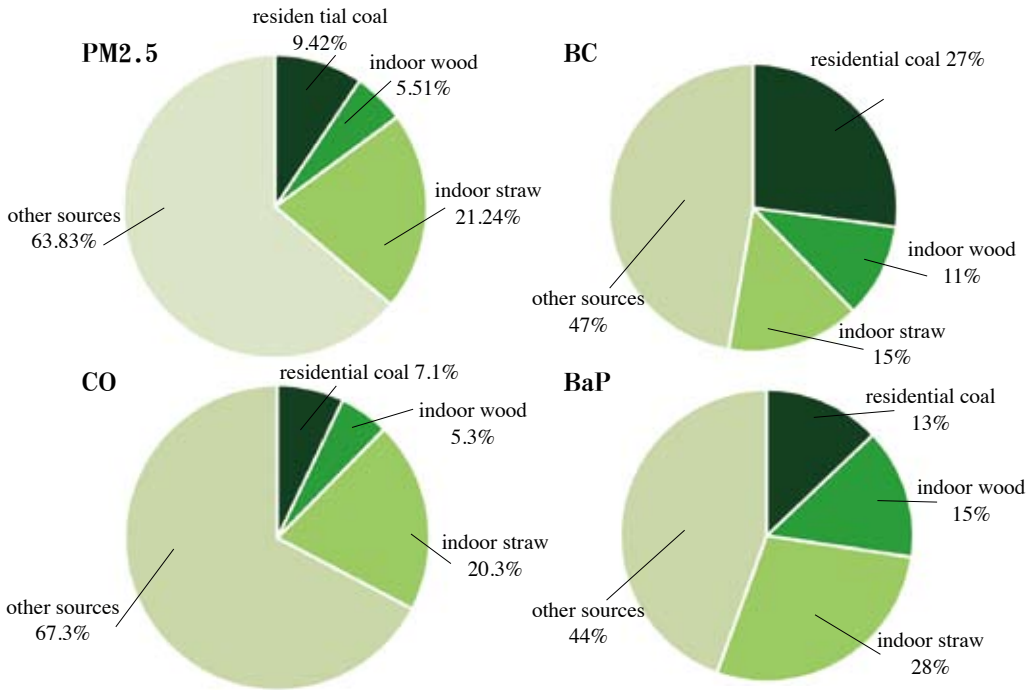

Figure D Emissions from solid fuel burning, % of total, 2007

According to the Global Burden of Disease Study 2010, exposure to smoke from burning solid fuels using traditional or unimproved stoves is estimated to cause over a million premature deaths annually in China. Specifically, lung cancer, chronic obstructive pulmonary disease, lower respiratory infections, cardiovascular disease, stroke and cataracts have been directly linked to unclean stove and fuel usage, with women and children most at-risk. Women are also disproportionately affected by reliance on solid fuels for cooking and heating given that they are

① Wang, S. X.; Zhao, B.; Cai, S. Y.; et al., Emission trends and mitigation options for air pollutants in East Asia. Atmos. Chem. Phys. 2014, 14 (13), 6571-6603.

often responsible for cooking and securing fuel for their families.

The cross-cutting nature of this issue now places addressing solid fuels and stoves within a broader subset of issues related to a number of China's other national strategies including its goals on urbanization, the Beautiful Village Initiative, the upgrade of rural energy structure, and low carbon development. Rapidly scaling the adoption of cleaner stoves and fuels in China's vast market requires strong political will and comprehensive government support; all of which is more likely now given the issue's relevance across multiple government interests.

Finally, technology has improved significantly. Many of the stoves distributed during the NISP are assumed to be out of use or in disrepair, providing an opportunity for replacement with new, cleaner technologies.

The government needs to address three major challenges in order to successfully reduce China's dependency on solid fuel burning and provide cleaner, more efficient solid fuels and solid fuel burning stoves.

The first challenge is to develop an attractive, accessible and affordable clean fuel solution for heating. A survey of 3,600 households showed that 97%-99% of the fuel burnt by heating stoves comprised of solid fuels.

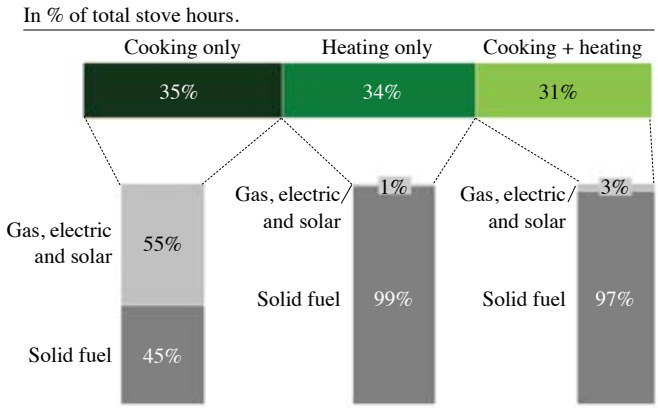

Figure E Dependency of solid fuels split by stove purpose

It also shows that electricity and gas, while increasingly popular for cooking (used for 55% of all cooking only stove hours in Figure E), is not likely to be the answer for heating, especially for poorer households, at least not in the short term. Therefore, there is a role for the government to play in developing cleaner, more efficient solid fuel alternatives for heating, such as processed biomass pellets.

The second challenge is to change rural cooking and heating behaviors and address diverse consumer needs, in a context where consumer preferences and habits are incredibly varied and engrained. For example, the practice of smoking meat in southern China drives preference for stoves that produce smoke, and the taste of certain specialty dishes across China is perceived to be

much better with unprocessed coal or wood than gas or electricity. Variations in climate and fuel availability across regions, as well as seasonality also drive wide diversity of stove and fuel usage. Given this diversity and the challenge of changing long standing behaviors, a clear understanding of the drivers of preference and behavior across all target consumer segments is required.

The third challenge is that the quality of solid fuels and solid fuel burning stoves is inconsistent across rural China due to industry fragmentation, and the lack of consistent standards enforcement due to a gradual decline in national policy focus and coordination. This has resulted in the inefficient cost of production of the sector as few producers reach economies of scale. Clear standards and enforcement help drive industry consolidation and technology innovation.

The final challenge is that the existing government subsidies (based on irregular and changing local government orders) have created "stop-and-go" market dynamics, which constrain manufacturer incentives to scale, as manufacturers learn to manage to an expected share of subsidy programs, rather than to market demand (Figure F).

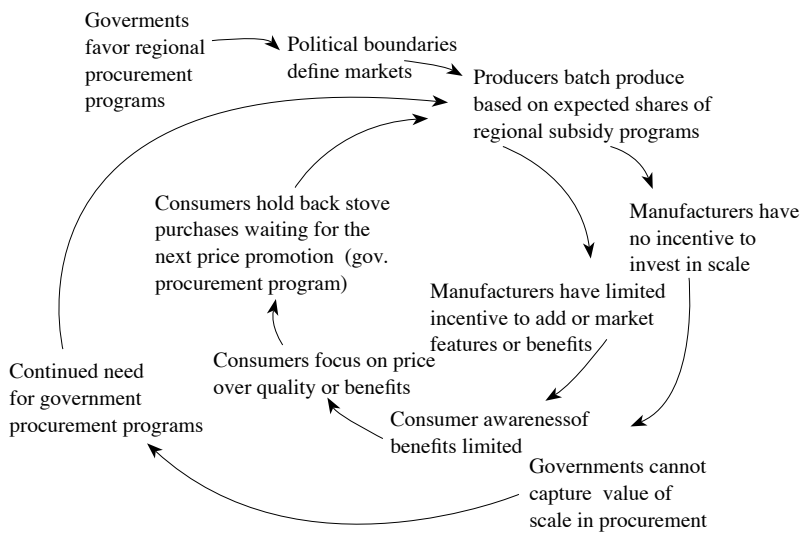

Figure F Dynamics driven by current subsidy program: stove products stuck in "stop-and-go" market dynamics

A second national program presents a great opportunity to address these challenges and drive greater adoption in cleaner cooking and heating.

Building on past successes, the second national program needs to drive four actions:

1. Strengthen focus toward increasing the affordability and accessibility of cleaner fuels, not just cleaner stoves.

In the past, policy programs have focused primarily on promoting resource-saving stoves. Going forward, more impact per dollar of investment can be gained by focusing on increasing

the affordability and accessibility of cleaner fuels, as well as cleaner stoves. This is because fuel economics drive consumer purchase decisions as fuel costs are the major driver of total cost of ownership. Therefore, investing in making cleaner fuels more attractive also encourages greater usage of cleaner stoves.

The evidence for this can be seen in fuel and stove stacking behaviors. In China, rural households manage and stack a portfolio of stoves so as to take advantage of accessing different fuels in different seasons. Figure G shows the extent of stove stacking where surveyed households in 6 provinces owned between 3 and 7 stoves each.

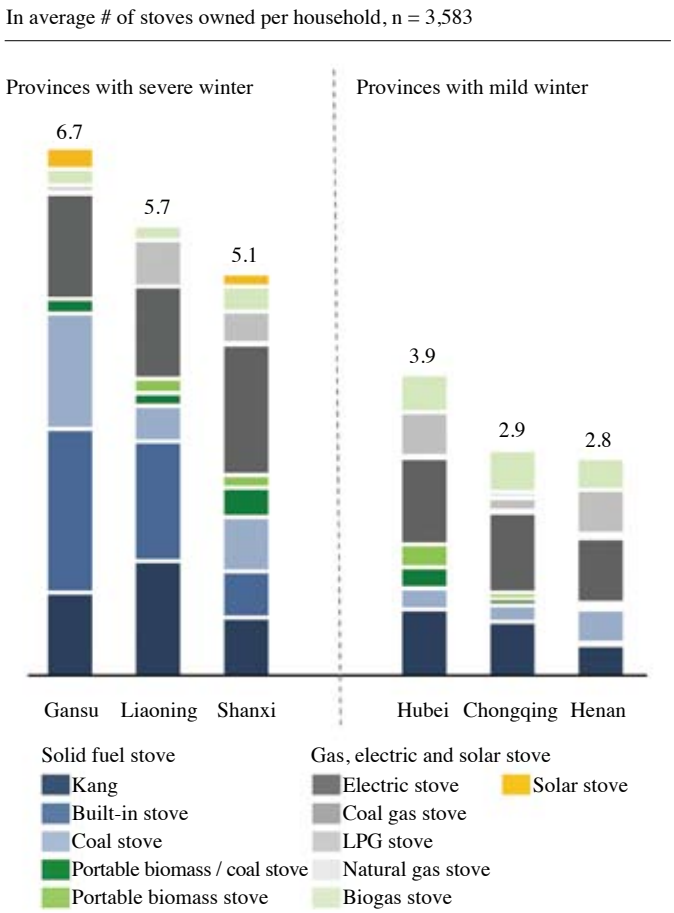

Figure G Stacking behaviors in rural Chinese households

Figure G shows the switching behavior between stove and fuel combinations through different seasons to balance cost and convenience.

Focusing on fuels also makes sense because on average, fuel-switching has a greater impact on reducing harmful emissions than stove-switching. It is also easier to develop policies targeting

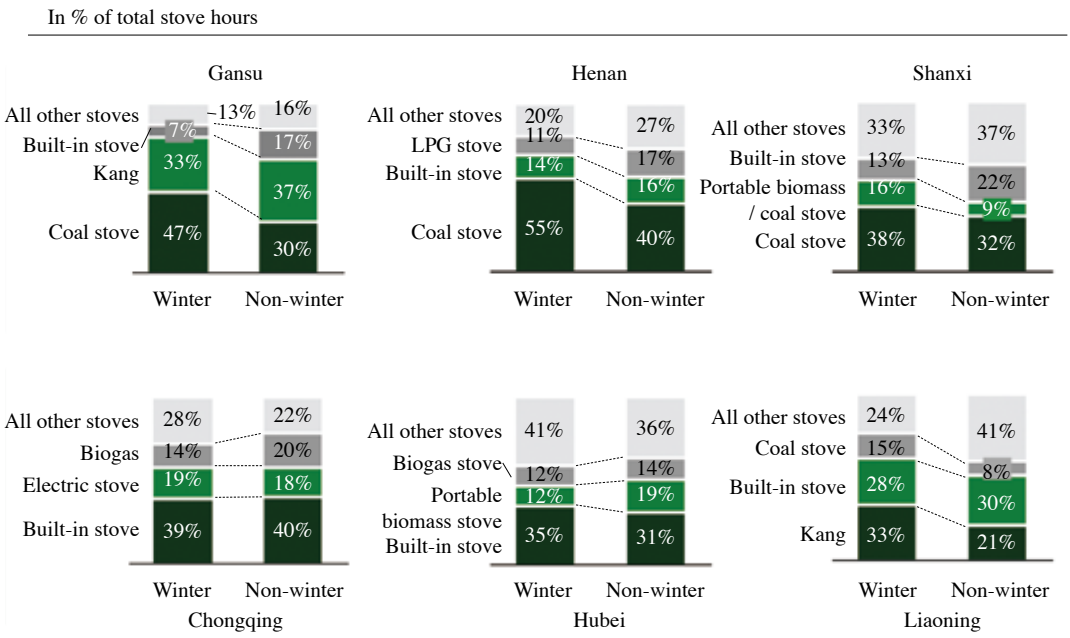

Figure H Changing stove/fuel preference through seasons

fuels rather than stoves, as fuel differences and quality are easier to distinguish.

Specifically, the greatest opportunity for government investment in cleaner fuels is to scale biomass pellet production as a fuel substitute for coal and raw biomass (particularly for heating). Biomass pellets are cleaner than coal and other raw and unprocessed solid fuels. They are also a more attractive heating fuel substitute, given the strong preference for solid fuels over electricity and gas for rural heating. However, pellets currently cost twice as much as coal. Scale benefits are not yet captured, as there is currently little incentive to process raw biomass, given how plentiful biomass residue is in China. China produces approximately 1 billion tons of crop straw per year which is a typical fuel source for stoves in China, theoretically more than is needed to satisfy all of rural China's household energy needs.

It is estimated that if biomass pellets more affordable than coal, a large number of rural households would switch a significant portion of their solid fuel use from raw biomass and coal to biomass pellets. Based on this report's segmentation data, the addressable market size is estimated at 90 million rural households, which consists of medium to high income rural households with primary dependency on raw biomass and/or coal.

Two actions will enable greater scale of the pellet industry by creating stronger incentives to process raw biomass to pellets. The first action is to re-design the existing biomass pellet subsidy policy to create a level playing field. This means offering the same subsidy value to all producers rather than varied amounts. Currently, producers receive varying subsidy amounts ranging from 5% to 60% of revenue, which creates incentives for producers to maximize their share of subsidies, rather than produce to market demand. As a result, producers are not incentivized

to lower the costs of production, resulting in cost inefficiency. Analysis comparing the supply curves for coal briquette producers and biomass pellet producers show the effect of subsidies and incentives on the cost-efficiency of the industry. In Figure I below, the coal briquette supply curve (where each producer is a grey box) is very flat, with very few inefficient producers (the producers on the right hand side of the curve). In stark contrast, Figure J below shows the biomass pellet supply curve, where costs of production are highly varied.

In price (RMB), sales (units per year), n = 31; in production cost (RMB), production (units per year), n = 33

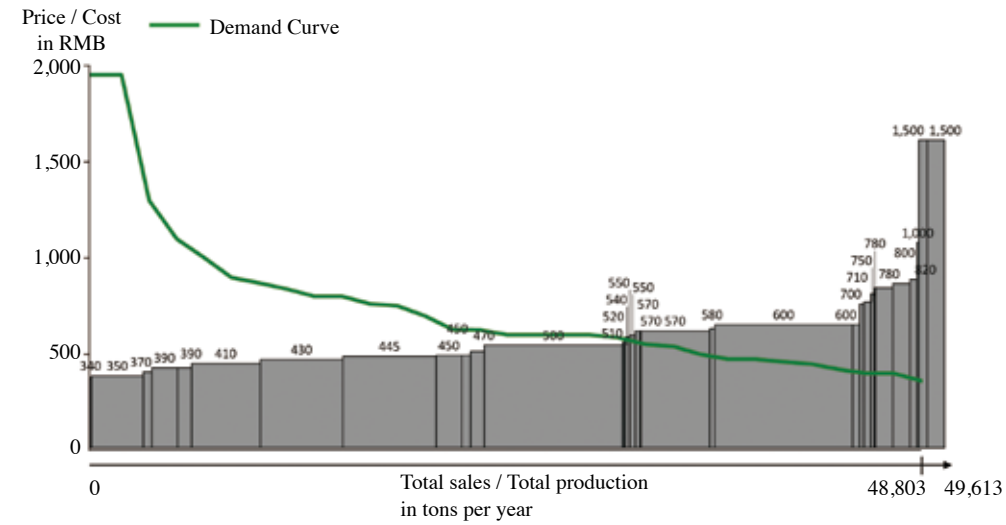

Figure I Coal Briquette Demand/Supply/Cost Curves

Source: GACC Household Survey data, 2014; Dallberg analysis.

In price (RMB), sales (units per year), n = 26; in production cost (RMB), production (units per year), n = 28

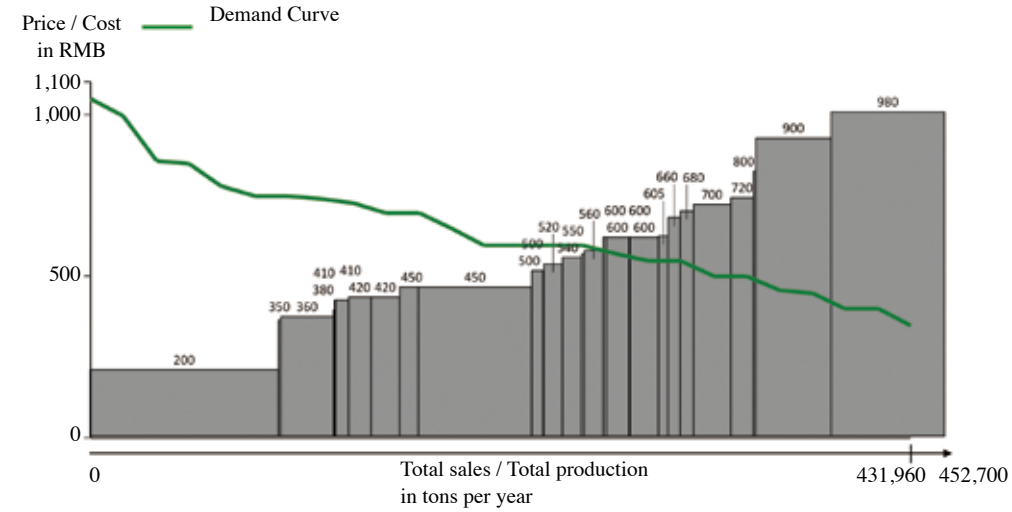

Figure J Biomass Pellet Demand/Supply/Cost Curves

Source: GACC Household Survey data, 2014; Dallberg analysis.

The second action is to consider supporting decentralized business models of pellet production by covering the initial capital expenditure of pelletizer machines. Decentralized, village-level pellet production businesses can be effective in making pellets accessible and affordable in harder to reach geographies. However, these models require assistance on the cost of pelletizer machines. Therefore, the government could consider subsidizing the initial capital expenditure to incentivize replication of these business models in remote villages across the nation.

Importantly, not all consumers will switch to pellets and therefore, there is still a need for consumer-based subsidy programs to upgrade existing stoves, especially for low income consumer segments. For higher income segments already purchasing solid fuels, it is estimated that no subsidies will be needed as the economic attractiveness of pellets will incent these households to purchase their own pellet burning stoves. However, low income segments (around 110 million rural households) tend to rely more on collecting solid fuels, which today is free, posing an economic disincentive to switch to pellets and purchasing improved stoves. Therefore, reaching these consumers may require subsidies to upgrade their existing solid fuel stoves in order to improve the cleanliness and efficiency of their solid fuel consumption. This leads to the report's second recommendation below.

2. Address stove quality and cost issues by implementing national standards and by re-designing existing manufacturer subsidy programs.

Quality can be enhanced through the refinement and enforcement of national standards. In order to be effective, national standards should meet two conditions: 1) they should be based on efficiency and emissions impact for each stove type; and 2) they should be internationally recognized in order to open the global market to stoves made in China. Standards enforcement will require manufacturers to meet minimum quality standards and will lead to less fragmentation in the industry, as highly inefficient and/or low quality players will likely not be able to afford the cost of meeting standards. The effect of a more consolidated industry will also positively impact demand through higher quality products, and lower costs of production due to scale increases.

Cost-efficient production can be encouraged through re-designed manufacturer subsidy programs. As mentioned above, current subsidy structures create "stop and go" markets, which incentivizes producers to maximize their share of subsidies, rather than produce to market demand. As a result, manufacturers have little incentive to invest in scale and lower their cost of production. In order to take advantage of market-based incentives to scale, manufacturer subsidies could be re-designed and switched to consumer rebates. Consumer rebates allows the market to set demand for production, instead of government procurement programs. Manufacturers receive a subsidy based on proof of sale to consumers covered in the rebate program.

3. Accelerate consumer awareness of the health and environmental value of cleaner and more efficient fuel burning, through consumer labels and targeted awareness campaigns.

Consumer labels on stoves can accelerate awareness and link to China's carbon market agenda. Creating labels that indicate the extent to which stove products meet standards will help educate consumers on the value of cleaner, more efficient stoves, as well as provide transparency to aid consumer choice. In turn, this will create manufacturer incentives to improve quality and meet higher tiers of standards, at better prices, in order to stay ahead of the competition.

Historically, creating consumer labels has only been done in China on more valuable consumer appliance products such as air conditioners and refrigerators. Stove labeling has not been seen as worthwhile due to low profit margins and low scales of production. However, moving forward, China's determination to create a carbon market by 2017 adds new incentives for consumer labeling for stoves. Labels could reflect emissions impact and the industry could utilize carbon credits and financing to supplement the costs of implementing consumer labels.

Targeted awareness campaigns utilizing the Internet and village-level demonstrations are also needed to help shift consumer mindsets to see the value of cleaner, more efficient stoves and fuels, and spread awareness of less familiar options like biomass pellets. Social media offers highly effective and scalable channels to communicate messages broadly to affect consumer choice. China has relatively high acceptance of social media platforms, and this could be explored as a means to create community level engagement and pressure for consumers to switch to cleaner fuels and stoves. The Internet is also a growing channel for stove purchase.

In addition, village level demonstrations will still have an important role to play to convince consumers of the value of specific fuel and stove products. Our data shows that these have historically been highly effective.

4. Utilize consumer segmentation as an input into designing and prioritizing policy actions and practitioner strategies.

Institutionalizing consumer segmentation and a data-driven approach in developing national and provincial policy will equip leaders to smartly invest in programs that carry the highest benefit for the money invested. This will be especially applicable when thinking through where to apply specific stove and fuel strategies (such as the promotion of biomass pellets), and how to influence and shift consumer behavior and awareness.

Segmentation analyses for rural China showed that the three most powerful explainers of behavioral differences among rural consumers were: 1) whether the household was situated in a province with high or low access to coal; 2) whether the household was situated in a remote location (far from town and/or in a mountainous/hilly terrain) or was close-to-town; and 3) whether the household had low or high income.

These drivers were used to group consumers into eight segments that had different behavioral preferences towards their fuel and stove usage and purchase.

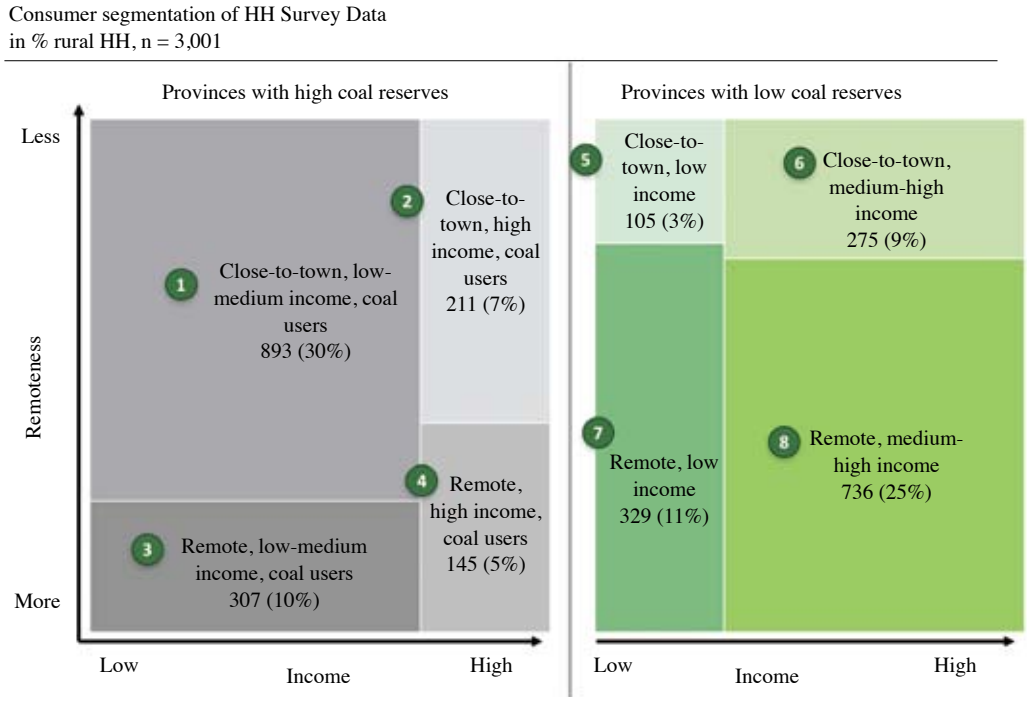

Figure K Eight consumer segments based on the research

This analysis in combination with the earlier analysis on total stove hours by stove purpose and fuel type (Figure H) can be powerful tools for policy makers to stress test their strategies. They provide a useful guide to understand the diversity of behaviors within a given province and/or region, as well as the relative contribution of each consumer segment to the overall problem of solid fuel dependency. Figure L below shows an example of how segments can be prioritized based on 1) their contribution to solid fuel usage (the y axis); 2) their ability to pay (the x axis); and 3) the relative population of each segment (the size of the bubble).

For example, in the analysis below, the "close to town, low-medium income, coal user" is both a large segment and burns significant average hours of solid fuel. Strategies targeting this segment would be particularly effective in reducing overall solid fuel burning. Importantly, priority segments will differ from province to province based on this analysis.

The second national program will ultimately target the adoption of cleaner stoves and fuels by 40 million households by 2020. Our model shows, as of 2013 the current market penetration for clean cookstoves is 25% and it will only come to 31% by 2020 under the baseline scenario which assumes clean adoption is only driven by economic growth alone and no further interventions (business as usual). If the 40 million target achieved, it will drive the penetration to

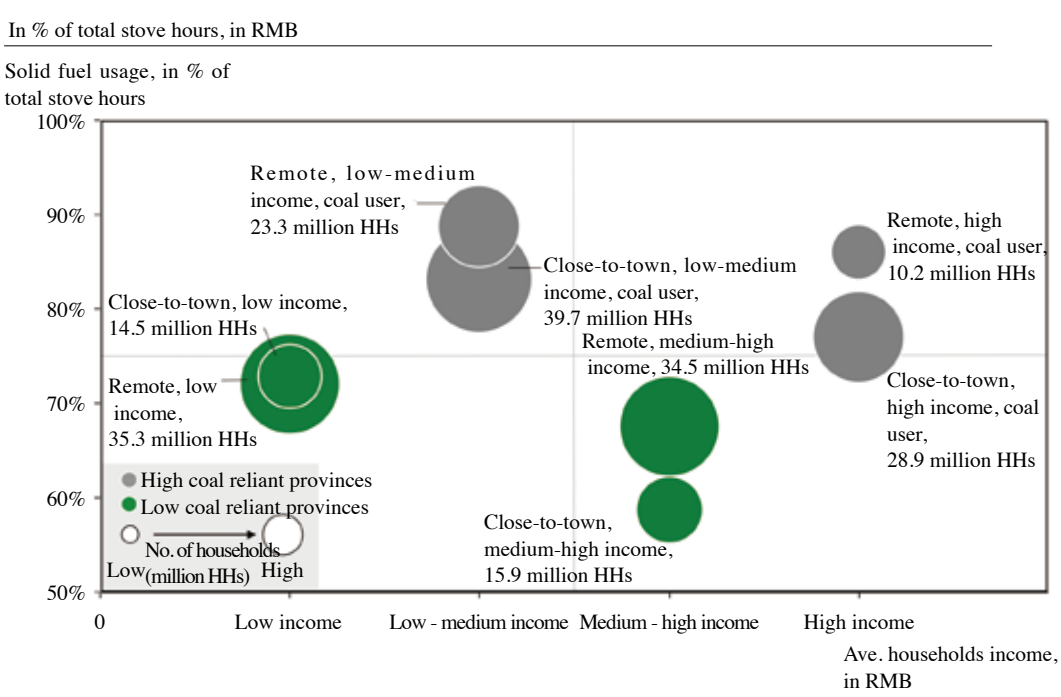

Figure L Consumer segmentation prioritization matrix

49%. This will only be achieved with strong political will and government policy support.

As a next step, the Alliance and REEA have committed to testing and refining these recommendations through a pilot phase in Alliance Phase 2 from 2015. The results of this pilot phase will inform the final design and implementation of the second national program to be implemented through 2020.

As a final remark, the next national program is an opportunity not just to improve China's domestic goals, but also to show international leadership in clean cooking and heating. China could become a center for research, as well as an exporter of quality stoves and effective policies for improving clean cooking and heating globally. Promoting China's clean cookstoves and fuels technology and best practices is practicing the country's top national foreign affairs strategy as well, such as the South-South collaboration and the "One Belt, One Road" initiative.

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Introduction

Nearly half of China's population, or approximately 600 million people, still rely on solid fuels (coal and biomass) for cooking and heating and many of them do not have access to clean and efficient stoves, especially in remote rural areas, and IEA estimates that 241 million people will remain the same by 2030 under the BAU case. The impact of less-efficient cooking and heating activities in China is significant: over one million people die from household air pollution (HAP) each year, including over 11,000 children, according to the Global Burden of Disease Study 2010.

The Chinese government is dedicated to tackling this issue and explicit provisions promoting the adoption of cleaner stoves and fuels are included in its current 12th Five-Year Plan. It has joined the Alliance as a Country Partner through the National Development and Reform Commission (NDRC) in May 2012, which acts as the national focal point overseeing clean stoves cooperation in China. The Alliance and NDRC have signed a Memorandum of Understanding to work closely, along with the Ministry of Agriculture (MOA), the Ministry of Science and Technology (MOST), the All-China Women's Federation (ACWF) and other Chinese ministries and stakeholders, over the coming years to foster the widespread adoption of clean stoves for rural households in China in order to bring health, environmental, social, and economic benefits to local communities.

This study was commissioned by a joint partnership between the Alliance and Rural Energy & Environment Agency (REEA) to conduct a market assessment to understand the current situation of stoves and fuels for cooking and heating in rural China. It aims to identify barriers and opportunities to catalyze the adoption of cleaner stoves and fuels. Data analysis got the help from Dalberg, the recommendations of this study are meant to inform pilot programs that will test specific solutions ahead of another national stove program, and will contribute to the Chinese government's clean stove policy planning under the 13th Five-Year Plan.

Distinctive features of this report

This study builds on the work of many researchers and policy makers noted in the acknowledgements and in the bibliography. Research and analysis presented here has aimed to extend this work in four respects:

1. National and provincial level data

This report combines both a national and provincial view of the stoves and fuels situation in China. Six provinces ① were carefully selected to represent diversity in China so that rural

① For ease of reference, we will refer throughout this document to the six 'provinces', however, we recognize here that Chongqing is a municipality.

demand dynamics could be accurately studied and understood.

China is typically divided into five regions based on climate and geography: Northeastern Plain Region, Northwestern Arid Region, Huang-huai Sea Plain Region, Southwestern Plateau Mountainous Region and Southeastern Hills Region. A variety of selection criteria was considered and each region had 1-2 provinces chosen to represent its characteristics: variation in climate and geography (including terrain), income level, stove and fuel usage, current concentration of stove and fuel producers, and the level of institutional support for improved stove and fuel programs. Liaoning, Henan, Hubei, Chongqing, Shaanxi and Gansu were finally selected. A brief profile of the selection is available in Figure 1.

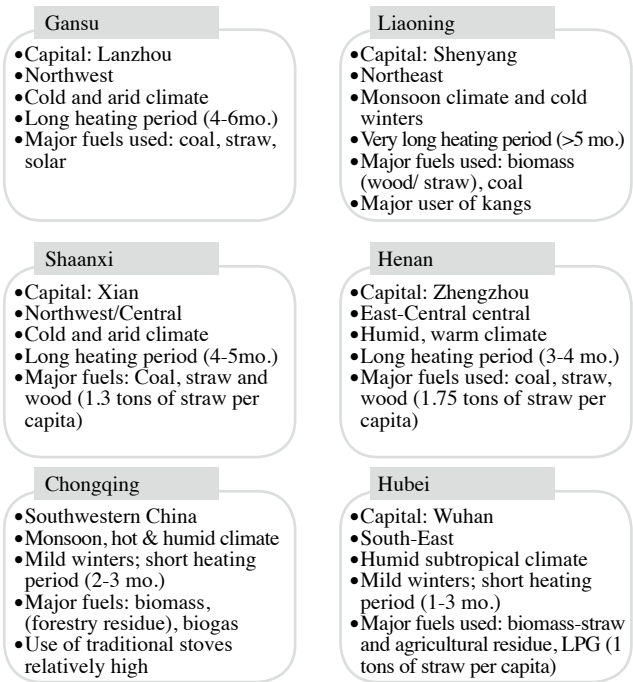


Figure 1 Profiles of selected provinces and selection criteria

Profile of the Five Regions and stoves and fuels use

1) Northeastern Plain Region, including Liaoning, Jilin and Heilongjiang province, has 290 counties (cities/districts) with a population of 107.15 million people. It contributes to 10.1%, 8.3% and 8.4% of China's total number of counties, national land area and total population. It includes 121,000 villages, 15.73 million rural households and 56.92 million rural population. Averagely each village has 130 households, 472 people and produces 1,000 tons of crop straw production. It has severe cold winters and long heating period. Primary household fuels are firewood, straw and coal.

2) Northwestern Arid Region, including Shanxi, Inner Mongolia, Shaanxi, Ningxia, Gansu, Xinjiang and Qinghai province, has 576 counties (cities/districts) with a population of

149.46 million people. It contributes to 20.1%, 45.7% and 11.7% of China's total number of counties, national land area and total population. It includes 589,000 villages, 25.54 million rural households and 103.27 million rural population. Averagely each village has 43 households, 175 people and produces 220 tonnes of crop straw production. It has dry and cold winters and long heating period. Primary household fuels are coal (43.2%) and straw (33.3%). Although per capital straw resource is high (1.3 tons), utilization rate is less than 40%.

3) Huang-huai Sea Plain Region, including Beijing, Tianjin, Hebei, Shandong, Henan, Jiangsu and Anhui province (not including the south area of Huai River in Jiangsu and Anhui), has 614 counties (cities/districts) with a population of 354.58 million people. It contributes to 21.5%, 7.1% and 27.8% of China's total number of counties, national land area and total population. It includes 611,000 villages, 74.16 million rural households and 270.47 million rural population. Averagely each village has 121 households, 442 people and produces 770 tonnes of crop straw production. Climate is warm and humid but has long winter. Primary household fuels are coal (40%) and straw (38%) and wood (12%). This region is a traditional agriculture and pasture production zone and has rich straw resource with 220 million tons of annual production or 1.75 tons per person.

4) Southwestern Plateau Mountainous Region, including Yunnan, Guizhou, Chongqing, Sichuan, Guangxi and Tibet province, has 618 counties (cities/districts) with a population of 250.39 million people. It contributes to 21.6%, 27.0% and 19.6% of China's total number of counties, national land area and total population. It includes 798,000 villages, 53.94 million rural households and 205.51 million rural population. Averagely each village has 68 households, 258 people and produces 160 tonnes of crop straw production. It is in subtropical monsoon climate, but high plateau areas in Tibet, Western Sichuan, Yun-Gui Plateau has heating needs. Primary household fuels are wood, straw and coal. Wood and straw accounts for 60% of total energy consumption and has an annual production of 130 million tons in this region. However, they are mostly burned directly resulting in heavy pollutions.

5) Southeastern Hills Region, including Shanghai, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Hainan, Jiangsu and Anhui province (not including the north area of Huai River in Jiangsu and Anhui), has 763 counties (cities/districts) with a population of 413.6 million people. It contributes to 26.7%, 11.9% and 32.4% of China's total number of counties, national land area and total population. It includes 858,000 villages, 91.3 million rural households and 341.46 million rural population. Averagely each village has 106 households, 398 people and produces 400 tonnes of crop straw production. The region is humid subtropical climate and has mild winters and shorter heating period. Primary household fuels are wood, straw, coal and LPG. Wood and straw accounts for 55% of total energy consumption.

2. Strong collaboration between the Alliance and REEA to undertake intensive grass-roots discovery work

The Alliance and REEA jointly led survey design for the household and stove/fuel

manufacturer surveys carried out under this study. REEA led the data collection effort, which involved surveying more than 3,600 households (door to door) and 134 stove and fuel suppliers across the six provinces. The household survey covered multiple topics including demographic and income data, current stove and fuel ownership, stove and fuel usage behaviors, future stove and fuel outlook, and drivers of purchase and usage. The supplier survey covered topics on general company information, current sales, production capacities, customer bases, marketing methods, sales channels, subsidies received, competition, and future plans for growth and expansion.

Extensive effort was taken to ensure that insights are fact-based and generated from reliable data collection. The survey instruments were co-designed and pilot-tested by international and local experts, ensuring cultural appropriateness and clarity in meaning. Two workshops were held with the MOA's national and provincial leaders in November 2013 and January 2014 to design the survey. A pilot test covering village areas around Beijing was conducted to further refine the survey for field usage. The sampling process ensured that county selection represented China's diversity. Counties were analyzed based on their average income and climate distribution and proportionally selected to create a strong mix of data points (Figure 2).

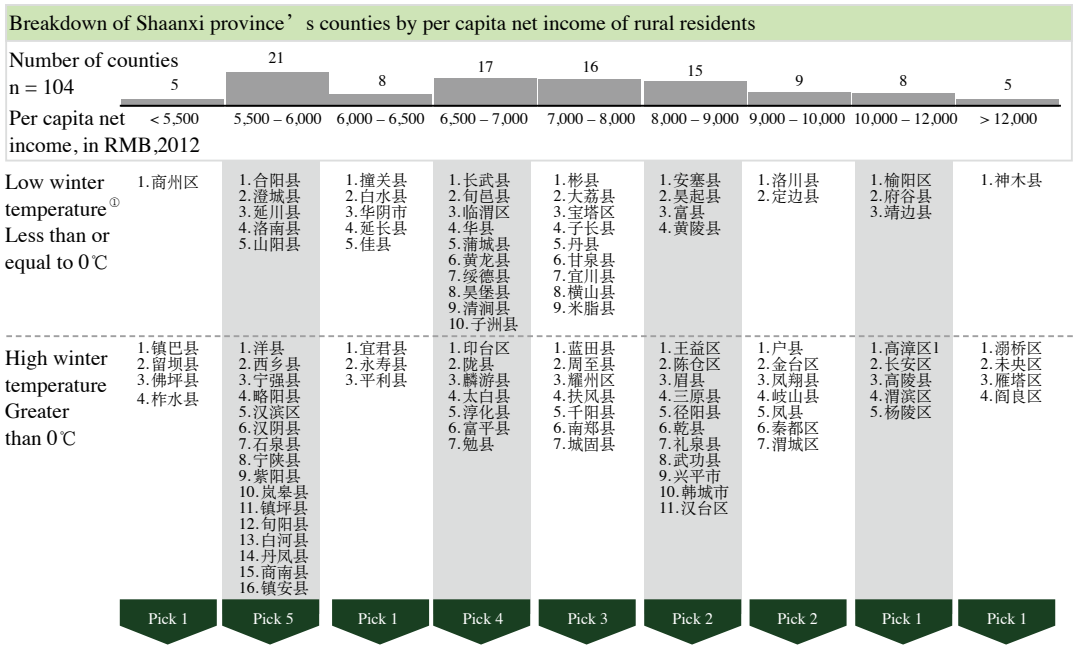


Figure 2 County selection approach was designed to deliver a representative cross-section (Shaanxi Province example below)

Note: ① Average temperature in the month of January. 2014 is taken to classify counties into low and high winter temperature categories.

Source: China Bureeu of Statistics; accuweather. com; Dalberg analysis.

Finally, surveyors were trained to conduct household surveys door-to-door, on a randomized basis, to minimize sampling bias. The result is a very rich data set on rural consumer behavior

and industry dynamics (Figure 3). This will aid future practitioners and policy makers in understanding demand and developing targeted approaches to driving adoption of improved stoves and fuels.

In addition to surveys, field visits were conducted in three of the six provinces: Hubei, Chongqing and Gansu. During these field visits, eight focus groups, over thirty household visits and interviews, and five stove and fuel supplier visits were conducted.

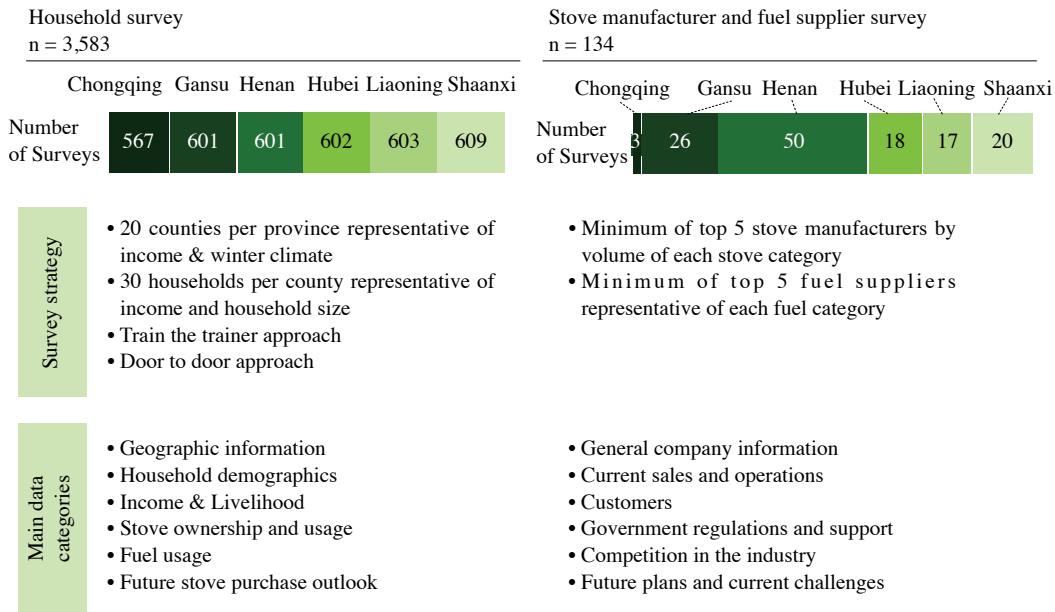


Figure 3 Summary of this study's data set

3. Market segmentation and Industry analytics

In understanding demand for stoves and fuels, this study applied tools from marketing science. Differences were analyzed across the six provinces and crosscutting themes were identified through customer segmentation analytics. A regression and correlation analysis was used to identify variables that most influence rural household behavior. These variables were used to group rural consumers with similar needs and preferences for stoves and fuels in order to identify consumer segments that can be separately understood and targeted.

On the supply side, the study looked to not only profile the industry, but also to analyze the underlying economic sustainability and the drivers of value and viability of te industry. The analysis used sales and cost curves to understand industry structure and dynamics across different manufacturer segments. Interviews were conducted to understand the practice and effects of subsidies on market demand and supply, and to develop key implications for policy makers seeking to grow and regulate the industry.

4. National program and policy-driven recommendations

This study was results-driven and focused on delivering national-level policy and program recommendations. The Alliance and REEA worked collaboratively to identify specific policy implications and recommendations, providing references for the national government making relative policies during the 13th Five-Year Plan period.

Outline of the report

Chapter 1 outlines China's successful history in addressing the issue of reducing solid fuel burning through past national and provincial level programs. It shows that despite past success, efficiency and cleanliness of solid fuel burning in rural China is still a significant issue requiring further government focus and investment. This chapter introduces the opportunity for a second national program to increase efficiency and cleanliness of solid fuel burning, and improve health, environmental and social outcomes for China. Today's context is highlighted as a great opportunity for another national program given improvements in technology and a favorable political environment.

Chapter 2 discusses consumer demand for stoves and fuels and the value of a customer segmentation approach. First, the chapter profiles four regional differences and shows how these drive variances in the mix of stoves and fuels used across China. Next, the report discusses the eight consumer segments identified in the analysis, which cut across all regions. It shows how an understanding of these segments can be used to identify the biggest opportunities to improve efficiency and cleanliness of solid fuel use. It also reflects how understanding consumer segments can help policy makers and manufacturers more effectively and efficiently design and prioritize policy and marketing efforts.

Chapter 3 discusses two major supply-side challenges of the solid stoves and fuels industry: 1) The inconsistency of quality due to industry fragmentation and the lack of standards and their enforcement; and 2) the cost inefficiency of producers, due to the current nature of subsidy programs.

Chapter 4 provides an overview of national level recommendations and provides detail on the four actions proposed by this report for the next national program.

1. There is a great opportunity to increase efficiency and cleanliness of solid fuel burning in rural China

China has made significant progress in reducing solid fuel burning and improving stoves since the 1980s. Since then, China's reliance on solid fuel burning as a proportion of total rural energy consumption has decreased by 21%. China's progress can be attributed to strong government policies (including the highly successful National Improved Stoves Program), urbanization and economic development.

However, despite progress, government investment is still needed to reduce solid fuel burning. While the share of solid fuel burning has decreased, the total quantity of solid fuel burning has doubled since 1980. Solid fuel burning creates harmful emissions that have damaging effects on the environment and public health. The majority of rural consumers still uses and will continue to use solid fuels for cooking and heating in the foreseeable future.

Today, stove technology has improved, such as appearance, design, cleanliness, and pellets fuels processing. Therefore, there is a great opportunity for a second national program to further China's progress in reducing solid fuel burning. It will be helpful in speeding up rural energy upgrading, promoting low-carbon development and realizing the targets of energy-saving and emission reduction.

1.1 China has made significant progress in improving efficiency of solid fuel burning and improving stoves since the 1980s

China has a successful history of improving efficiency of solid fuel burning through improved stoves and fuel promotion. In 1980, burning solid fuels almost exclusively powered China's rural energy consumption. In 2013, the share of solid fuel in rural household energy consumption was estimated[①] at ~78% (33% coal, 28% straw, 17% wood), representing a 21% decrease since 1980.

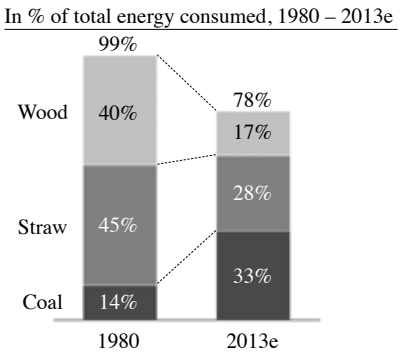


Figure 4 Reduction in share of solid fuel consumption in rural China

Note: 2013 figures for rural energy consumption is a Dallberg estimate.

More specifically, data from 1980 to 2013 reveals the following key trends in the mix of total rural energy consumption (Figure 5):

• The share of biomass (straw and wood) has steadily decreased from 85%-45%, reflecting increases in biomass stove efficiency, policy efforts regarding deforestation, and fuel switching to modern fuel stoves like electricity and gas for cooking activities due to increasing incomes.

• The share of coal increased from 14% to 33%, reflecting increasing accessibility and affordability of coal. Recent policies restricting coal sales in towns and cities and increasing incomes are likely contributors to the slight decrease in the share of coal from 2005 to 2013.

• The share of electricity has increased from ~1% to 7%, reflecting the steady progress that

① The 2013 figures were estimated based on a simple regression model between inflation adjusted GDP per capita and the relative shares of fuels from 1980 to 2005. Estimates were used because recent data sets in statistical yearbooks do not account consistently for non-commercial energy (straw, wood etc.). The analysis was based on a data set compiled by Zhang et al. which collected, compared and rectified data across official sources (MOA and State Statistics Bureau) to provide a consistent view of fuel mix (both commercial and non-commercial) from 1980 to 2005.

In % of total energy consumed by rural households in coal equivalents, 1980—2013e

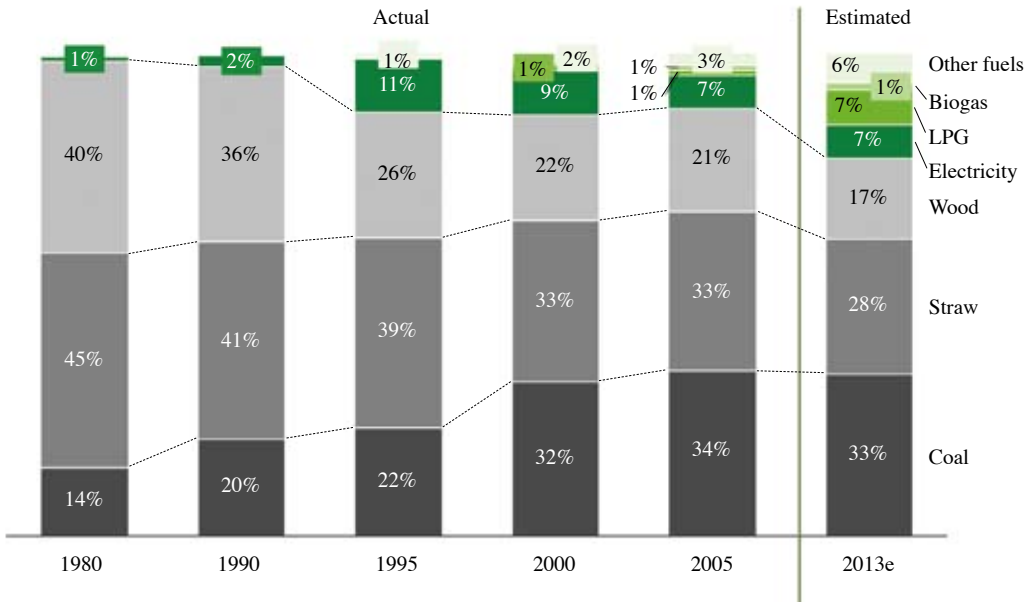
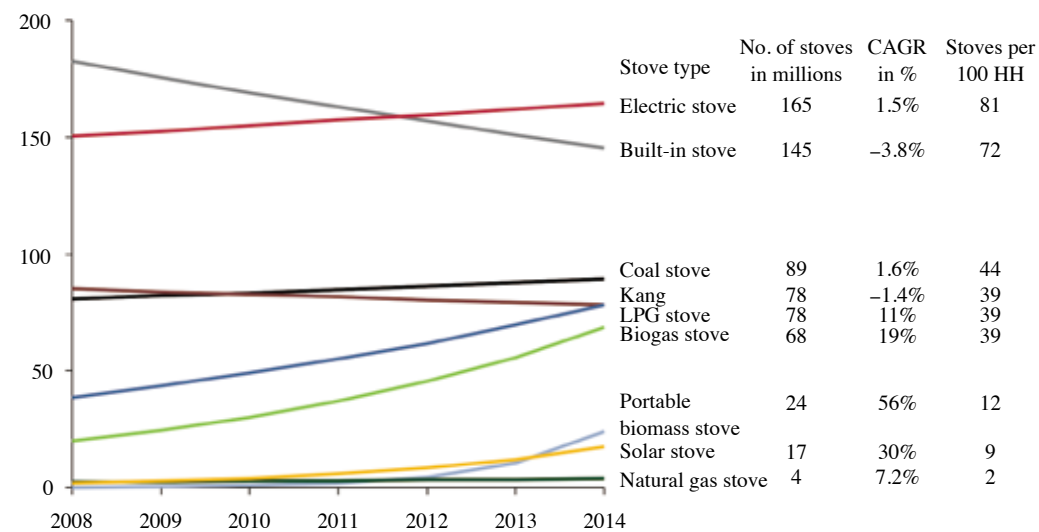


Figure 5 Breakdown of rural household energy consumption in China, 1980—2013

Note: ①2013 figures for rural energy consumption are Dalberg estimates; ②Other fuels includes gasoline, kerosene, diesel oil and natural gas.

In million stoves, in stoves per 100 households (HH), 2008—2014



Stove type	No. of stoves in millions	CAGR in %	Stoves per 100 HH
Electric stove	165	1.5%	81
Built-in stove	145	–3.8%	72
Coal stove	89	1.6%	44
Kang	78	–1.4%	39
LPG stove	78	11%	39
Biogas stove	68	19%	39
Portable biomass stove	24	56%	12
Solar stove	17	30%	9
Natural gas stove	4	7.2%	2

Figure 6 Estimated number of stoves by type in rural China

Note: The analysis aggregated survey data across six provinces and used a population-weighted oenetration rate as the basis for estimating national numbers.

China has made to electrify rural China, and the convenience of electric stoves, particularly for cooking.

• The share of LPG was flat until experiencing rapid growth from 2005 to 2013, where it is now estimated to be ~7%. Growth in LPG is linked to growth in incomes and the continued modernization of rural China.

• The share of biogas grew marginally since 2005, mostly due to continued biogas promotion programs.

The landscape for stoves in rural China has also changed considerably in recent years. Figure 6 above shows estimates① of today's stove mix by different types, and how the mix has changed since 2008. The analysis from the survey suggests that the total stock of stoves is split evenly between solid fuel stoves and electricity, gas and solar stoves, where solid fuel stoves include built-in stoves, coal stoves, kang stoves and portable biomass stoves. The two most prevalent stove types are electric stoves at 165 million and built-in biomass stoves at 145 million in rural China.

1.2 Policy, urbanization and economic development are the primary drivers of change in China's stove and fuel mix

Policy

China has a successful history of implementing large-scale stove policy programs to improving efficiency of solid fuel burning. Given the scarcity of fuel resources in the early 1980s, the Chinese government implemented a National Improved Stove Program (henceforth "NISP") to provide rural households with more energy-efficient biomass stoves. These stoves were built-in stoves that had better ventilation and efficiency than traditional stoves. This program was coordinated by the MOA along with the support of additional programs in individual provinces.

The national rollout was the first of its magnitude and it is estimated that over 60% of rural households with basic stoves upgraded to energy-efficient built-in stoves during the time①. The successful rollout eventually led to nearly 200 million energy-efficient built-in stoves deployed in rural China by the late 1990s②.

Figure 7 below shows the growth in penetration of households with energy-efficient built-in stoves due to the impact of NISP from 1986 to 2012. In 1986 we estimate that the proportion

① Source: Alliance China Household Survey, 2014; World Bank, China Accelerating Household Access to Clean Cooking and Heating, 2013; ADB, Rural Biomass Energy 2020, 2010; China National Statistical Yearbook, 2013; Zhang et al, "Rural energy in China: Pattern and policy", 2009; ESMAP; Dalberg analysis.

② http://climate.org/publications/Climate%20Alerts/Autumn2009/StoveRevolution.html#ii.

③ http://ehs.sph.berkeley.edu/krsmith/publications/2010/nisp_combined.pdf.

of households with energy-efficient stoves was around 39%. By 2012, the number of households with energy-efficient stoves was 85%.

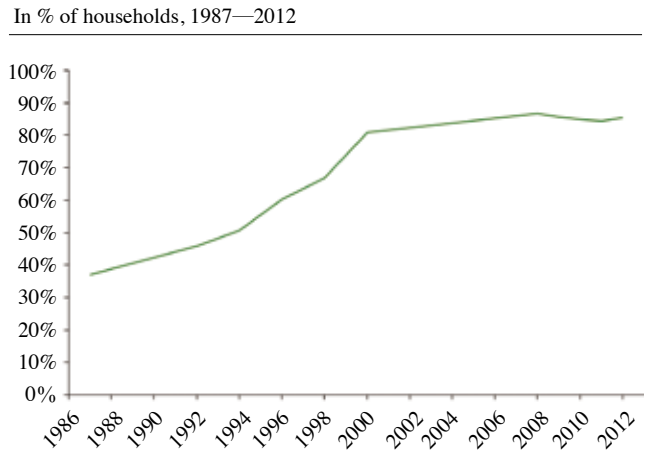


Figure 7 Adoption of energy-efficient stoves due to NISP

Resource-saving efforts through the NISP and other national reforestation programs had a largely positive effect on preserving China's national resources. From 1977 to 2003, forest area in China increased at an annual rate of 0.51%①.

Urbanization

In addition to China's policy programs, rapid urbanization has also led to changes in China's stove and fuel mix.

In the past ten years alone, China has experienced unrivaled urbanization. Just forty years ago, only 12% of China lived in urban areas. In 2010, the urban population overtook the rural population and has continued to increase. The government estimates that by 2020, the rural population of China will make up 40% of its total residents②.

The implications of urbanization on stove usage are significant. As men from China's rural villages move into the cities for employment, many of those villages are populated with the elderly, women and children. As a result, less cooking capacity is needed, and families prefer quicker, more convenient cooking options such as electricity or gas. Often family members who experience the convenience of electricity or gas in the cities bring these stoves back to their rural

① L. Shi et al, The Changes in China's Forests: An analysis using the forest identity, 2011.

② Source: China's National Stats Yearbook, 2013; Estimates to 2020, based on National New-type Urbanization Plan (2014-2020) released by the central committee of the Communist Party.

In millions of people, in % of total population, 1980—2020e

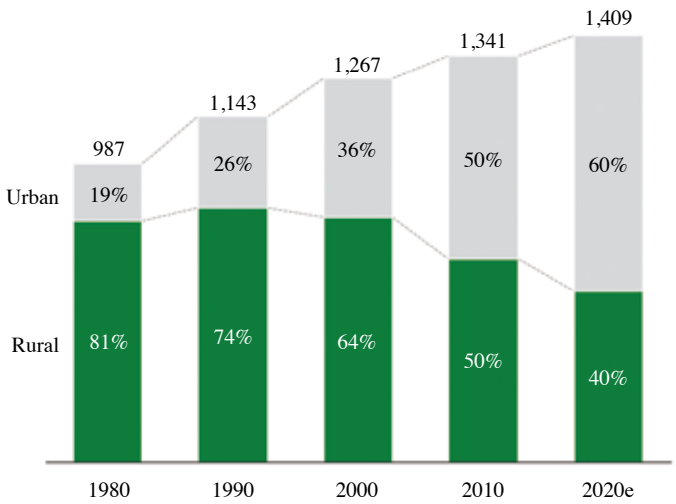


Figure 8 Rural vs. urban population

In number of rural households, 2000—2020e

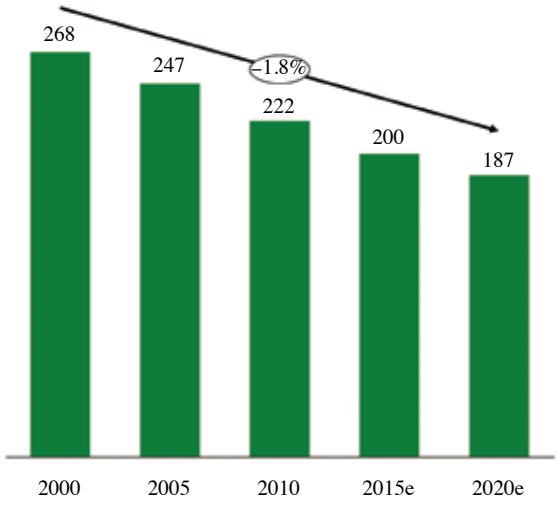


Figure 9 Total number of rural households

families. In such cases, traditional built-in and biomass stoves play less of a role for cooking. However, they are still regularly used for heating activities.

Economic development

In addition to urbanization, increased wealth of rural areas is also driving changes in the stove and fuel mix. The average rural income today is more than four times what it was in 2000 (Figure 10).

In millions of RMB, 2000—2020e

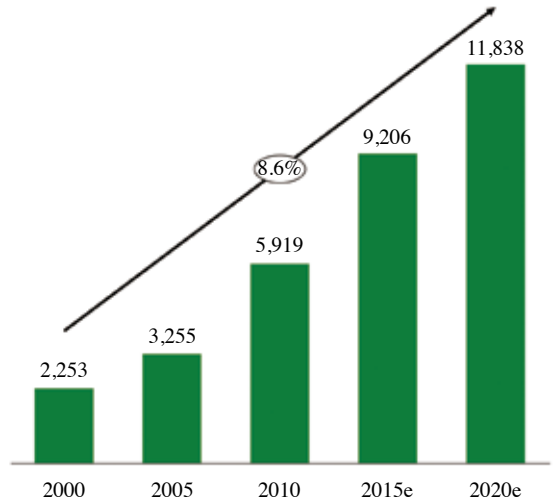


Figure 10 Average net rural per capita household income

Economic growth has also resulted in increased access and appetite for technology in rural areas. Rural China is now almost 100% electrified. Figure 11 depicts the electrification of rural households from 1980 to 2004. While just over 60% of households had access to electricity in 1980, 99% of rural households have access to electricity today.

In percentage of rural households with access to electricity, 1980—2004

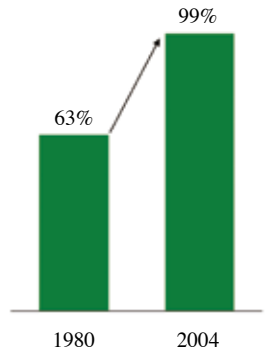


Figure 11 Access to electricity

Access to electricity has made electric stoves highly accessible for cooking activities. It also has increased access to various technologies, which has changed the way messages are received and how markets operate in rural areas.

The penetration of TVs, computers, cell phones and the use of the Internet have all sped up market promotion and penetration of various household appliances, including modern stoves and

fuels. During the time of the NISP, almost no rural residents had a TV. By 2012, most households owned a TV, and many had more than one. In 2000, only 1 out of every 100 rural households owned a computer. Today, nearly one in every four rural households has access to a computer. The cell phone has also seen a rapid increase in penetration in rural China. During the NISP, nearly no rural residents had access to a cell phone. Today nine out of every ten residents owns one.

Internet penetration is also on the rise. Internet service providers are now targeting rural China as their next big market, particularly through mobile devices. According to the China Internet Information Center, 67.3% of rural users use a mobile device to connect to the Internet—ten percentage points higher than that of urban Internet users[①].

The changes in technology access described above are making rural markets more efficient through faster, better access to information. These technologies are changing the way rural consumers learn about new products and services, and how they purchase goods and services.

1.3 However, despite progress, government investment is still needed to increase efficiency and cleanliness of solid fuel burning

Despite a decrease in the share of solid fuel as a proportion of total rural energy consumption, the total quantity consumed in absolute terms has increased significantly. The data on how much it has increased differs considerably based on different sources[②].

There are three reasons why government investment is needed to address this issue. The first is simply that the issue is likely to persist without further intervention. The majority of rural consumers still primarily uses and will continue to use solid fuels. Despite China's rapid economic growth and increased living standards, there is still a large market need for improved stoves and fuels. Based on the 2010 census, 160 million rural households (approximately 75% of all rural households—17.1% coal and 58.6% biomass) are still primarily dependent on solid fuels[③].

Many of these rural households are likely to continue using solid fuels in the near future. Figure 12 below shows estimates for China's 2020 energy composition using a simple regression model projecting fuel mix trends based on GDP per capita. The model's baseline estimates that China's predicted economic growth will result in a further 9% (4% wood, 5% straw) reduction in solid fuel usage from 2013 to 2020, attributable to increased relative usage in electricity,

① http://government.huawei.com/ar/static/GOVERNMENT-323773.pdf.

② Chinese statistical yearbook estimates total rural Chinese household energy at ~346 mtce in 2010: significantly less than Zhang's estimate, which suggested that total quantity has doubled from 250 million tonnes of coal equivalent (mtce) in 1979 to 531 mtce in 2006. Zhang's estimate was based on an amalgamation of Chinese statistical yearbooks.

③ Tang, Liao, Energy poverty and solid fuels use in rural China: Analysis based on national population census, May 2014.

LPG and biogas. However, despite gains due to China's economic growth, an estimated 69% of energy consumption in 2020 will still be generated through solid fuel burning.

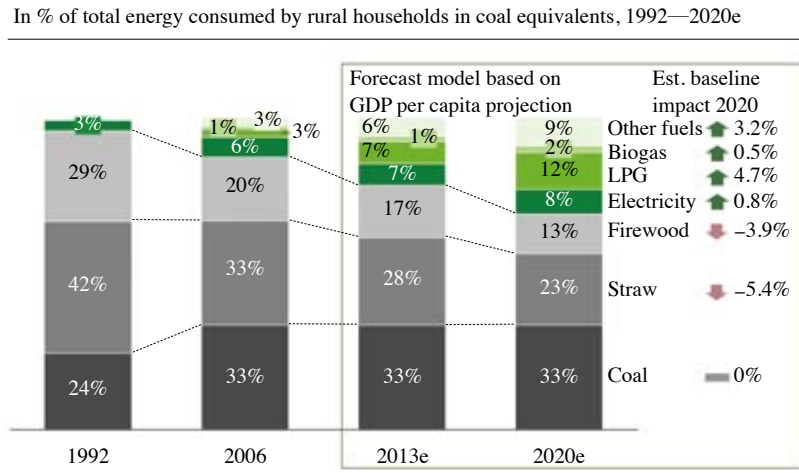


Figure 12 Forecast model based on GDP per capita projections

This analysis suggests that increasing net income per capita alone is not enough to achieve a significant transition away from solid fuels in China. Figure 13 shows that while solid fuel usage decreases with increasing incomes in the survey data, the rate at which this happens is relatively limited: moving from the lower than 20,000 RMB income bracket to greater than 40,000 RMB bracket results in only an 11% reduction in solid fuel. Therefore, increased wealth alone is not enough to significantly reduce solid fuel usage. More needs to be done to address the underlying affordability, accessibility and availability of cleaner fuels.

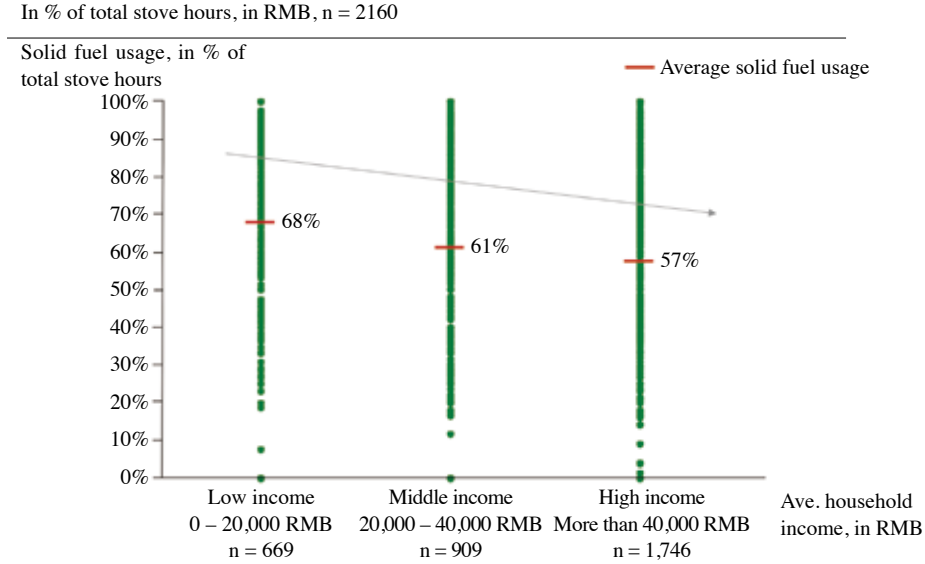


Figure 13 Solid fuel usage by different income groups

The limited impact of increased income is partly explained by the relative cost of collecting vs. purchasing fuels and the relative value of fuels for cooking vs. heating. Rural consumers with higher incomes are likely to switch away from fuels that incur the time cost and inconvenience of fuel collection (straw and wood). As a result, we see that income has a stronger effect on straw and wood than coal, which remains relatively constant in the model.

In addition, the continued popularity of coal can also be attributed to its greater efficiency and cost-effectiveness for space heating. This is because heating requires significantly more energy over longer periods of time, and therefore the economic cost of switching away from using solid fuels, such as coal, is higher.

This distinction between cooking and heating is shown in Figure 14 below, which shows a breakdown of stove hours by purpose. The figure shows that energy transition to gas and electricity has only significantly happened for stoves purposed solely for cooking, whereas stoves purposed for heating or for both cooking and heating are still dominated by solid fuels. Figures 15 to 17 show the breakdown of stove and fuel combinations represented by Figure 14.

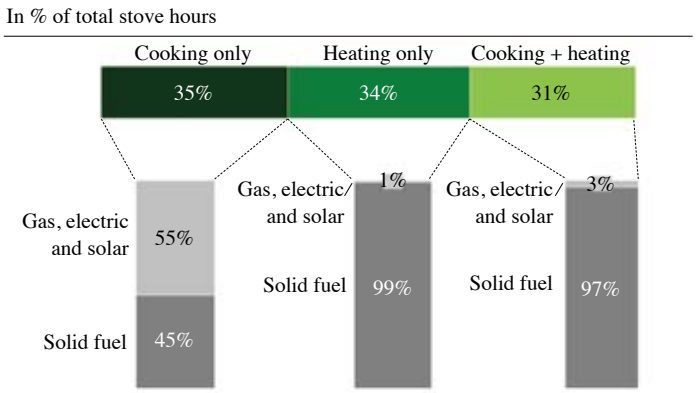


Figure 14 Baseline analysis for all six provinces

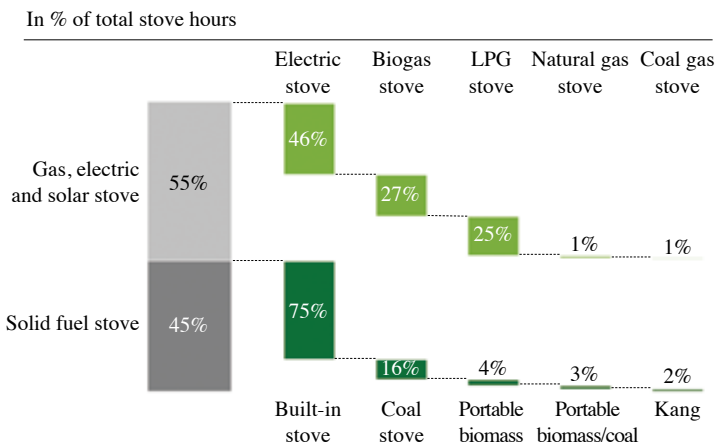


Figure 15 Breakdown of stove types for cooking only stoves

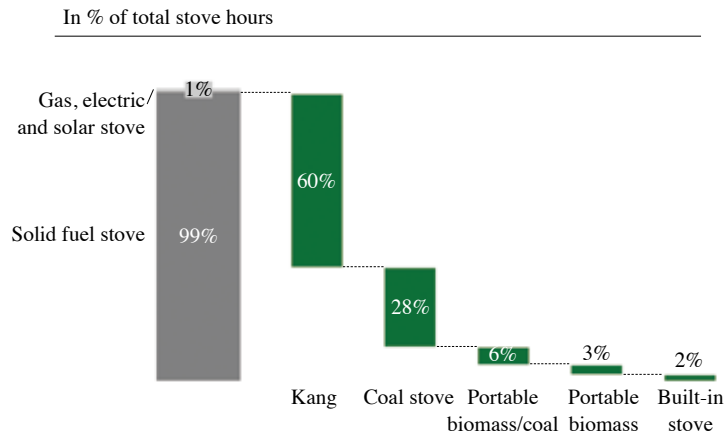


Figure 16 Breakdown of stove types for heating only stoves

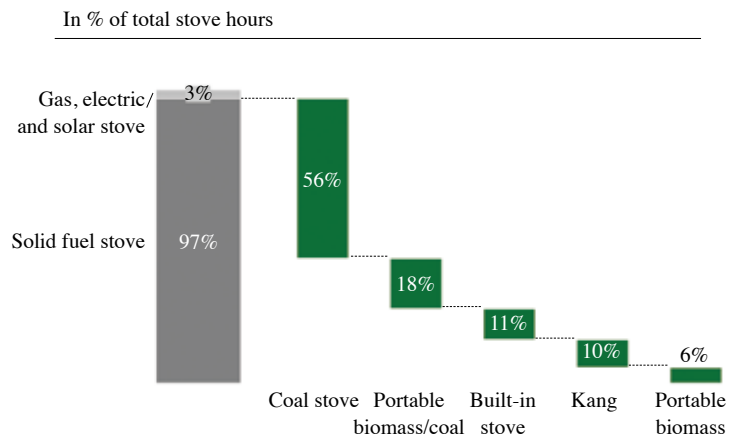


Figure 17 Breakdown of stove types for cooking and heating stoves

The second reason the government should invest in reducing solid fuels is because burning solid fuels emits harmful emissions that damage the environment and increase health risks.

Environmentally, burning solid fuel releases carbon dioxide (CO_2), particulate matter (PM10, PM2.5), sulfur dioxide (SO_2) nitrogen oxides (NOx) and volatile organic compounds (VOCs) and other harmful emissions due to incomplete combustion. They pose a major impact to air quality and threaten human health. Among these, CO_2 and black carbon are the primary cause of regional and global warming and climate change. High levels of PM2.5, NOx and VOCs are the main contributors to air pollution and smog. Residential coal and biomass combustion is a significant contributor to China's total annual emissions of PM2.5, black carbon, organic carbon

and benzopyrene (BaP)[①]. For example, a review of recent studies estimates that residential combustion could account for up to 33%-47% of China's total PM2.5 emissions annually, 46%-67% of black carbon, 82%-91% of organic carbon and 55%-65% of benzopyrene (BaP). A recent study of Peking University showed the specific breakdowns of emission sources and it indicated solid fuels burning from rural households (residential coal + wood + straw) contributes to 36% of China's total PM2.5 emissions, 53% of total black carbon emissions, 33% of total CO emissions, 56% of total benzopyrene emissions and 74% of total organic carbon emissions[②].

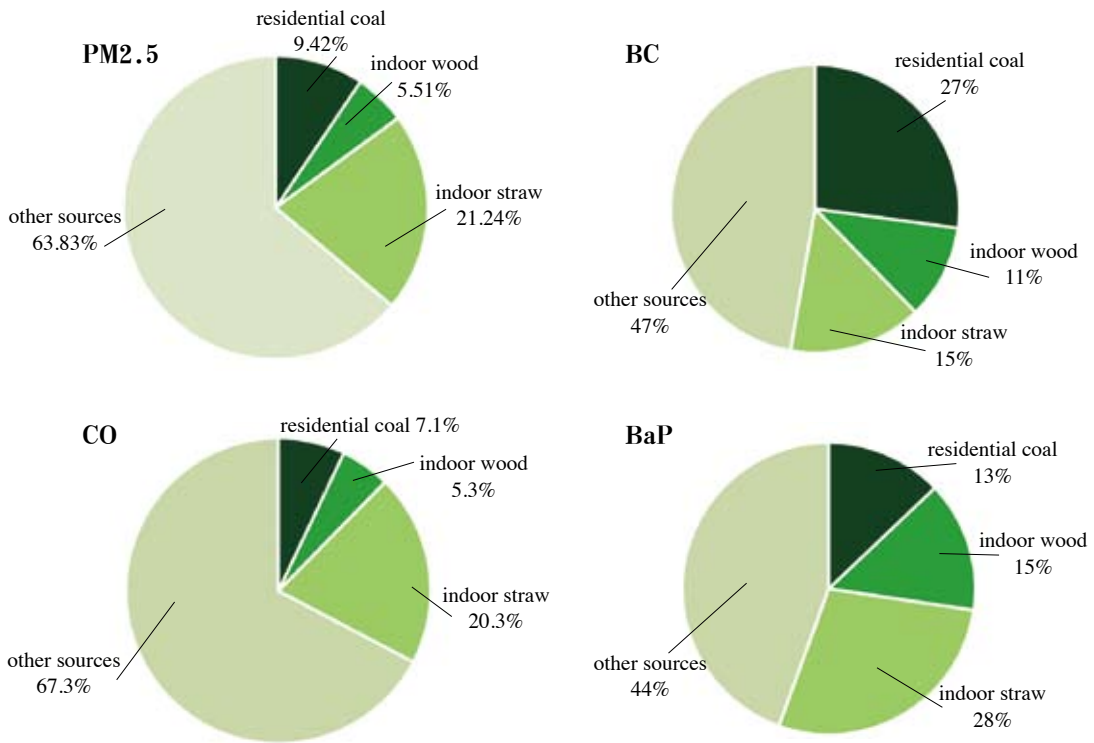


Figure 18 Emissions from solid fuel burning, % of total, 2007

In addition to cooking and heating, household level burning extends to burning biomass

① Literature reviewed include: 1) Lei, Y., Zhang, Q., He, K., Streets, D. Primary anthropogenic aerosol emission trends for China, 1990—2005. Atmos. Chem. Phys. 2011, 11, 931-954; 2)Shen, H., Huang, Y., Wang, R., et al., Global atmospheric emissions of polycyclic aromatic hydrocarbons from 1960 to 2008 and future predictions. Environ. Sci. Technol. 2013, 47, 6415-6424; 3) Wang, R., Tao, S., Wang, W., et al., Black carbon emissions in China from 1949 to 2050. Environ. Sci. Technol. 2012, 46, 7595-7603; 4) Zhang, Q., Streets, D., Carmichael, G., et al., Asian emissions in 2006 for the NASA Intex-B mission. Atmos. Chem. Phys. 2009, 9, 5131-5153; 5) Huang, Y., Shen, H., Chen, H. et al., Quantification of global primary emissions of PM2.5, PM10, and TSP from combustion and industrial process sources. Environ. Sci. Technol. 2014, 48, 13834-13843.

② Tao, S. et al., http://inventory.pku.edu.cn/, Peking University.

in fields. China produces approximately 300m tons of crop straw annually. Given that biomass is plentiful, rural farmers often burn excess straw, emitting more harmful emissions (Figure 19) .

Figure 19 Excess straw being burnt in fields

Smog in China contains extremely dangerous levels of PM concentrations. High PM concentrations result in lower crop yields, posing a threat to rural farmers and food production. Other potential environmental effects of smog and CO_2 emissions include high levels of acid rain and eutrophication, where pollutants build up in bodies of water and lead to the loss of plant and animal diversity①.

In terms of public health, pollutants released by solid fuel burning adversely and severely affect the health of those most exposed to the smoke with PM concentrations occasionally over fifty times the World Health Organization's recommended daily limit. Carbon monoxide (CO) and products of incomplete combustion (PIC), when coupled with the emissions discussed above, pose harmful health effects. Household air pollution (HAP) is one of the top five risk factors in China. The Institute for Health Metrics and Evaluation attributes over 1 million deaths (including over 10 thousand child deaths) annually to HAP in China②. In addition, the WHO attributes over 4 million Disability Adjusted Life Years (DALYs) annually to HAP in China③. Increased exposure to household air pollution is associated with an increased risk of respiratory diseases, cardiovascular disease and cancer. Specifically, cataracts, lung cancer, lower respiratory infections and COPD have been directly linked to unclean stove usage, with women and children most at risk. Exposure to emissions from unclean stoves is reported as the primary factor for the high proportion of rural Chinese children under five with respiratory infections④.

The economic cost of these healthcare problems caused by air pollution is significant. It is estimated that without further intervention, the existing situation will grow to cost the government over RMB 10 billion per year by 2020 in government subsidies for medical care costs alone⑤.

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① http://government.mass.gov/eea/docs/dep/air/aq/health-and-env-effects-air-pollutions.pdf.

② Institute for Health Metrics and Evaluation (2010) - Global burden of diseasas, injuries, and risk factors study 2010.

③ WHO Estimated deaths & DALYs attributable to selected environmental risk factors, by WHO Member State, 2004.

④ http://www.cmaj.ca/content/182/16/1718.full.

⑤ K. Smith "A Chinese National Improved Stove Program for the 21st Century to Promote Rural Social and Economic Development".

The final reason for focusing investment on reducing solid fuels is that the biomass stoves and fuels industry is still dependent on subsidies, and the supply of biomass and coal is subject to inconsistent product quality and inefficiencies in cost of production. Both issues require government intervention to move the market toward scale-efficiency and self-sustainability.

1.4 Today, there is a great opportunity for a second national program to further China's progress

Today's environment provides a great opportunity for another national program. Advancements in stove and fuel technology, a strongly supportive political environment, and increased ability and willingness to pay for cleaner fuels and stoves all lead to a promising environment to drive further improvement in efficiency of solid fuel burning in rural China.

Advancements in stove and fuel technology since the 1980s mean that stoves installed under the NISP are no longer considered as efficient or as clean as they were three decades ago. There has been considerable improvement in the thermal efficiency of biomass stoves since the 1980s, from around 15% thermal efficiency to 30%-40% today. This represents a significant opportunity to be captured by updating existing stoves.

In addition to taking advantage of improved technology, policy makers can also take advantage of the current focus of China's top leadership on environmental and climate issues. A second national program could be highly effective in simultaneously meeting several political goals, including preventing deforestation, green development, addressing climate change, "beautifying" the Chinese countryside, and contributing to the planned carbon market by 2017.

The environmental effects of pollution became a major topic at the Third Plenary Session of the 18th Central Committee of the Communist Party of China, resulting in leaders concluding that the measures needed to be taken are to be "unprecedented in both scale and degree," with the hope of achieving significant results by 2020on the climate change front, the government's most recent Five-Year Plan has set a target of 16% reduction in energy consumption per unit of GDP, 17% reduction in carbon emissions per unit of GDP, and an increase of non-fossil energy to 11.4% of all energy used. On the air quality front, the State Council released the Air Pollution Prevention and Control Action Plan in 2013 setting a target of 10% reduction of inhalable particulate matter in cities against 2012 level. The level of fine particulate matter in Beijing-Tianjin-Hebei Province, the Yangtze River Delta and the Pearl River Delta will be cut by 25%, 20% and 15% respectively and the annual concentration of fine particulate matter in Beijing will be kept at 60μg /m3. It also set a goal of accelerating the transition to new energy and clean energy technology by 2017, such as "coal to gas" and "coal to electricity", in areas that are not covered by power infrastructure, promoting efficient and environmental-friendly stoves and

small boilers. As a result, there is a strong political framework and focus that could be leveraged in favor of a second national program.

1.5 A national program for today's context requires a new approach

While the opportunity is great, today's context is very different from the last national program in the 1980s. The changes in urbanization, wealth, lifestyles and technology all lead to a very diverse picture of demand, notwithstanding China's already diverse regional characteristics. Therefore, the challenge is in implementation. Specifically, there are four key questions:

1) Where are the greatest opportunities for increasing the efficiency of solid fuel burning?

2) What does demand for stoves and fuels look like today across rural China, and what are consumer needs and preferences?

3) What is the state of supply in terms of quality and cost?

4) What should the role of the government be and what policies would be most effective in creating a self-sustaining market for cleaner stoves and fuels?

These questions are difficult to answer, and national Ministry of Agriculture leaders outlined three key challenges they have faced in addressing this issue in recent times:

1) There is a lack of sufficient consumer data, particularly on customer/farmer demand preferences and needs at the regional levels. Huge dispersion and variance across geographies and consumer types have made this difficult. As a result, without clarity on the preferences and needs of rural consumers, it is difficult to gauge consumer demand and set the right policies in place.

2) There are gaps in policy support, particularly in finance and marketing. Since the national rollout was successful, there has been less focus on the industry for solid fuel stoves. As a result, policies have lacked coordination and centralization, leading to inconsistencies in policy support across provinces.

3) Local governments lack monitoring and evaluation capability, particularly the infrastructure, the technical know-how, and the human resources to effectively implement this across the nation. As a result, market monitoring and coordination is lacking, and the overall quality of stoves installed and sold is inconsistent.

This report provides insights on the above four questions, utilizing extensive household and manufacturing surveys to better understand the ground situation in six provinces. Chapters 2 and 3 outline insights from today's demand and supply situation, and Chapter 4 summarizes the key policy recommendations for the next national program.

2. Rural demand for stoves and fuels is better understood through consumer segments

Rural China is diverse and consumer demand is driven by four regional factors: climate, food and cooking habits, fuel availability and wealth. Given regional differences, the mix of stoves and fuels demanded and used by rural households differs across region and season.

Despite this diversity, this report identifies eight consumer segments, which cut across all regions in rural China. These segments group consumers who behave similarly and can be addressed by similar innovations in policies and interventions in markets.

Consumer segments can also be used to identify the biggest opportunities to improve efficiency of solid fuel use. This analysis helps provincial leaders prioritize consumer segments based on their contribution to solid fuel burning, size and relative willingness to pay. The insights generated from this analysis are also useful to national policy makers and practitioners. The chapter finishes with an example of how these insights could be applied in one of the six focus provinces.

2.1 Rural China is diverse and consumer demand is driven by four regional factors

Rural China is highly diverse and regional differences affect demand for stoves and fuels. Regional differences can be categorized into two types of factors: “need” factors (climate and food and cooking habits) and “cost” factors (fuel availability and wealth).

Need factors drive why consumers purchase and use stoves. They define the underlying consumer need that stoves and fuels address. For example, if consumers live an area with severe winter, they will have a need for stoves with heating capability. Similarly, if consumers live in a region that has a tradition of smoking meat, then they will look for stoves that can produce enough smoke to preserve their meat.

Cost factors determine the relative cost of ownership for any given stove/fuel combination, and the relative willingness of consumers to pay. A given stove may be economically more or less attractive based on the availability of its required fuel relative to a given location (fuel availability). In addition, wealthier regions and households will have a higher willingness to pay for convenience and efficiency, and therefore be more willing to switch to cleaner, more improved stoves and fuels.

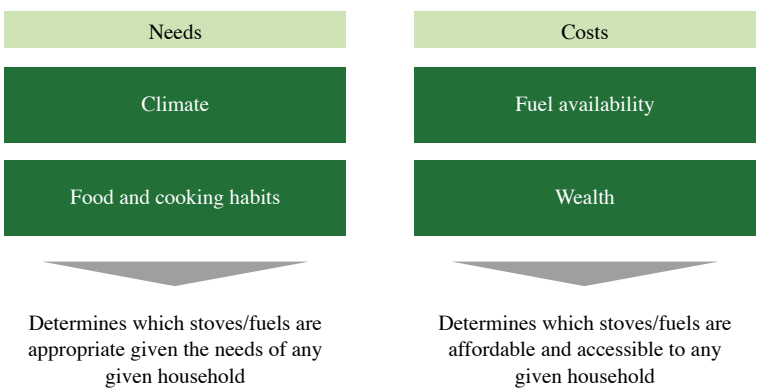


Figure 20 Factors that drive rural consumer behavior

In this section, we go through these factors in more detail as an introduction to the diverse landscape across China. These factors provide the context for understanding the differences in demand for stoves and fuels among regions.

Climate

China has the full breadth of climate differences: extremely cold winters in the north and

across the Tibetan plateau, and an almost tropical or sub-tropical climate in the south. As a result, the need for heating varies considerably across the nation. Unsurprisingly, northern areas have a bias toward stoves and fuels that are better for space-heating and provide multi-functionality (cooking and heating). Coal is heavily used in the northern parts of China (provided it is available and accessible) due to its heat efficiency. In addition, Kang stoves are highly popular to heat beds for winter sleeping.

Climate Diversity in Winter

Average winter temperature in January	Province
⩽ −10℃	Xinjiang, Inner Mongolia, Heilongjiang, Jilin
−10 ~ −5℃	Qinghai, Gansu, Ningxia, Shaanxi, Shanxi, Liaoning
−5 ~ 0℃	Tibet, Beijing, Tianjin, Hebei
0 ~ 5℃	Henan, Hubei, Shandong, Jiangsu, Zhejiang, Anhui, Shanghai
5 ~ 10℃	Sichuan, Yunnan, Chongqing, Guizhou, Hunan, Jiangxi
10℃⩾	Guangxi, Guangdong, Fujian, Hainan

Food and cooking habits

Food and cooking habits also vary across the country, impacting preferences for certain stove and fuel types. Notably, provinces in southern China preserve meat through smoking, and as a result, prefer stoves that produce smoke. Hubei and other provinces have a particular "burned rice" dish, which tastes best when cooked using a traditional built-in stove with wood as the fuel. Provinces in the northeast and south brew stew and soup, and therefore have a preference toward convenient, fast-heating stoves for heating and re-heating soups. In addition to food for humans, there are also cooking habits related to livestock. For example, many

households in rural areas house pigs and the built-in stove is used to cook pig feed, as it has the largest surface capacity.

These built-in stoves are also popular during Chinese New Year, where the custom is for rural people to return to their village to celebrate with family. Food is central to the celebration, and therefore, traditional built-in stoves are often kept due to their large capacity.

Fuel availability

China is rich in natural resources; however, access to these resources is uneven across the nation. Straw and agricultural residue feature strongly across all of China, particularly in the central and northeastern parts of the nation. Firewood is most available in the northern, central and southwestern regions of China, particularly in mountainous regions. Coal reserves are highest in the north pare of China, with the exception of Yunnan and Guizhou, which are provinces with high coal reserves in southern China.

Figures 22 to 24 below show the relative distribution of solid fuels across China.

Straw Distribution

Agricultural residue, 2010 (In million tons)	Province
5 ~ 85	Heilongjiang, Henan, Shandong
31 ~ 50	Inner Mongolia, Jilin, Hebei, Sichuan, Hubei, Anhui, Jiangsu, Hunan
11 ~ 30	Xinjiang, Gansu, Shaanxi, Shanxi, Liaoning, Chongqing, Yunnan, Guizhou, Guangxi, Guangdong, Jiangxi
0 ~ 10	Tibet, Qinghai, Ningxia, Fujian, Zhejiang, Shanghai, Beijing, Tianjin, Hainan

Wood Distribution

Firewood resources, 2005 (In million tons)	Province
8 ~ 10	Heilongjiang, Liaoning, Sichuan
6 ~ 7	Yunnan, Guangxi, Hubei, Hunan, Jiangxi
3 ~ 5	Tibet, Inner Mongolia, Jilin, Shaanxi, Hebei, Henan, Anhui, Zhejiang, Chongqing, Guizhou, Guangdong, Fujian, Hainan
0 ~ 2	Xinjiang, Qinghai, Ningxia, Gansu, Shanxi, Beijing, Tianjin, Shandong, Jiangsu, Shanghai

Coal Distribution

Identified coal resources (In billion tons)	Province
15 ~	Inner Mongolia, Shanxi, Shaanxi
10 ~ 15	Xinjiang, Guizhou, Hanan
5 ~ 10	Gansu, Ningxia, Yunnan, Heilongjiang, Liaoning, Hebei, Shandong, Anhui
0 ~ 5	Tibet, Qinghai, Sichuan, Chongqing, Jilin, Beijing, Tianjin, Jiangsu, Hubei, Shanghai, Hunan, Jiangxi, Zhejiang, Fujian, Guangdong, Guangxi, Hainan

Fuel availability is a powerful explainer of consumer behavior as it drives the relative cost of ownership of any given stove and fuel combination. The ongoing cost of using any stove is dependent on the fuel consumed. As a result, depending on where a consumer is located, fuel prices vary based on overall availability, making certain fuels more or less attractive.

Fuel availability can also vary by season. In harvest season, agricultural residue is plentiful, and consumers may switch to using straw due to high availability.

Wealth

Finally, differences in wealth both at the regional and individual household level have a strong impact on consumer demand. Wealth is a key proxy for a consumer's willingness to pay. Generally speaking, wealthier rural consumers have less preference for solid fuels, and are more likely to switch to modern or improved stoves.

China's economic growth has been impressive, yet unevenly distributed. Wealth and economic growth in China have historically been concentrated in the east. In particular, the east coast of China has the highest average rural incomes, in some cases four times that of provinces in the west.

Rural Income Distribution

Annual net income of ruralhouseholds, 2012 (In RMB)	Province
~ 12 000元	Beijing, Tianjin, Jiangsu, Shanghai, Zhejiang
9 000 ~ 12 000	Liaoning, Shandong, Fujian, Guangdong
6 000 ~ 9 000	Xinjiang, Inner Mongolia, Ningxia, Heilongjiang, Jilin, Hebei, Shanxi, Henan, Sichuan, Chongqing, Hubei, Anhui, Hunan, Jiangxi, Guangxi, Hainan
3 000 ~ 6 000	Tibet, Qinghai, Gansu, Shaanxi, Yunnan, Guizhou,

2.2 Therefore, the mix of stoves and fuels used by rural households changes across regions and seasons

Given this regional diversity, different types of stoves and fuels are used across regions and seasons in rural China. Interestingly, one stove and fuel combination does not meet all needs, and it is not at all uncommon to find 4-5 stoves in any given rural Chinese household (see Figure 26). This practice is called “stove stacking”. In this section, general insights around the practice of stacking are outlined, followed by specific regional and seasonal differences, using the six focus provinces as examples.

Figure 26 One household’s stove ownership in Hubei

The practice of stove and fuel stacking in rural China:

In order to meet their diverse needs, and manage seasonal changes, rural Chinese households practice stove/fuel stacking (owning and operating more than one stove/fuel combination) in order to maximize their utility in cooking and heating.

Stacking is beneficial as different stove/fuel combinations have different functional benefits (some may be better for heating or have a larger cooking capacity), as well as different costs

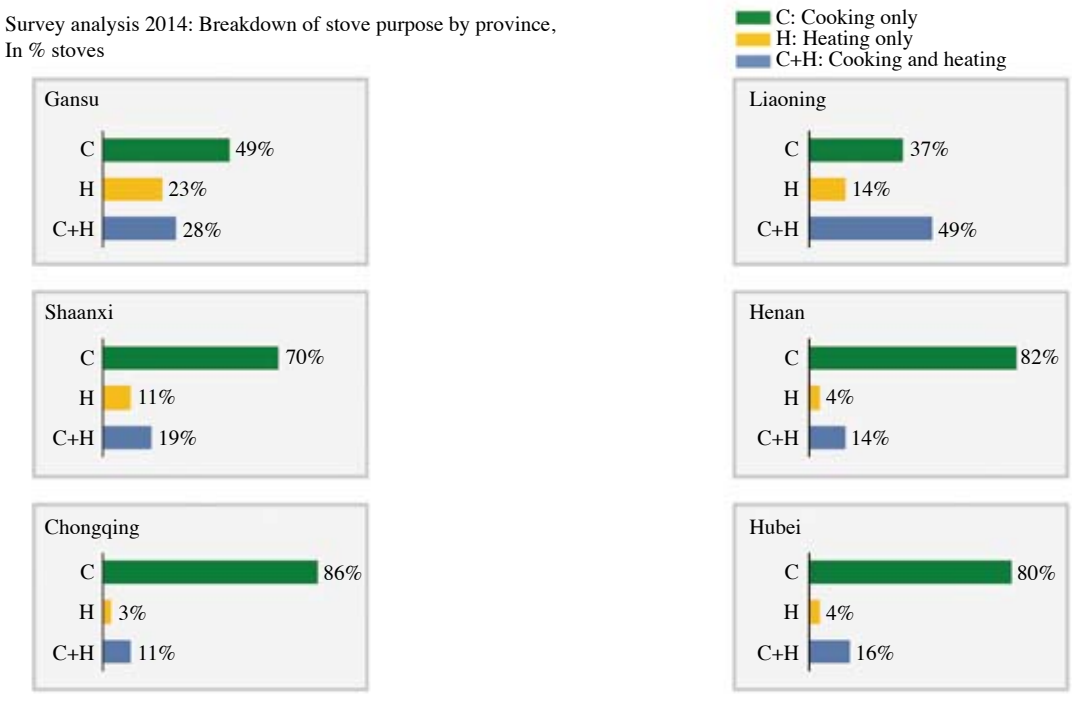


Figure 27 Breakdown of stove purpose by province

of ownership (some stove/fuel combinations are cheaper or more expensive depending on the season or need). For example, given regional and seasonal diversity in climate, rural households stack stoves based on their different utilities for cooking and heating.

In Figure 27, we see that in the provinces we examined, there is a clear division between provinces where stoves are predominantly used for cooking (Henan, Hubei, Chongqing, and Shaanxi), and provinces that have a strong mix of both cooking and heating (Liaoning and Gansu). Unsurprisingly, provinces with a higher share of heating stoves have a stronger tendency to stack stove/fuel combinations to cover both needs (Figure 28).

The need for heating is not the only functional difference driving the practice of stacking. Below are a few reasons why a household may decide to own and operate multiple stoves for different purposes:

• In addition to general daily use, a rural household may also keep a traditional built-in stove for the extra kitchen capacity needed during the annual Spring Festival, when family members return home; or because the extra capacity is great for cooking pig feed[①]; or because the heat and flavor that it produces is best for cooking certain local dishes such as a “burned rice” dish in Hubei.

① Many households also have a separate built-in stove for cooking animal feed.

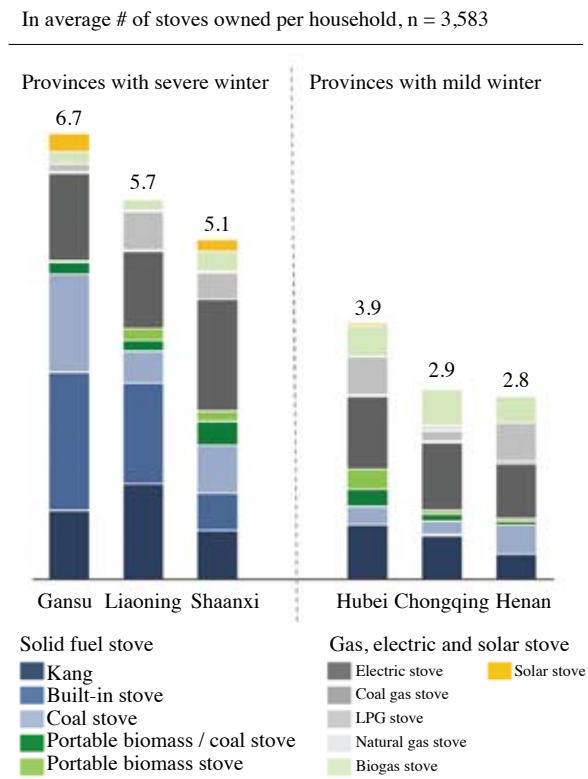


Figure 28 Stove stacking per household by province

• Portable biomass or biomass/coal stoves are used for everyday cooking needs, and also placed in rooms for space heating during winter.

• Ground stoves are used for gathering around the fire for warmth in winter time; they are also placed strategically next to hanging meat in order to smoke it during particular seasons in the southern regions of China.

• Electric stoves are seen as an alternative to traditional stoves for heating water, cooking soups, quick frying, and re-heating food.

• Kangs (bed stoves) are used mainly for space heating and, as a result, are mostly utilized during winter. Households often have more than one Kang.

• Solar stoves are mostly used for heating water / soups.

• Gas stoves (biogas, natural gas or LPG) are highly convenient and used for everyday cooking needs. While convenient, these options are expensive relative to biomass, particularly for heating needs. As a result, these stoves are often stacked with other stoves.

Stacking behaviors differ by province and the number of stoves "stacked" is largely driven by differences in the relative need for cooking and heating. Figure 28 shows the average number of stoves owned across the six focus provinces. The data shows that provinces with a more severe winter have more stoves per household, as stoves are needed for both heating and

cooking. Liaoning, Shaanxi and Gansu have stronger winters, so the average number of stoves per household ranges from 5.1 to 6.8. Conversely, Henan, Hubei and Chongqing have average/mild winters, so the average number of stoves per household is between 2.8 to 3.9.

Stacking and using multiple fuels is also common practice, given the value of balancing economic costs and the functional benefits of using different fuels in different seasons. For example, in a remote area, a household that has access to agricultural residue will use straw and other crop residue after the harvest season. However, straw and other crop residues are not as heat-efficient as coal. Therefore, in winter months this household switches and purchases coal, and will switch back to straw/crop residue after the winter.

Fuel stacking overall shows less regional variation than stove stacking, with the range being 2.6 to 3.8 fuel types per household, as seen in Figure 29.

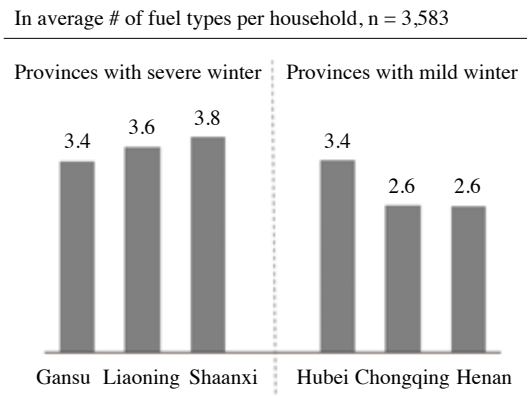


Figure 29 Fuel stacking per household by province

Specific regional and seasonal differences for stove and fuel ownership and usage:

The specific mix of stoves and fuels preferred by rural consumers is significantly different by region and by season. The analysis below shows the preferences of stove/fuel combinations using two metrics: “penetration”, referring to the total percentage of households that own this stove/fuel combination; and “hours of usage”, referring to the total percentage of stove hours taken up by this stove/fuel combination.

‘Penetration’ is useful when thinking about the popularity of a given stove/fuel combination. ‘Hours of usage’ is useful when thinking about the contribution of specific stove/fuel combinations to overall emissions. However, when analyzing consumer behavior, interpretation of ‘hours of usage’ must take into account the efficiency of the stove/fuel combination. Just because a stove/fuel combination may have low numbers does not mean it is not used regularly. For example, electric cookers show a low percentage of hours of usage, however, the reality is that these are used quite regularly, but only need a short period of time to fulfill their cooking function.

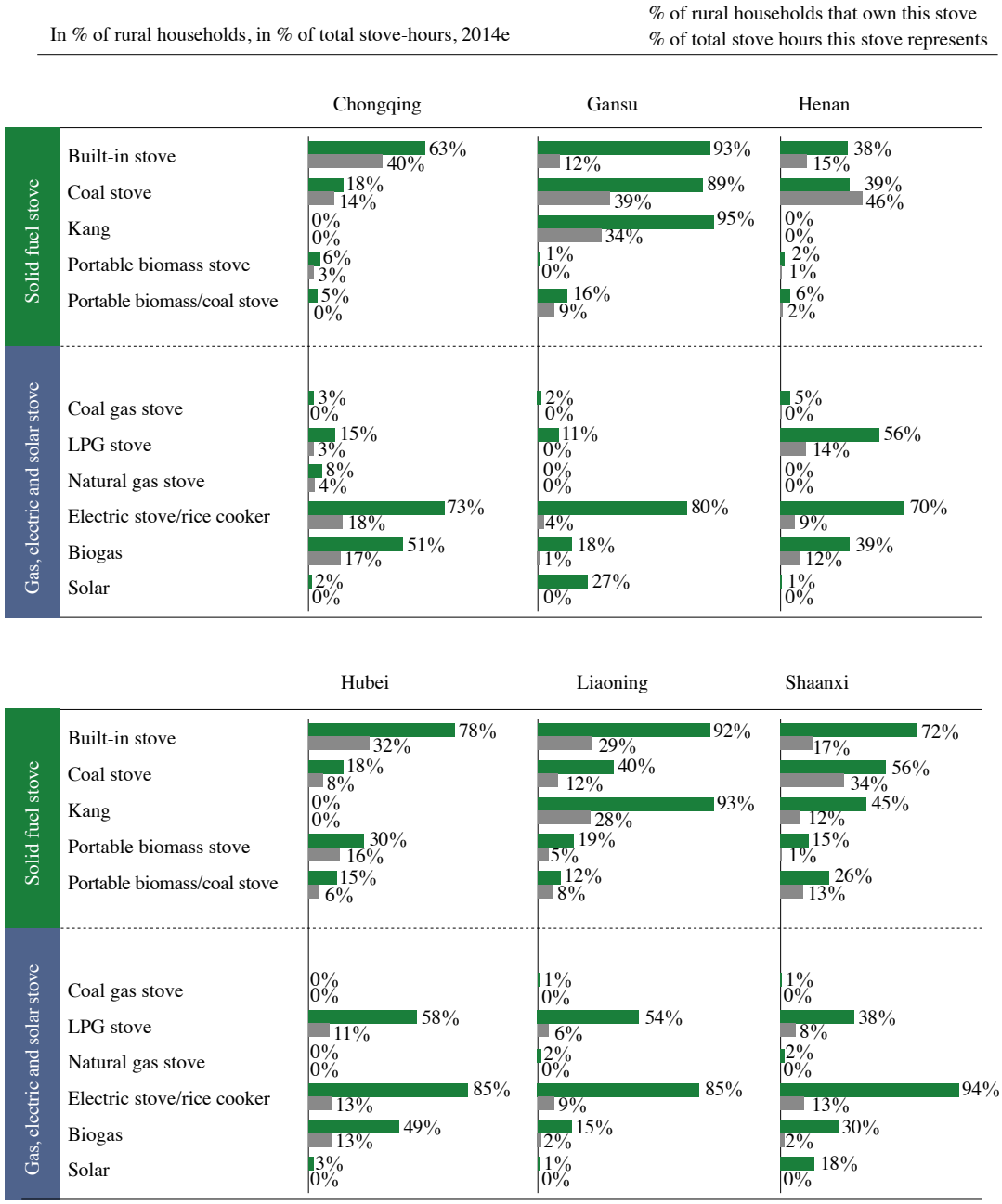


Figure 30 Stove ownership and hours of usage across six provinces

To see the differences in preference more clearly across regions and seasons, Figures 31 and 32 below isolate the top 3 stoves and fuels and show how they differ by province and season. They show clear differences in usage between seasons, as well as how the specific mix of stoves and fuels changes, depending on the fuel availability of a given province.

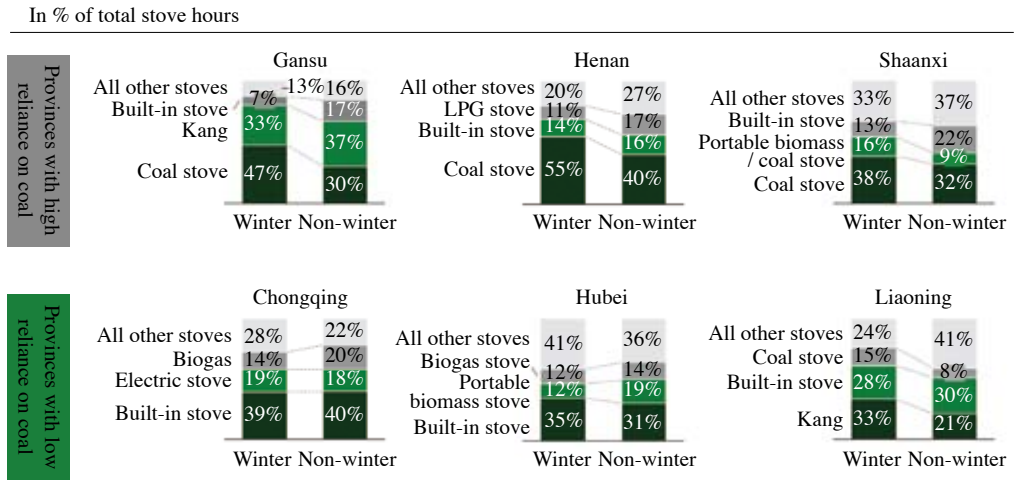


Figure 31 Top three stoves by province (winter/non-winter)

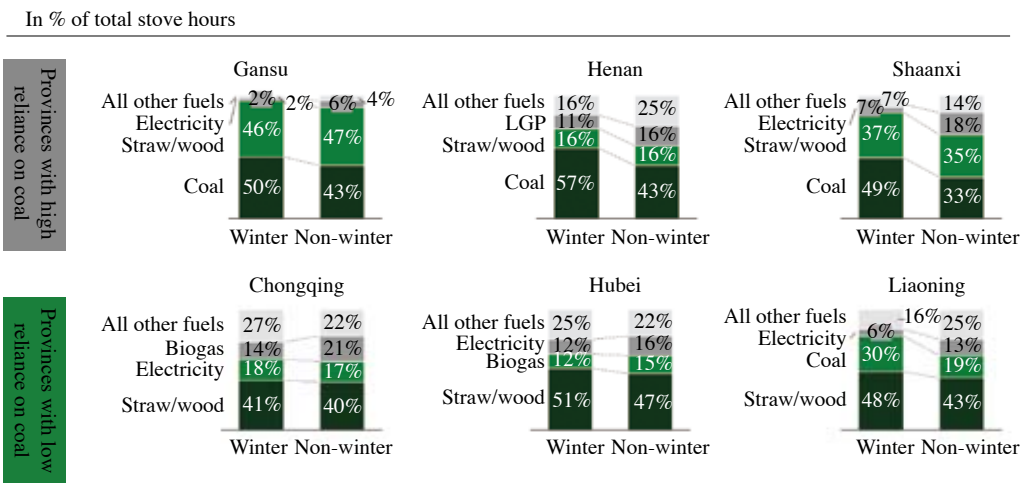


Figure 32 Top three fuels by province (Winter/Non-winter)

To further emphasize the importance of fuel availability, consider the following two examples, which contrast two provinces of similar climate needs, but with different fuel landscapes:

Example 1: Liaoning vs. Gansu (a comparison of provinces with a severe winter)

While provinces may have similar needs for cooking and heating, the usage mix of stoves and fuels by province varies significantly by location and season. In Liaoning, for example, where winter temperatures reach minus 10 degrees Celsius, Kang stoves are the most-used stove

(representing 33% of all stove hours for Liaoning). The second most-used stove is the built-in stove, with 28% of all stove hours, and the third is the coal stove at 15%. In the non-winter months, a different picture emerges. Kangs are less preferred in non-winter, at 21% of all stove hours.

On the other hand, Gansu, a province with a similarly harsh winter (temperatures of minus 15 degrees Celsius), has a significantly different top three stove and fuel usage profile. Similarly to Liaoning, Gansu has a strong Kang presence at 33% of stove hours during the winter. However, unlike Liaoning, Gansu's dominant stove is the coal stove, representing 47% of all stove hours in Gansu's winter. Built-in stoves play a smaller role at 7% of total stove hours. The non-winter picture for Gansu is similarly interesting. Coal stoves are still used for a large portion of time at 30%, but Kang stoves are the most preferred in the non-winter months at 37% of stove hours, and built-in stove use goes up to 17%.

Example 2: Henan vs. Congqing (a comparison of provinces without severe winters)

Comparing two provinces without a severe winter reveals a similar story of diversity. In Chongqing, traditional built-in stoves that use biomass (straw and wood) dominate both in winter and non-winter with 39% and 40% of all stove hours respectively. Electric stoves are the second most preferred at 19% and 18% stove hours in winter and non-winter respectively. Biogas stoves are the third most preferred at 14% and 20% stove hours in winter and non-winter months respectively.

In contrast, Henan has a very different stove and fuel usage profile. Coal stoves dominate both in winter and non-winter at 55% and 40% of all stove hours respectively. Built-in stoves are second at 14% and 16% respectively in winter and non-winter months, and LPG stoves come third at 11% and 17% respectively.

In the two contrasting examples above (Liaoning vs. Gansu and Chongqing vs. Henan), it is clear that needs and preferences for fuels and stoves differ by region and by season. These examples also highlight the importance of fuel availability. Whether a province has high or low reliance on coal affects stove and fuel choices substantially. Both Henan and Gansu have strong coal reserves. The usage profile shows strong coal use because coal is accessible and affordable. Liaoning and Chongqing, on the other hand, have lower coal reserves, and a high ability to substitute wood for coal (?), and therefore are much less reliant on coal.

2.3 Eight consumer segments were identified across regions

Consumer segmentation analysis uses the most important factors driving consumer demand to group those who behave similarly. Segmenting consumers into meaningful groups can be beneficial to policy makers and manufacturers in developing more effective and efficient strategies. Segmentation provides a middle ground between targeting an entire province with the

same strategy (efficient but not necessarily effective) and mass-customization to the individual (effective but not at all efficient). It helps policy makers and businesses prioritize consumer groups based on what behaviors they are trying to influence or change, and also provide the opportunity for cross-provincial learning or scaling of successful strategies to similar groups of consumers across China.

In order to develop consumer segments, over 30 variables were analyzed from the household survey in order to identify which variables most meaningfully explained differences in rural consumer behavior. The goal was to create segments that were 1) meaningful (in that the data actually explains differences in behavior) and 2) actionable (in that the segments can be easily understood and identifiable for policy/marketing considerations).

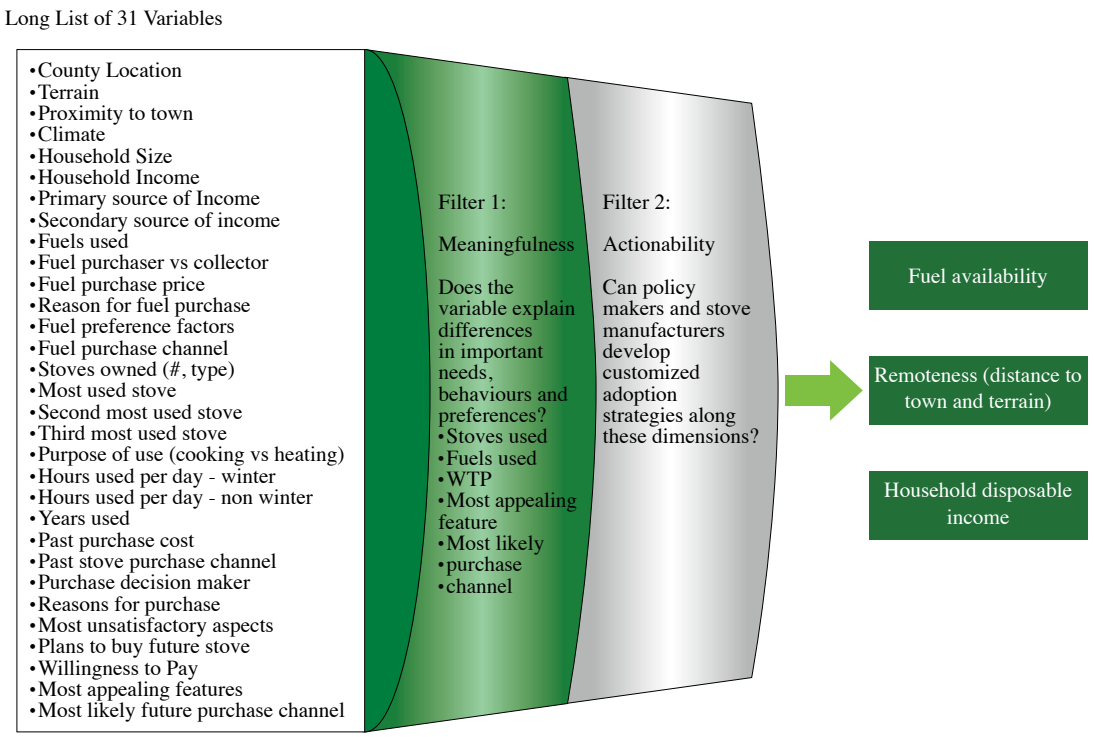


Figure 33 Filtering segmentation variables through meaningfulness and actionability

Through the analysis, the "cost factors" described above in 2.1 (fuel availability and wealth[①]) were the most important variables in explaining differences in rural consumer behavior. In addition, adding "remoteness" as an additional layer of geographic nuancing to fuel

① In the data analysis, wealth was represented by household income. Low income represented households with less than 20,000 RMB net income per year; medium income represented households with between 20,000 and 40,000 RMB net income per year; and high income represented households with over 40,000 RMB net income per year.

availability, was highly helpful in generating meaningful differences across consumer segments. Whereas "fuel availability" refers to the level of coal reserves① in a given province, "remoteness" brings in a household's specific geographic location within that province, which affects the extent to which they experience fuel availability on a daily basis.

"Remoteness," therefore, is a blended variable composing the distance to town and the terrain of a particular household. It is a proxy for understanding how physically accessible fuels are for a given household. The more remote a household, the more time and/or delivery costs it incurs in addition to the actual monetary cost of the fuel. For example, remote households are more likely to collect biomass, whereas households closer to town are more likely to purchase commercial fuels. As a result, "remoteness" provides an additional layer to "fuel availability"②.

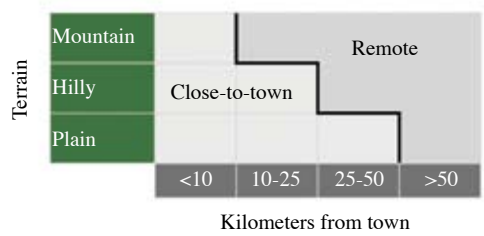


Figure 34 How remoteness is calculated

Segments were created using these variables in order to develop another perspective of rural demand in China. The result of the analysis was eight consumer segments, which can be seen in Figure 35 on the following page.

Segments 1-4 above are found in provinces with high coal reserves, and therefore a higher reliance on coal. Segments 5-8 are found in provinces with lower coal reserves, or with a higher reliance on wood as a substitute for coal. A brief description of the 8 segments is as follows.

Higher reliance on coal segments:

1) Close-to-town, low income, coal users (30%): This is the largest segment, representing 30% of the rural population. This segment is close to town and is easy to reach. They have low to medium income (<40,000 RMB per year). They typically own electric stoves, built-in stoves and

① Our analysis tested multiple variables for fuel availability – the most powerful explainer of consumer differences was the level of coal reserves in each province.

② Importantly, all of the key variables used in the segmentation analysis are academically verified as important drivers of fuel and stove behavior. L Jiang and B O'Neill in "The energy transition in rural China" 2004 confirm fuel availability/accessibility, geographical condition (terrain, location), and income all as important independent variables in their regression models.

coal stoves. Their most used stove/fuel combinations are coal stoves, kangs (straw/wood) and built-in stoves (straw/wood).

2) Close-to-town, high income, coal users (7%): This segment represents the easy-to-reach, wealthy consumers living in a coal-rich province. Their income is high at over 40,000 RMB annually. They typically own electric stoves, built-in stoves and coal stoves. Their most used stove/fuel combinations are coal stoves, LPG stoves (LPG) and electric stoves.

3) Remote, low income, coal users (10%): This segment is hard to reach, either because they live in hilly or mountainous areas, or because they live far from town (or both). Their average income is low to medium (<40,000 RMB per year). They typically own built-in stoves, electric stoves and Kangs. Their most used stove/fuel combinations are coal stoves, Kangs (straw/wood) and built-in stoves (straw/wood). While their most used combinations are the same as segment 1, this segment uses considerably more biomass, as coal is less accessible in remote areas.

4) Remote, high income, coal users (5%): This segment lives in remote areas that are difficult to access. They have high annual incomes (>40,000 RMB). They typically own electric stoves, biogas stoves and coal stoves. Their most used stove/fuel combinations are coal stoves (coal), Kangs (straw/wood), and improved biomass/coal stove (mostly straw/wood). Similarly to segment 2, these consumers spend money on better stoves, but instead of LPG, these consumers prefer improved biomass stoves, Kang or coal stoves due to their remote setting.

Lower reliance on coal segments:

5) Close-to-town, low income (3%): This is the smallest segment at 3%. This segment is close to town and easy to reach. Their income is low at less than 20,000 RMB per year. They typically own built-in stoves, electric stoves and Kangs. Their most used stove/fuel combinations are built-in stoves (straw/wood), coal stoves and Kangs (straw/wood).

6) Close-to-town, higher income (9%): This segment represents the easy-to-reach, wealthy consumers living in a low-coal province. Their income is medium to high at more than 20,000 RMB per year. They typically own electric stoves, built-in stoves and LPG stoves. Their most used stove/fuel combinations are built-in stoves (straw/wood), Kangs (straw/wood) and electric stoves.

7) Remote, low income (11%): This segment lives in remote areas and is difficult to reach. Their average income is low (<20,000 RMB per year). They typically own electric stoves, built-in stoves and biogas stoves. Their most used stove/fuel combinations are built-in stoves (straw/wood), electric stoves and biogas stoves.

8) Remote, higher income (25%): This segment lives in remote areas and is difficult to reach. Their income is medium to high at more than 20,000 RMB per year. They typically own electric stoves, built-in stoves and LPG stoves. Their most used stove/fuel combinations are built-in stoves (straw/wood), electric stoves and coal stoves.

The relative size and detailed descriptions of each segment can be found in the appendix.

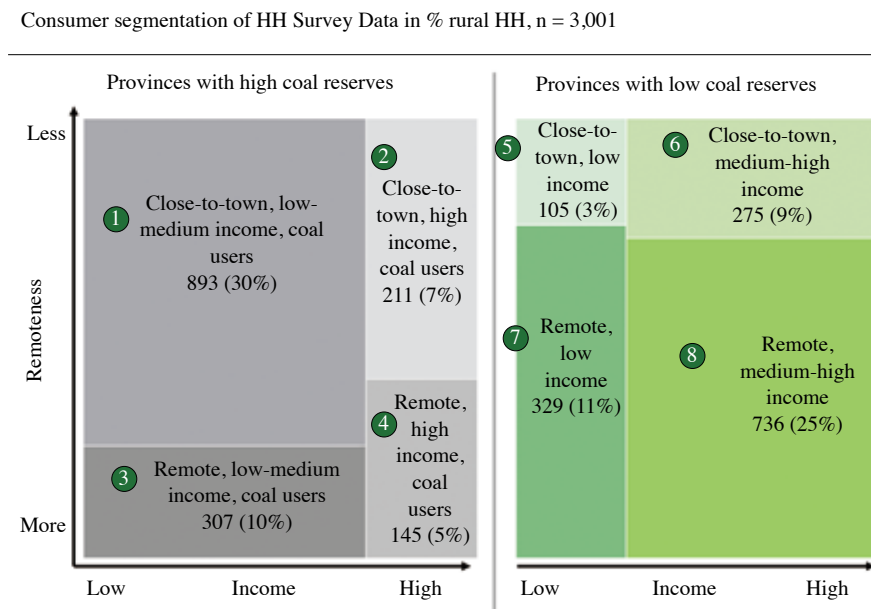


Figure 35 The eight rural consumer segments across China

The analysis emphasizes that the most powerful explainer of behavior is fuel availability. Fuel availability determines what is most affordable and accessible. As seen in Figure 35, in a province with a high reserve and reliance on coal, the most-used stove/fuel combination will be coal stoves with coal, regardless of any other segment differences. This is because coal is attractive and highly affordable for this segment.

Similarly, in a province with lower coal reserves and less reliance on coal, the most-used stove/fuel combination is traditional built-in stoves with biomass, regardless of any other segment differences. This is because biomass is free, and alternative commercial energies are not as affordable.

The second and third most important variables to explain behavior are household income[①] and level of remoteness. These variables were therefore used as frames to capture behavioral differences once fuel availability had been taken into account. As explained earlier, a household's income determines the affordability of different stoves and fuels.

There is a clear difference in the preferences of higher-income households for modern fuels such as LPG and natural gas, compared with poorer households, which tend to gravitate towards coal and biomass.

① The extent to which income influenced behavior was different for provinces with high coal reserves vs. low coal reserves. In the analysis for high-coal provinces, a stronger shift in behavior between medium- and high-income categories was found, and therefore these segments are grouped in two groups: low-medium and high. Conversely, in the analysis for low-coal provinces, a stronger shift in behavior was evident between low- and medium-income categories. Therefore, for these provinces, there are two groups: low and medium-high.

Figure 36 shows the impact of different incomes and levels of remoteness on the preferences for each segment's second- and third-most-used stove. Wealthier households tend to use more electricity and gas, and more remote households tend to rely more on biomass rather than commercial fuels.

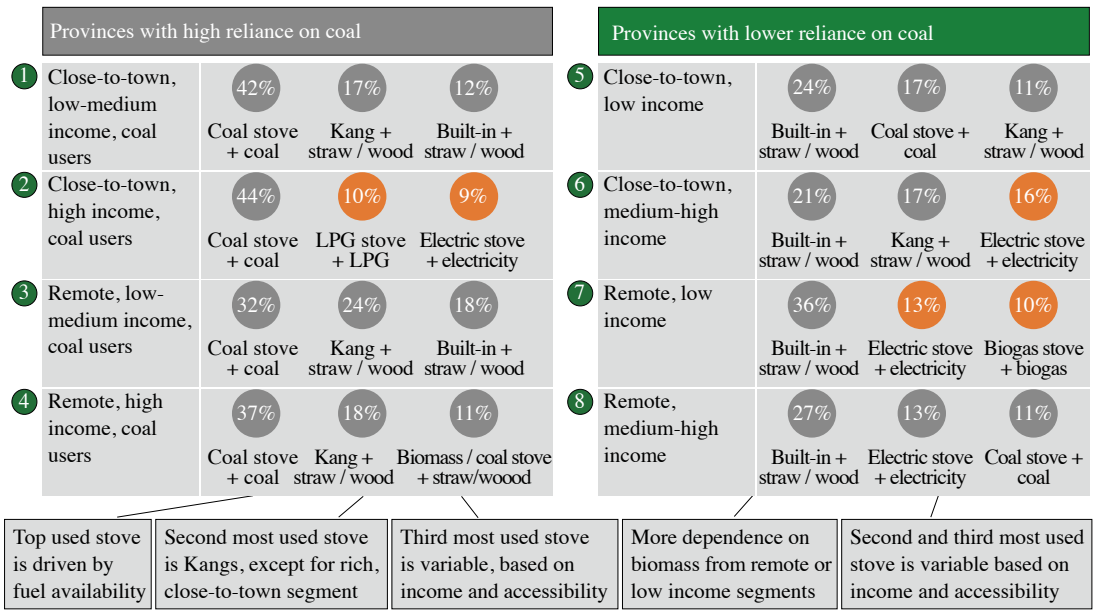


Figure 36 Preferences for stove and fuel usage by segment

2.4 Consumer segments can be used to identify the biggest opportunities to reduce solid fuel use

In order to reduce solid fuel burning, policy makers need to understand which groups of consumers contribute the most to it, and which groups of consumers are most cost-effective to target. Cost-effectiveness is a function of a segment's ability to pay as measured by income, and the relative impact, given the segment's size.

For example, when deciding on a subsidy program, it is helpful to consider whether the segment being targeted has a high use of solid fuels, whether the segment has a relatively high population, in addition to their ability to pay, to see if financing can be shared by public and private sources.

Figure 37 shows the relative value of consumer segments against these three considerations. The size of the bubble represents the overall size of the segment at a national level. Segments were sized using national statistic data and extrapolating survey data.

This analysis reveals the following insights at a national level:

• All segments still rely on solid fuels considerably (they are all above the 50% mark);

• In particular, provinces with high reliance on coal segments tend to have a higher proportion of solid fuel hours than lower coal provinces, representing a greater opportunity to reduce solid fuel usage;

• Different types of policy programs should be utilized for different consumer segments given varying abilities to pay and income levels;

• The largest segments in high-coal-reliance provinces are close to town, whereas the largest segments in lower-coal-reliance provinces are remote.

The implications of the above insights are significant. Figure 37 can help policy makers decide which segments are most valuable to target, given their size and existing use of solid fuels. It also highlights the fact that different strategies are needed to reach different segments, based on their fuel availability, income level and remoteness. The following section provides an example of how provincial leaders can use this analysis to be better informed on policy decision-making.

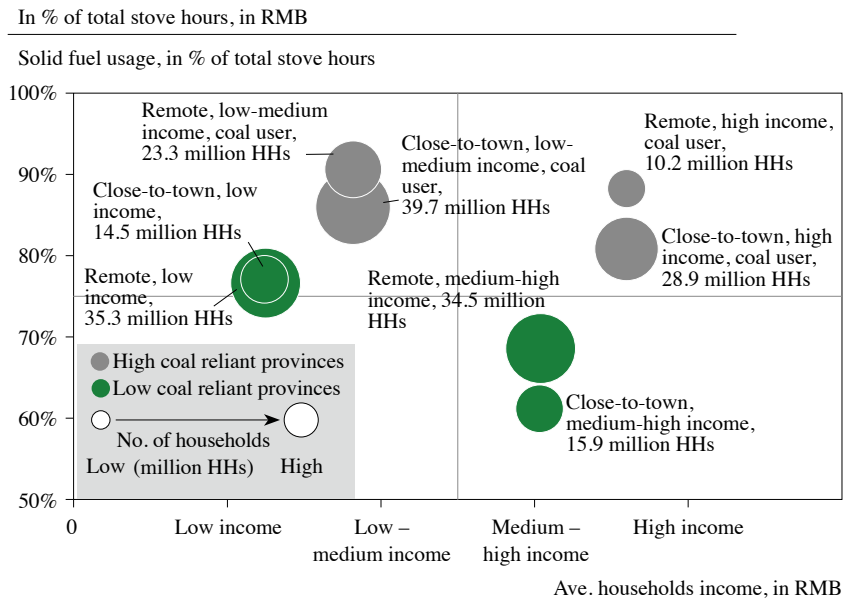


Figure 37 Relative value of consumer segments in reducing solid fuel burning

2.5 Examples of how the analysis provides a toolkit for provincial policy setting

This section outlines an example of how the analysis presented in this chapter may be used to inform policy at the provincial level.

In essence, this means applying tools presented here to answer three questions in step-by-

step fashion:

1) Which areas and activities contribute the most to solid fuel burning?

2) Which consumer segments are contributing the most to solid fuel burning?

3) How should policy makers and practitioners target behavior change for each priority consumer segment?

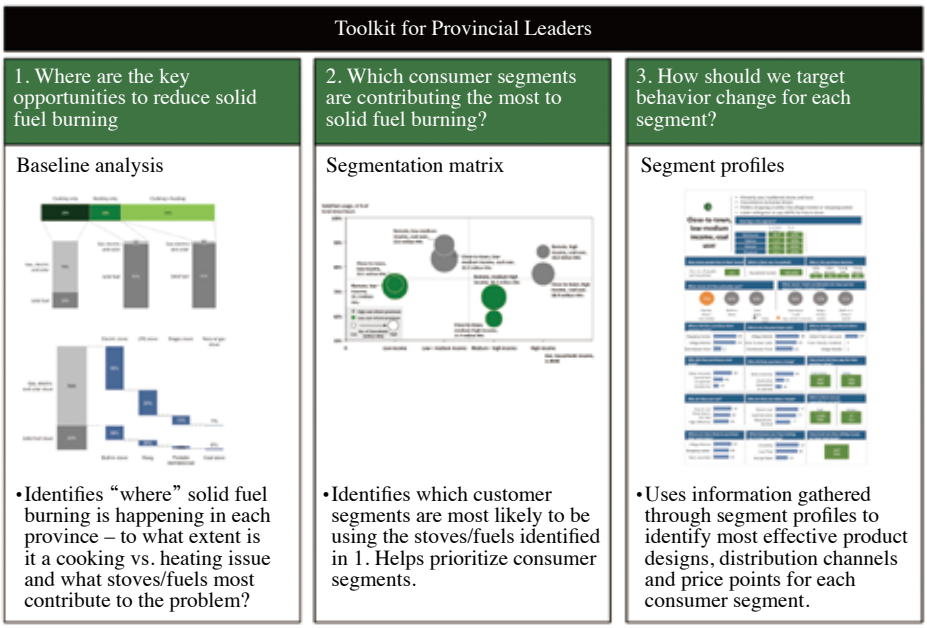


Figure 38 Toolkit for Provincial leaders

Using the toolkit to inform policy in Liaoning:

In Liaoning, 28% of the total stove hours are for cooking only, 18% for heating only, and 56% for cooking and heating together (Figure 39).

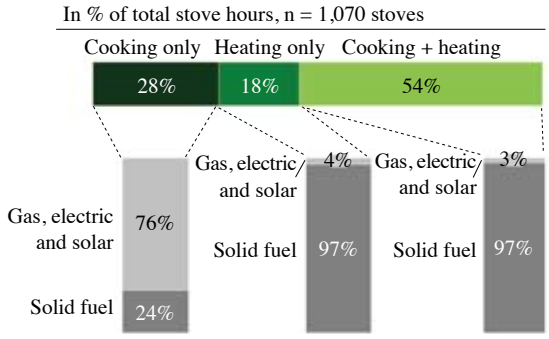


Figure 39 Baseline analysis for Liaoning

Interestingly, the problem of solid fuel burning in Liaoning is not in cooking but in heating. Energy for cooking in Liaoning is already mostly electricity and gas at 76% (Electric stoves at 55%, LPG stoves at 33%, biogas at 12% and natural gas at 1% - Figure 40). Solid fuels represent only 24% of total cooking hours, as compared with 97% for heating hours. Therefore, the biggest opportunity to reduce solid fuel burning in Liaoning is in addressing the issue of space heating.

The following three figures show breakdowns of current stove hours for solid fuels used for cooking and space heating stoves (both for dual-function stoves and for heating-only stoves). The analysis shows that there are four types of stove/fuel combinations being used for space heating in Liaoning: Kang stoves with biomass, built-in stoves with biomass, portable biomass/coal stoves with biomass and coal, and coal stoves.

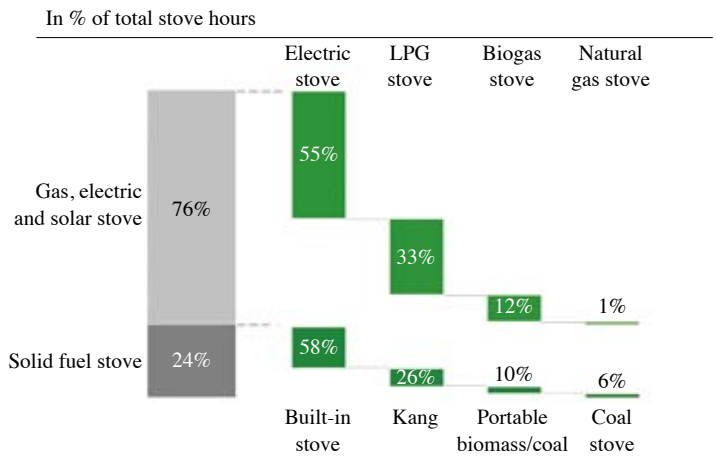


Figure 40 Breakdown of stove type for cooking-only stoves in Liaoning

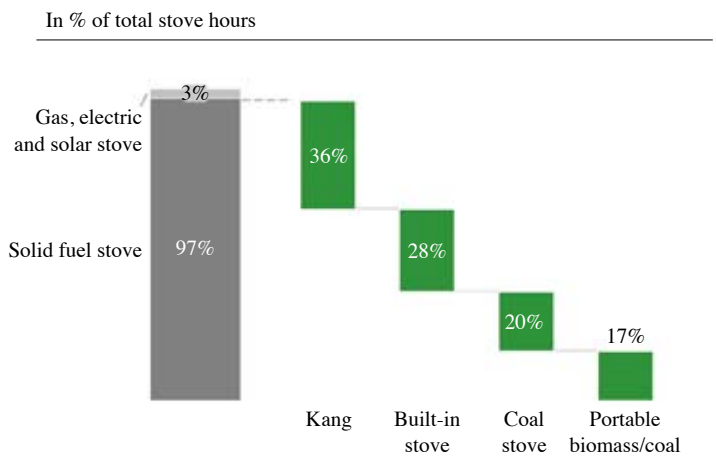


Figure 41 Breakdown of stove type for heating only stoves in Liaoning

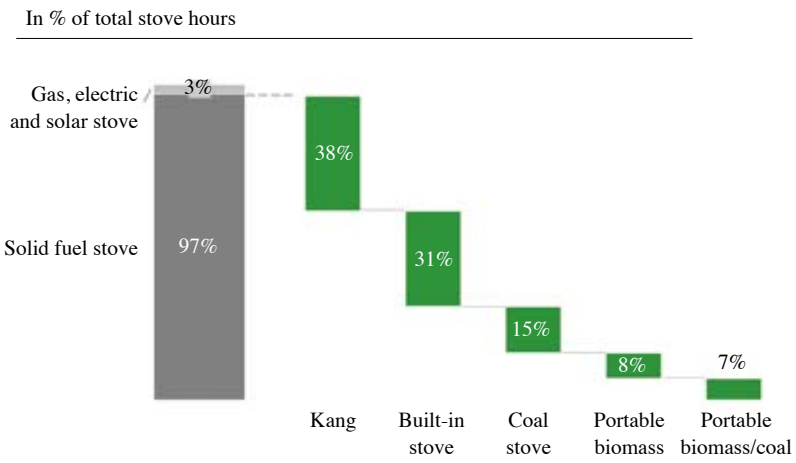


Figure 42 Breakdown of stove type for cooking and heating stoves in Liaoning

There are two possible options to improve the solid fuel situation: 1) improve the efficiency of the stoves used; 2) improve the fuel being used. In terms of improving stoves, how could more efficient and higher-quality Kangs, built-in stoves, coal stoves and portable biomass/coal stoves be more accessible and affordable? In terms of improving fuels, how could the use of biomass pellets (a cleaner, renewable source of biomass) be scaled?

The analysis on consumer segments provides insight on how provincial leaders could prioritize these options. The analysis helps us understand "who" is contributing the most to solid fuel burning and how one might be able to target behavior change in specific types of consumers.

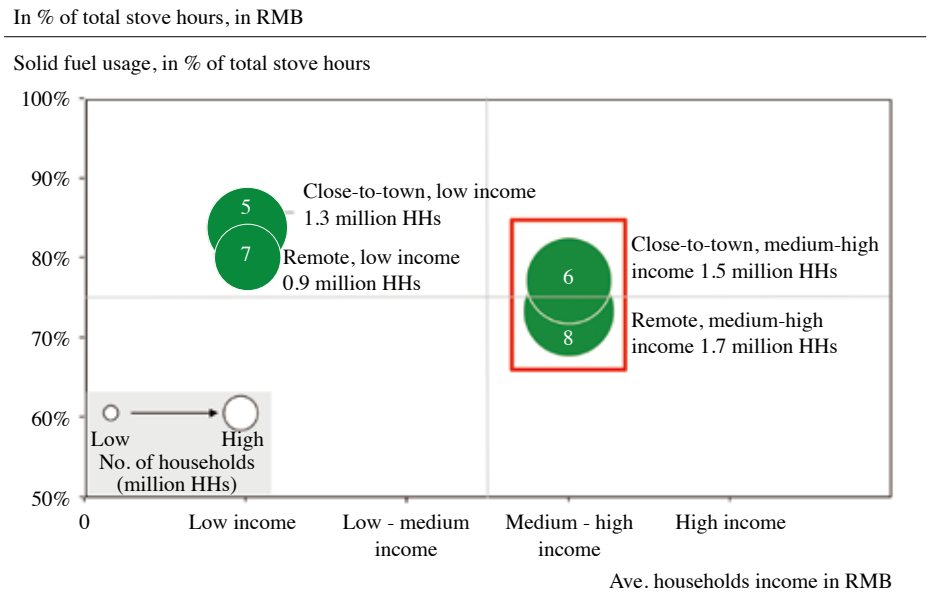


Figure 43 Segment Prioritization matrix for Liaoning

The analysis shows that the low-income segments have the largest proportion of solid fuel usage – both close to town and remote. However, the medium- to high-income segments (both close to town and remote) are also very high contributors, and they have a higher willingness to pay and a larger relative population.

Whilst all segments have high contribution to solid fuel, the government could decide to prioritize segments 6 and 8 (close to town, medium-high income and remote, medium-high income) for three reasons: 1) they have a larger relative population; 2) they have a higher willingness to pay; and 3) they still have relatively high use of solid fuels for space-heating issues.

In considering marketing strategies for targeting these segments, consumer segmentation profiles shown in figures 44-52 below may be helpful. Three areas are of most interest: 1) the segment's current usage pattern; 2) the segment's willingness to pay (proxies are their income and past purchase prices); and 3) their preferred distribution channels.

Therefore, using all this information, initial ideas for a locally tailored policy in Liaoning could look like:

• Focus on developing policy to address the reduction of solid fuel for space-heating (given the baseline analysis above);

• Develop and scale biomass pellet supply and corresponding availability of pellet-specific stoves/Kangs for space-heating targeting consumer segments 6 and 8;

• Develop two consumer campaigns – one targeting village campaigns for segment 8 and one in the towns for segment 6.

These are first suggestions only and are not intended to be limiting, but only to illustrate a logical process for prioritization. Similar analyses for other provinces can be found in the Appendix for reference purposes.

2.6 Examples of how analysis provides insights into marketing strategy for manufacturers

In addition to being relevant for policy makers, the analysis also has implications for the marketing decisions of manufacturers. These decisions include product choices, price points, placement channels and promotional messages. Figure 44 below summarizes the key decisions, showing which questions in the segmentation profiles are relevant, and highlighting key insights drawn from across all the profiles.

While there are unique differences in each segment, there are also general insights for the rural Chinese consumer market. These include:

• New product designs need to primarily focus on the consumer's pragmatic need to cook and heat everyday. The most popular stove/fuel combinations are the most basic in terms of

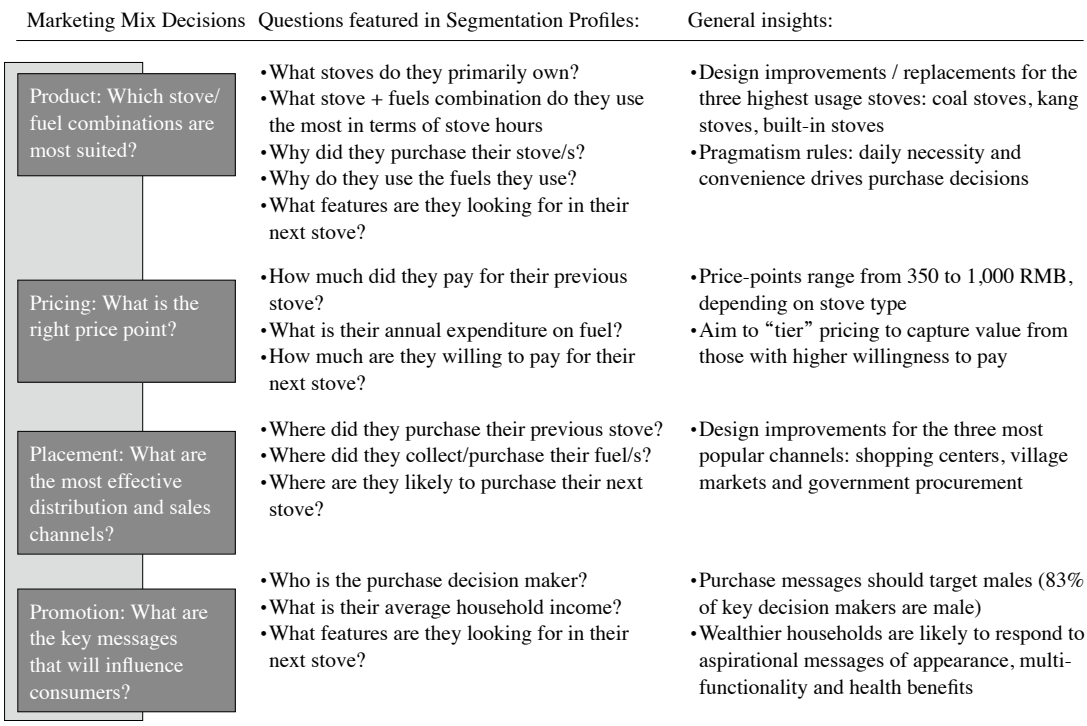


Figure 44 Segmentation profile insights inform marketing mix

technology and are simply the most convenient or accessible for daily use: coal stoves, Kang stoves and built-in stoves.

• There is room for price customization in the Chinese consumer market with willingness to pay and past purchase data ranging significantly. This suggests stoves are not simply commodity products, but that customers will pay more for more valuable products.

• Reaching consumers is different based on remoteness. Remote consumers rely on village markets whereas consumers closer to town have access to shopping centers.

• Males dominate purchase decision-making (83% of decision makers are male), despite women being the key user of stoves.

Detailed profiles for each consumer segment answering the questions highlighted in Figure 44 can be found on the following pages.

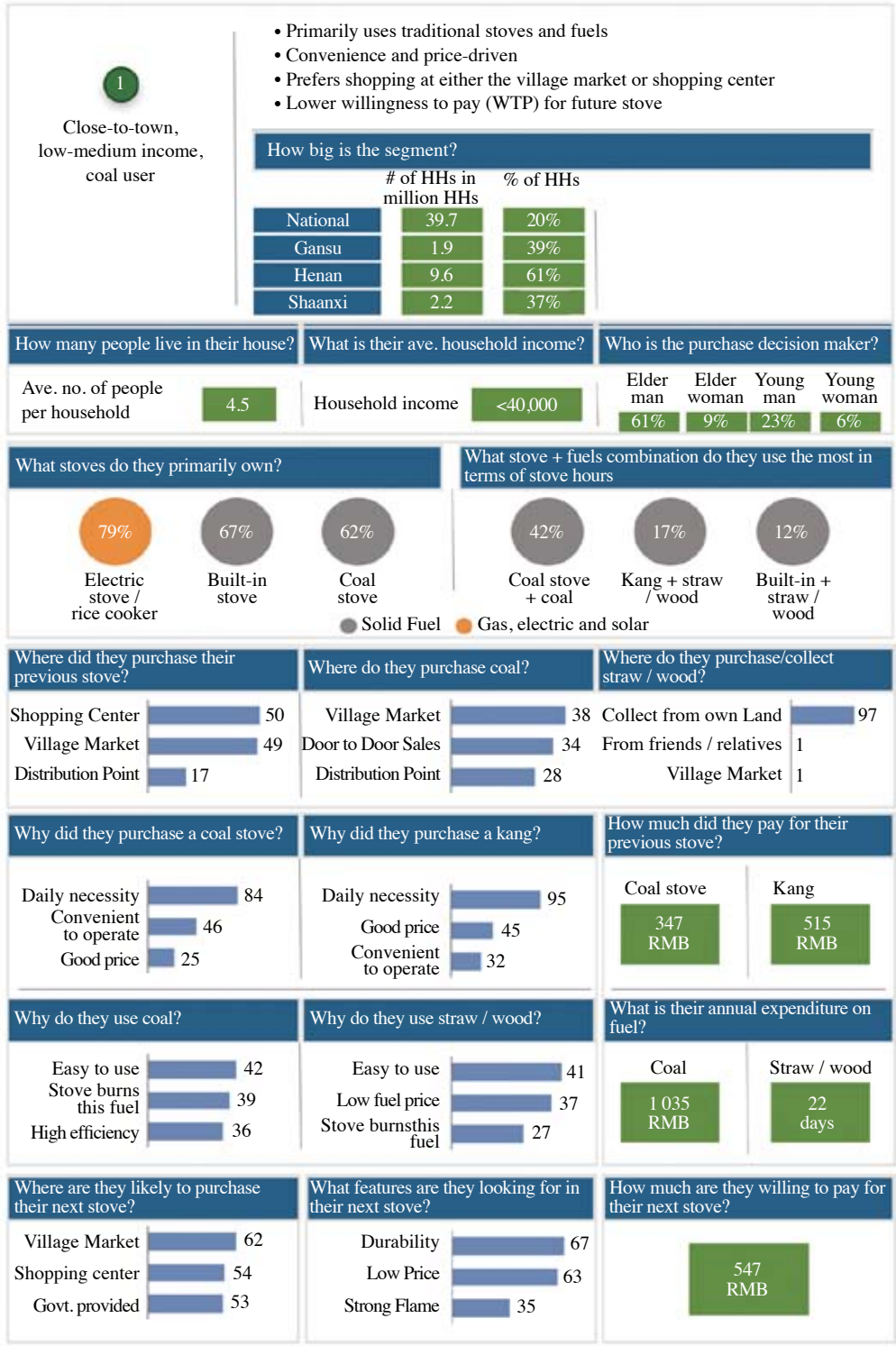


Figure 45 Close-to-town, low-medium income coal users profile

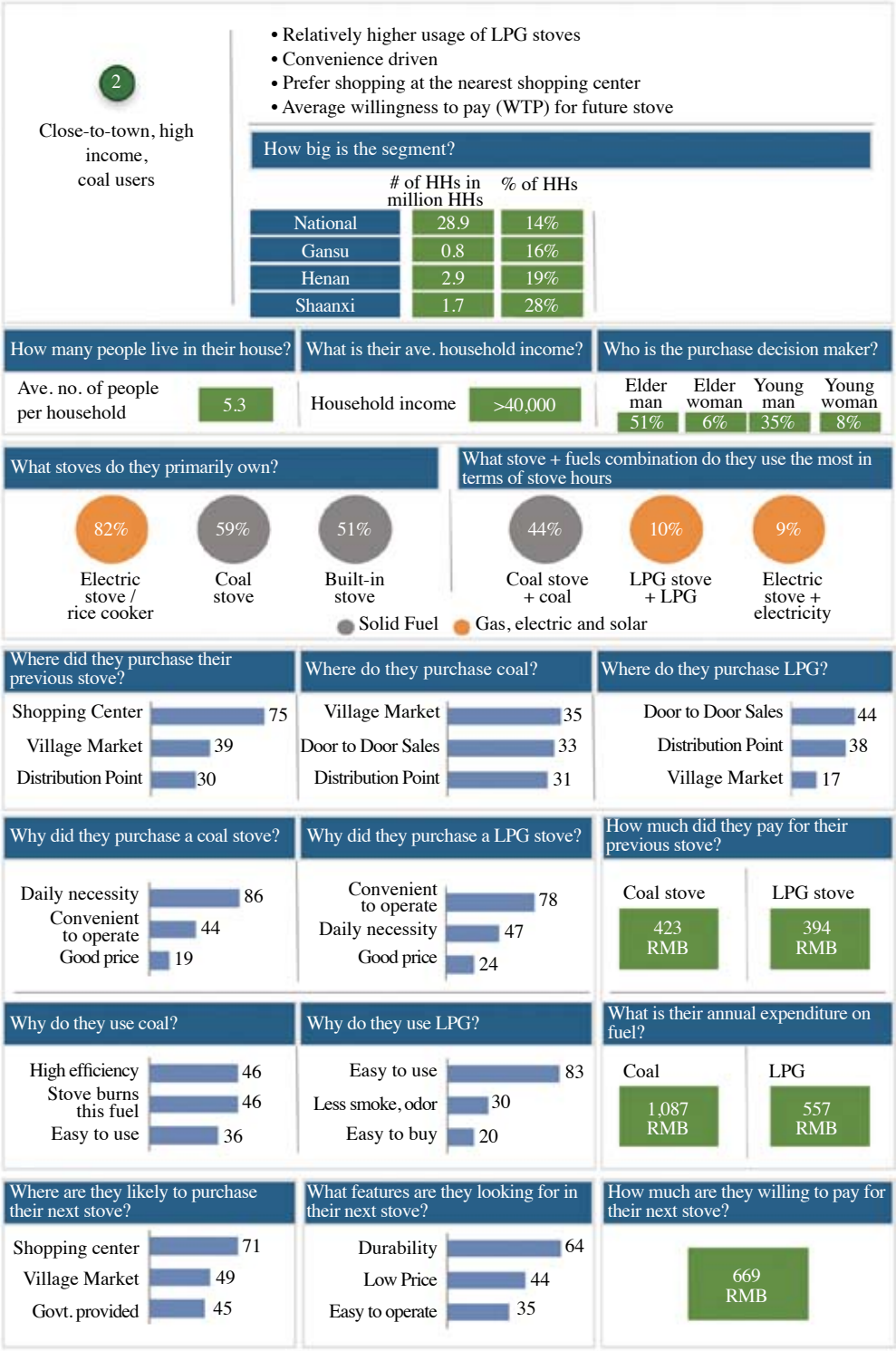


Figure 46 Close-to-town, high-income coal users profile

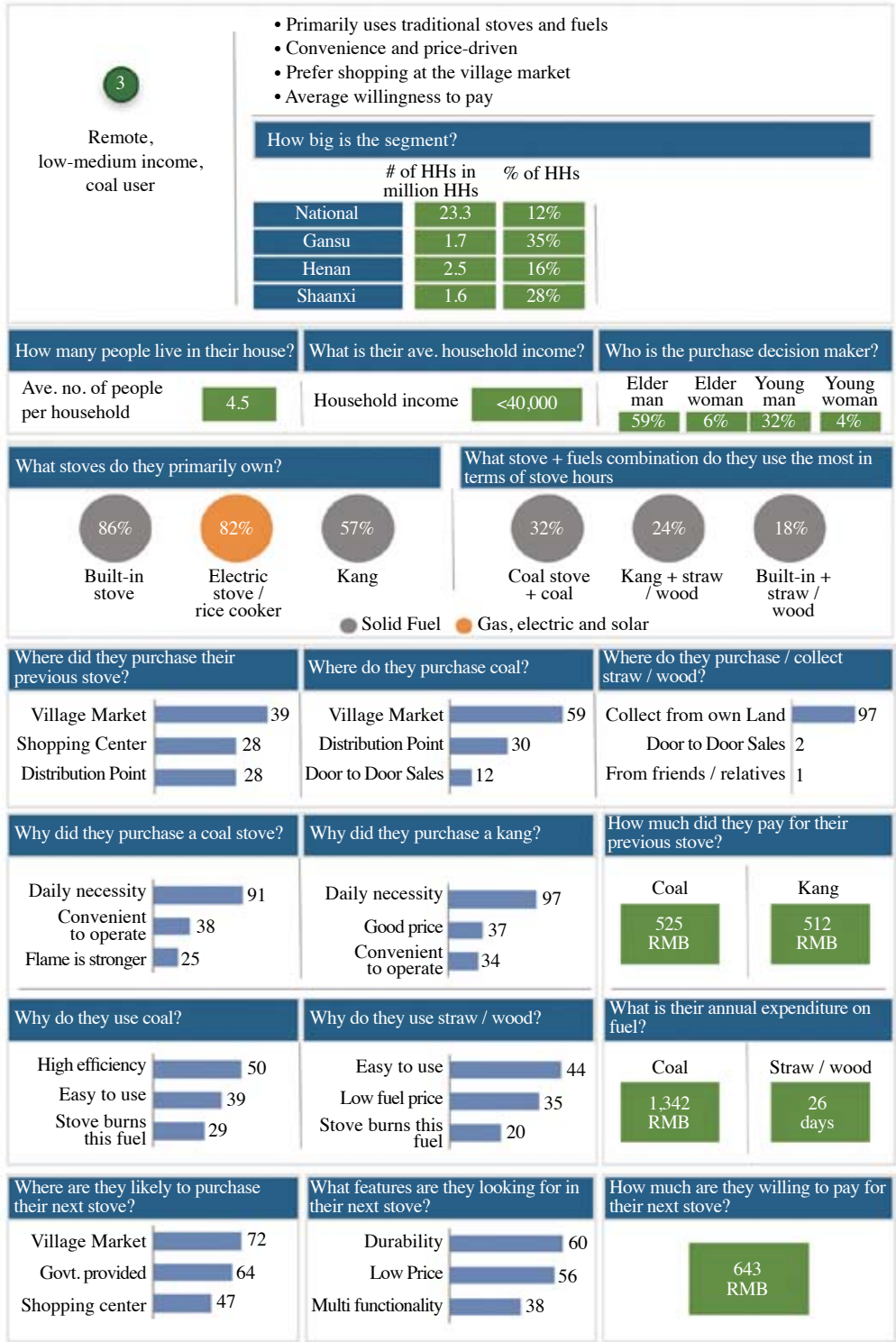


Figure 47 Remote, low-income coal users profile

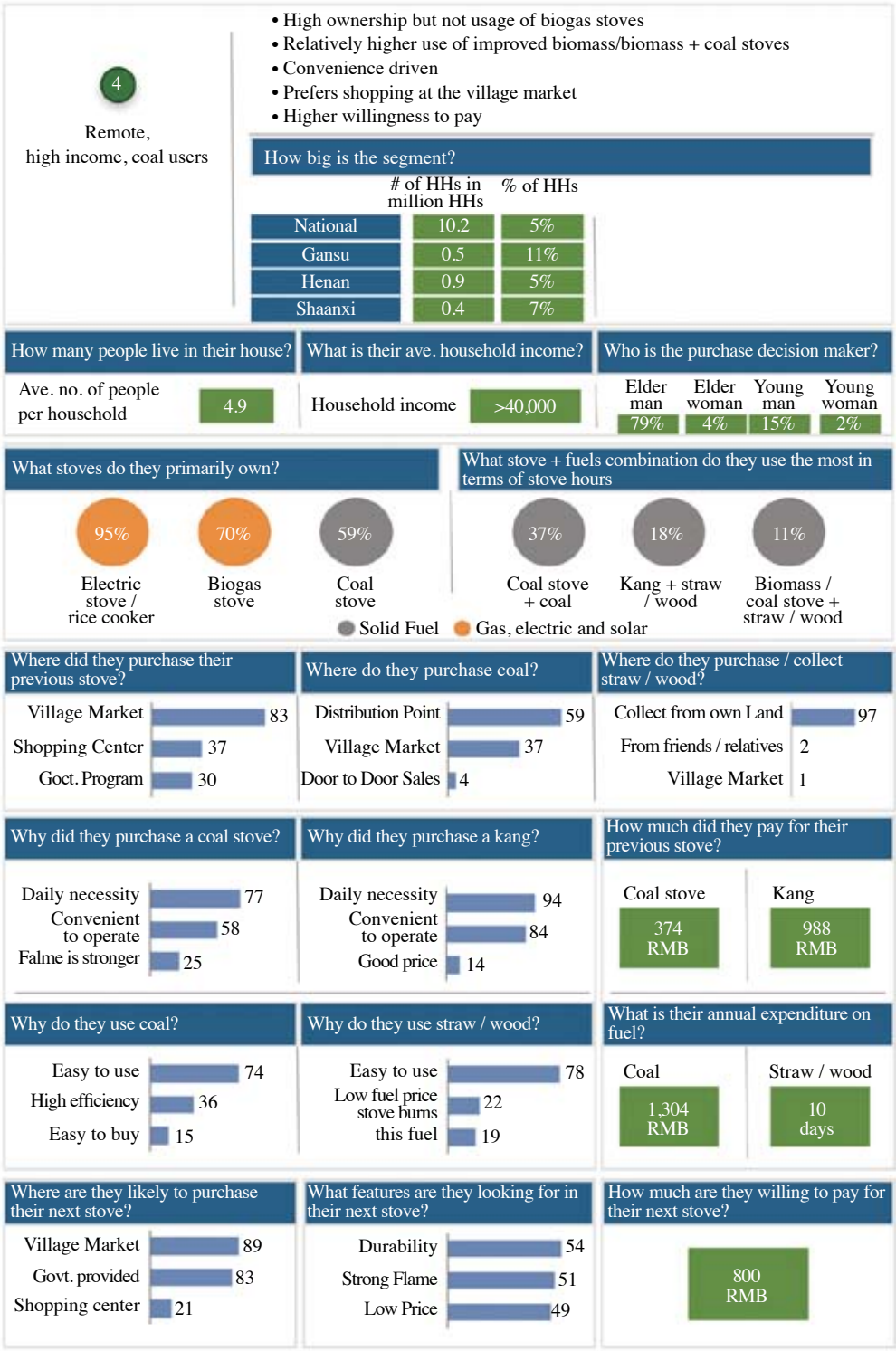


Figure 48 Remote, high-income coal users profile

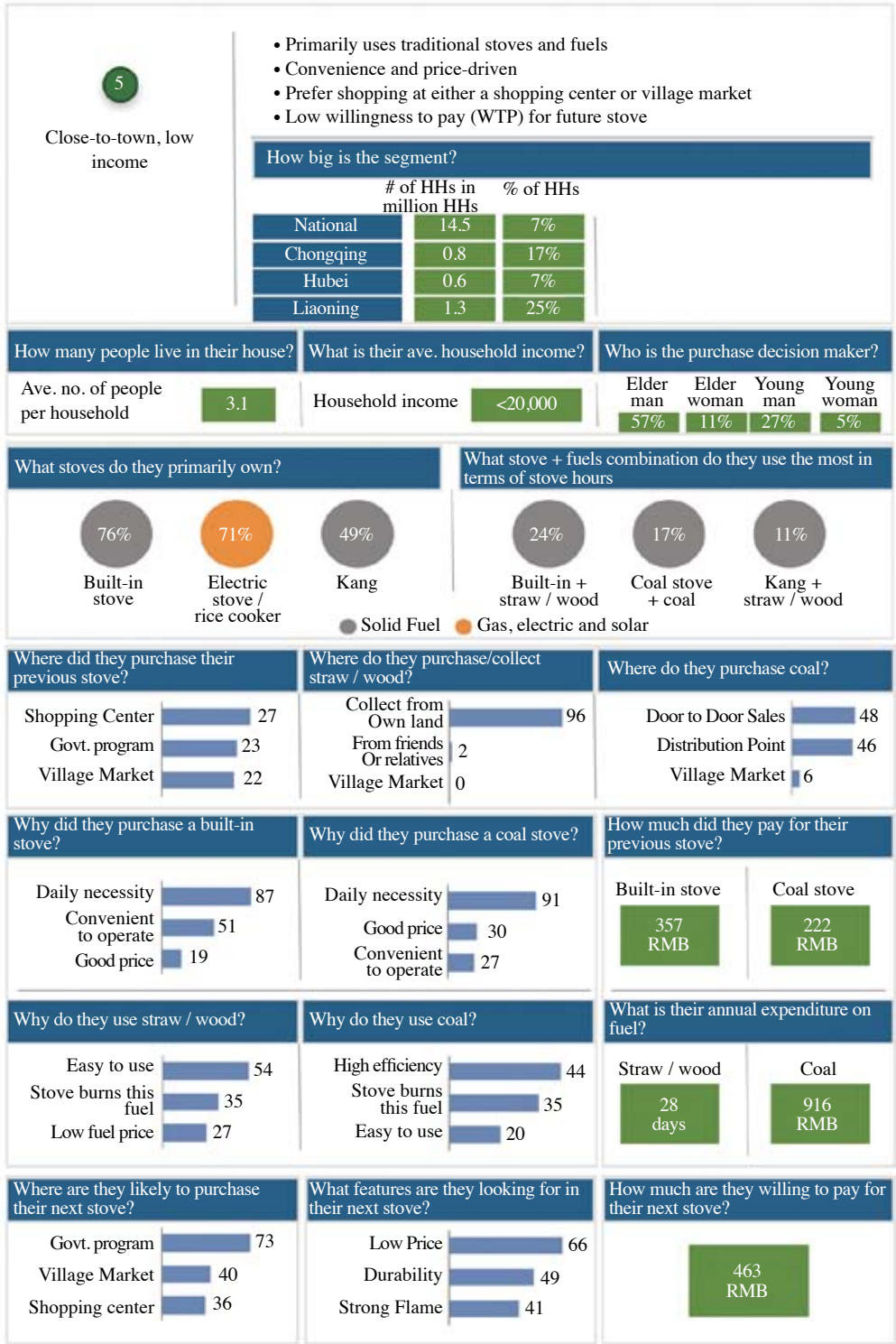


Figure 49 Close-to-town, low-income profile

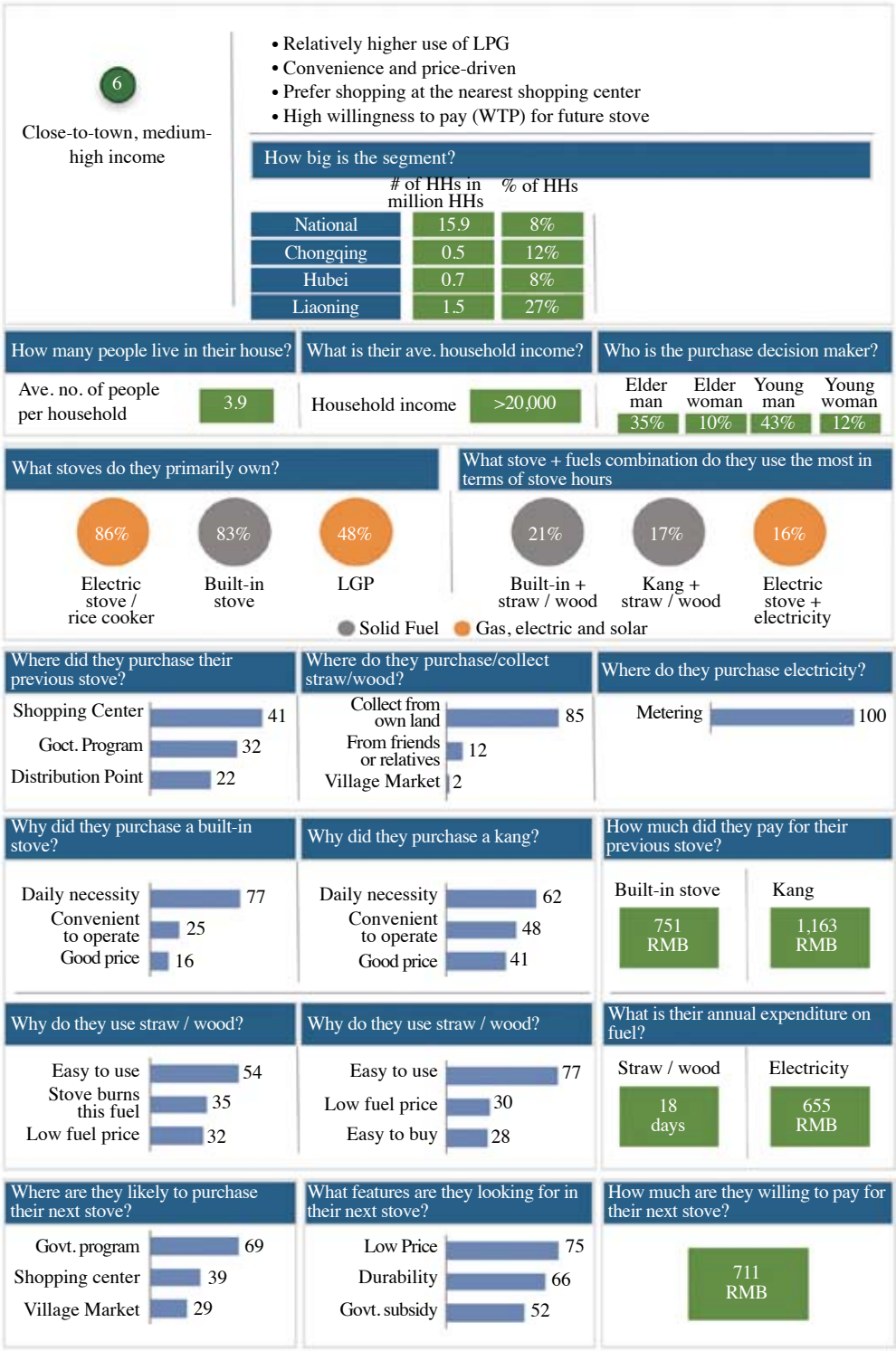


Figure 50 Close-to-town, higher-income profile

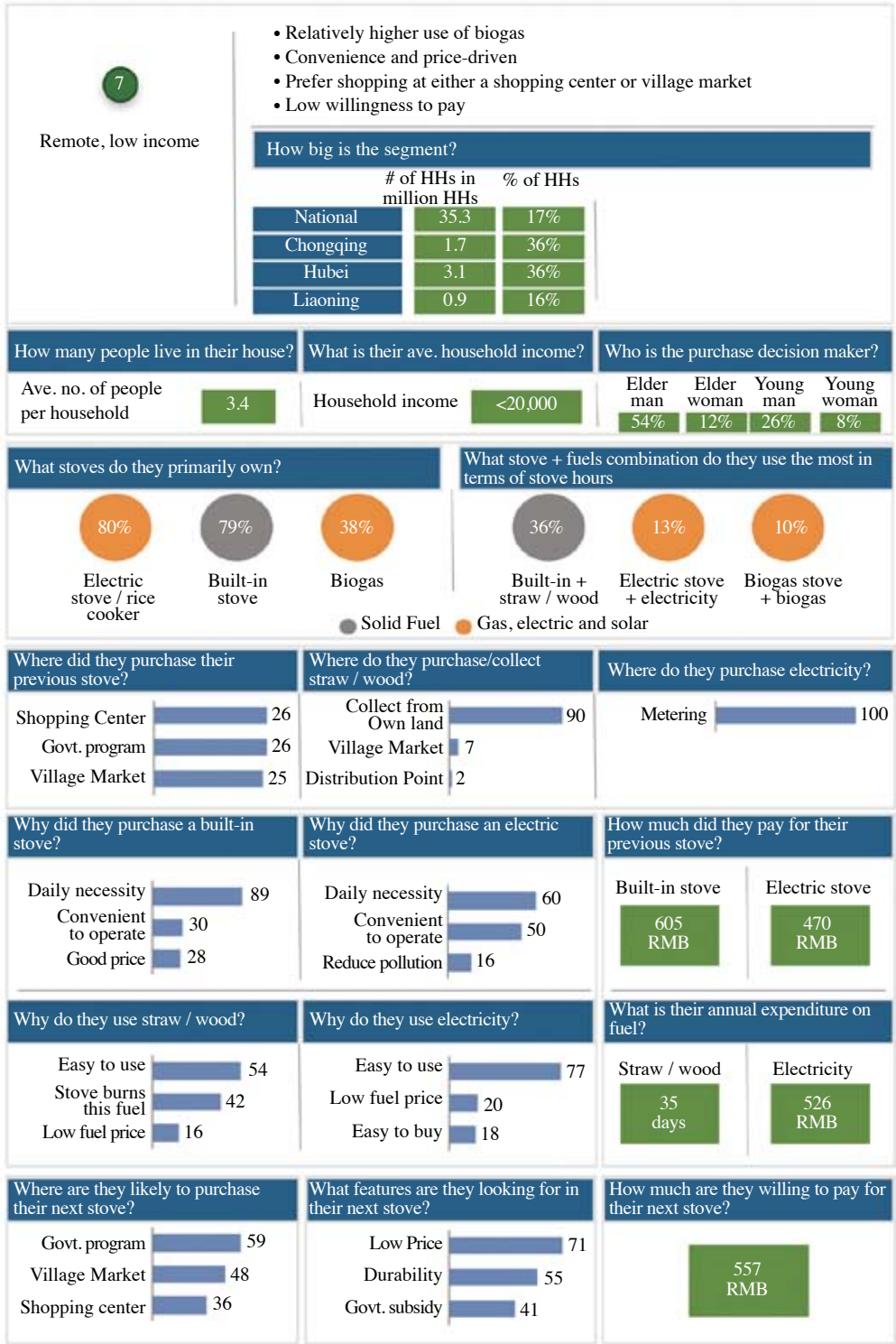


Figure 51 Remote, low-income profile

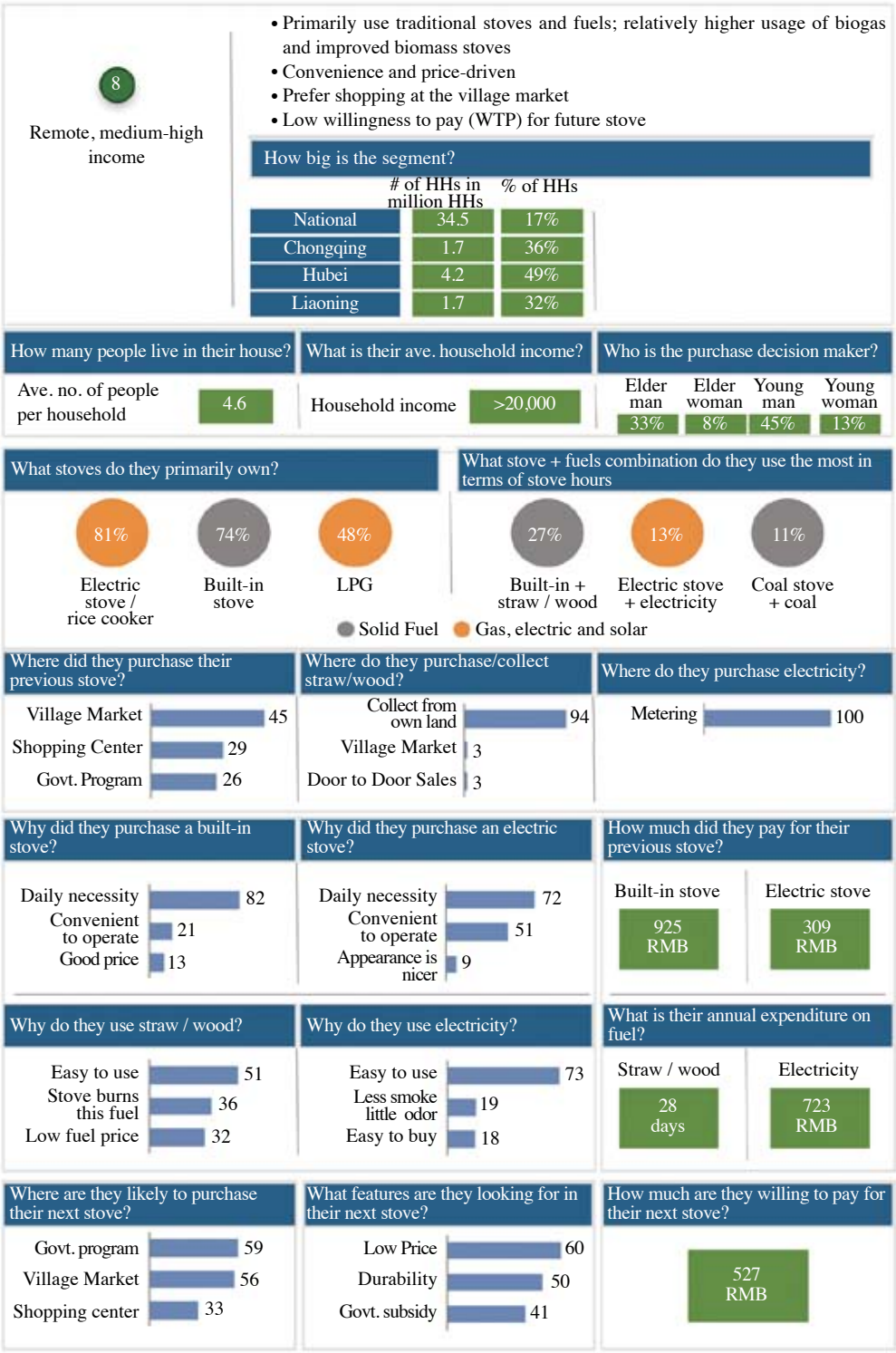


Figure 52 Remote, higher-income profile

3. Two challenges need to be addressed in stoves and solid fuels supply

The stoves and solid fuels industry consists of mostly smaller-scale and regionally focused players. Coal stove and fuel players are profitable and the industry is self-sustaining. In contrast, most biomass stove and fuel producers are dependent on government subsidies.

There are two major challenges to be addressed in order to scale and sustain efficient supply of cleaner stoves and solid fuels in rural China. First, quality is inconsistent due to industry fragmentation and the lack of standards and their enforcement. Second, biomass stove manufacturers and fuel producers are cost-inefficient, as existing subsidy programs create "stop-and-go" markets that inhibit market-based incentives for low-cost production to scale.

3.1 The current landscape of the stoves and solid fuels industry

This report focuses on the industry landscape for stoves and solid fuels for two reasons. First, the majority of rural consumers are likely to continue to use solid fuels in the foreseeable future, as they will not be able to afford or see the value in a full switch to electricity or gas for cooking and heating. Electricity and gas are more expensive relative to biomass and coal, particularly for space heating.

Second, the industries for electric and gas stoves are already a fairly mature market. Both LPG and electric stove markets in China have large players that are serving both domestic and international markets. For example, there are large-scale electrical appliance manufacturers with revenues of over USD 100m selling to hundreds of wholesalers and retailers in Asia, Middle East, America and the European Union. Prices are fairly low and competitive, with single-burner hotplates ranging from USD 2-8 and single-burner induction cookers ranging from USD 7-20. Similarly for LPG stoves, there are large-scale players selling a variety of gas and electric appliances, exporting to Asia, Africa, Europe and the Americas. LPG prices are similarly competitive ranging USD 8-20 for double burner LPG stoves.

Therefore, this report has focused on the less-developed market for stoves and solid fuels. A supplier survey was conducted of 134 stove manufacturers and fuel suppliers In order to understand the stoves and solid fuels industry. This sample comprises the largest 5-10 biomass and coal stove and fuel manufacturers in each of the six provinces.

The survey results show that the stoves and solid fuels market:

- is mostly smaller-scale and regionally focused;
- is profitable; however, biomass stove and fuel players depend on subsidies for profitability;
- tends to distribute through government and wholesale channels.

Smaller-scale and regionally focused:

Most stove manufacturers surveyed were small scale. Figure 53 shows that 70% of biomass stove manufacturers, 54% of biomass/coal stove manufacturers, and 76% of coal stove manufacturers produce less than 10,000 units per year. By contrast, companies that produce appliances for developed consumer markets (such as washing machines or televisions) tend to produce hundreds of thousands or millions of units per year.

The picture is similar for surveyed fuel producers, where 65% of all biomass pellet producers and 100% of coal briquette producers produce less than 10,000 tons of fuel annually. Again, compared to bulk manufacturers producing processed materials for regional or national markets, these are small numbers.

In addition to being small scale, surveyed stove manufacturers were also highly regional. The majority only sell within their home province and sometimes only to parts of a province. The picture

is even more extreme for fuel producers, where the vast majority are local producers that sell within their own province (86% of biomass pellet producers and 98% of coal briquette producers).

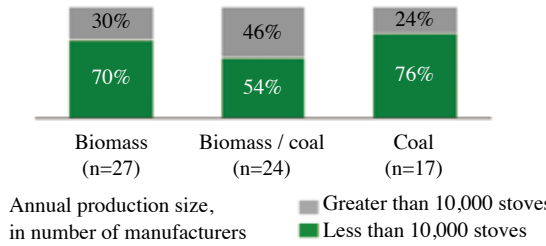


Figure 53 Annual production size of stove manufacturers

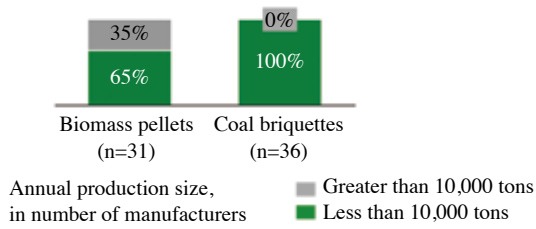


Figure 54 Annual production size of fuel producers

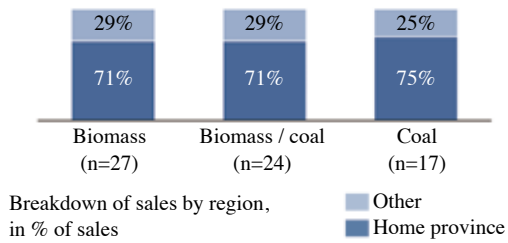


Figure 55 Sales breakdown by region of stove manufacturers

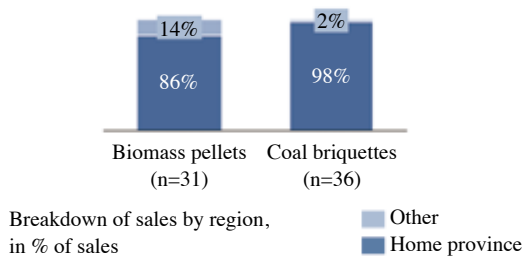


Figure 56 Sales breakdown by region: fuel producers

Biomass stove and fuel players depend on subsidies:

Stove manufacturers surveyed had between 18%-21% average margins, regardless of stove type.

Average selling prices for different stove types vary. On average, a portable biomass stove is being sold for 791 RMB, a portable biomass/coal stove for 846 RMB, and a coal stove for 499 RMB.

Average manufacturing costs are also varied. On average, portable biomass stoves cost 644 RMB to produce, portable biomass/coal stoves cost 670 RMB, and coal stoves cost 408 RMB.

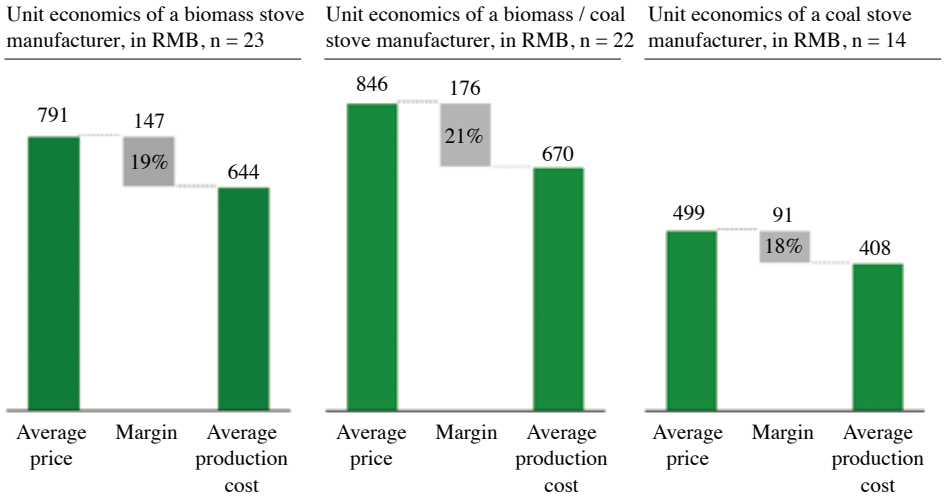


Figure 57 Manufacturer unit margins by stove type

Biomass stove manufacturers depend on subsidies. Figure 58 below shows that 50% of portable biomass stove manufacturers and 54% of portable biomass/coal stove manufacturers receive subsidies. On average, these subsidies cover 72%-74% of the manufacturers' revenue. As a result, without subsidy support, half of the manufacturers in this industry would not likely

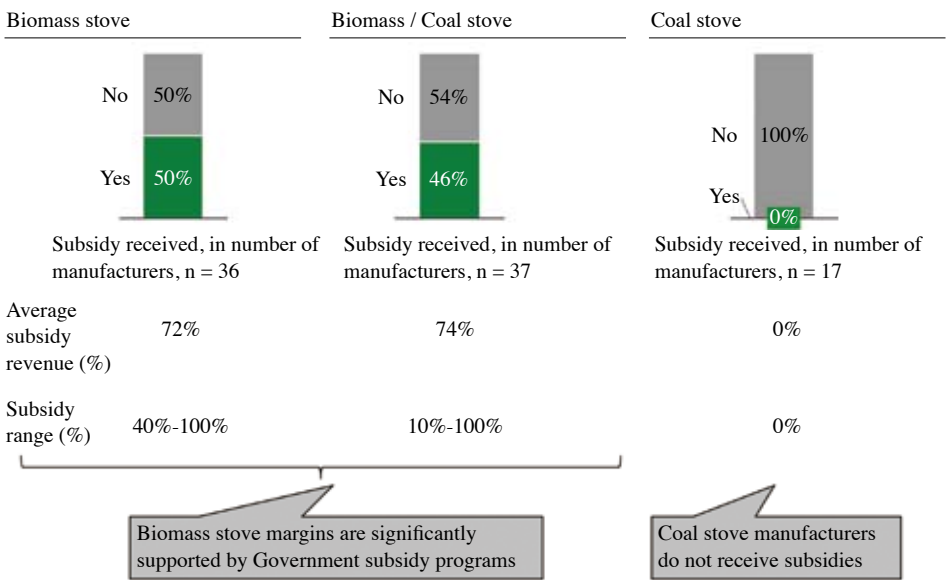


Figure 58 Subsidies by stove type

survive without making significant adjustments to their business model.

Coal stove manufacturers, on the other hand, are not subsidized at all. They are a self-sustaining industry due to healthy consumer demand.

Regarding fuel production, surveyed fuel producers average 14% profit margins. On average, the price per ton for surveyed biomass pellet producers was 641 RMB and the price per ton for surveyed coal briquette producers was 656 RMB. Importantly, the different calorific values of biomass pellets and coal briquettes mean that one ton of coal briquettes is equal to roughly two tons of biomass pellets in terms of energy production. As a result, biomass pellets are almost twice as expensive as coal briquettes in practice.

On the cost side, biomass pellet producers incurred an average production cost of 522 RMB per ton whereas coal briquettes incur 564 RMB per ton.

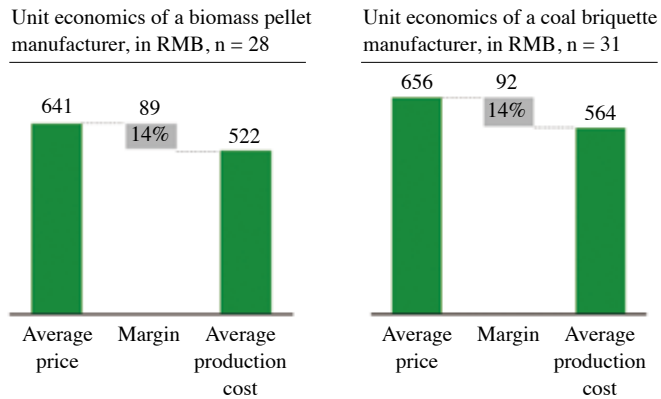


Figure 59 Fuel producer unit margins by fuel type

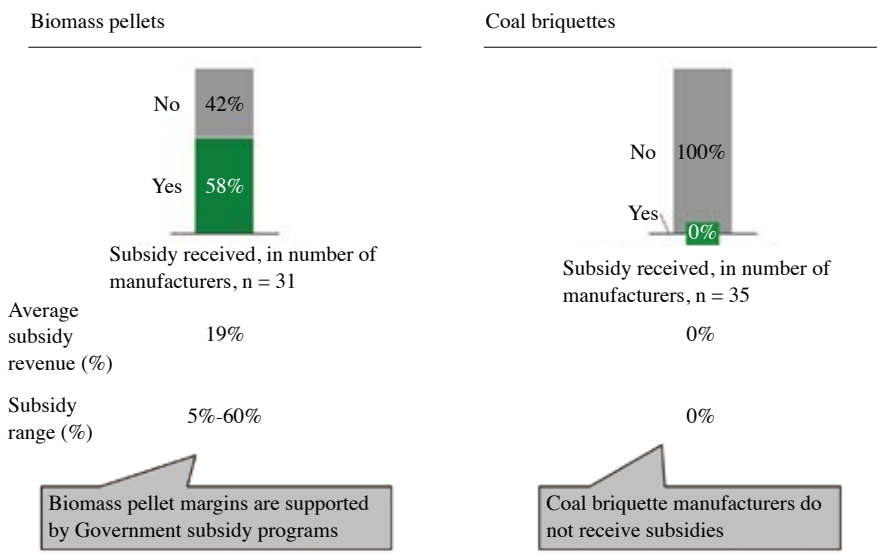


Figure 60 Subsidies by fuel type

Biomass pellet producers are also dependent on subsidies. The average subsidy size is 19% of total revenues. 58% of biomass pellet producers receive a subsidy, with a significantly large range in the subsidy value received by producers. The range in the survey was between 5% and 60%.

Coal briquette producers, on the other hand, are not subsidized at all. The industry is self-sustaining.

Distribution and advertising:

Stove Manufacturer Distribution

Surveyed stove manufacturers relied on five distribution channels to move product to consumers: wholesale, government, local retail, door-to-door, and online. The top three distribution methods for stove manufacturers are wholesale, government (through government subsidy or procurement processes) and local retail. Interestingly, online is a significant distribution channel for biomass stove manufacturers at 30%, evidencing increasing Internet usage and access in rural areas.

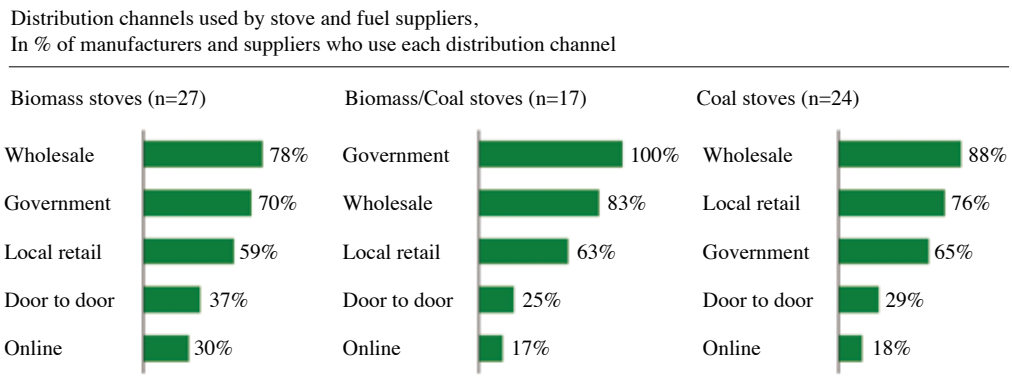


Figure 61 Stove manufacturer distribution channels

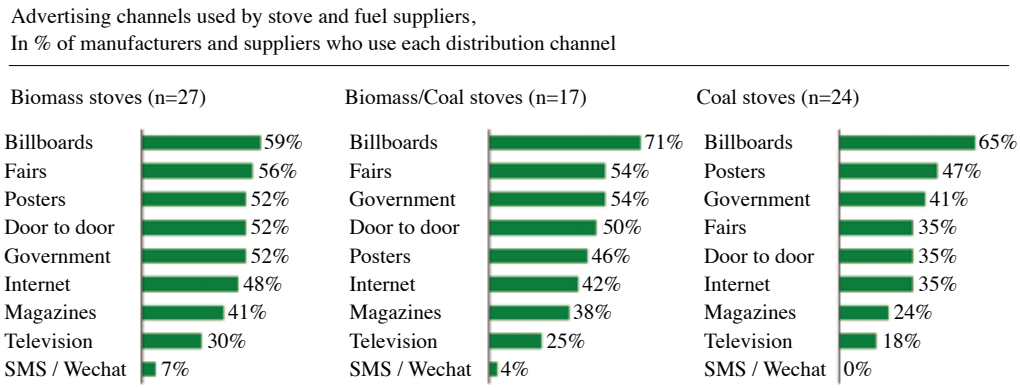


Figure 62 Stove manufacturer advertising channels

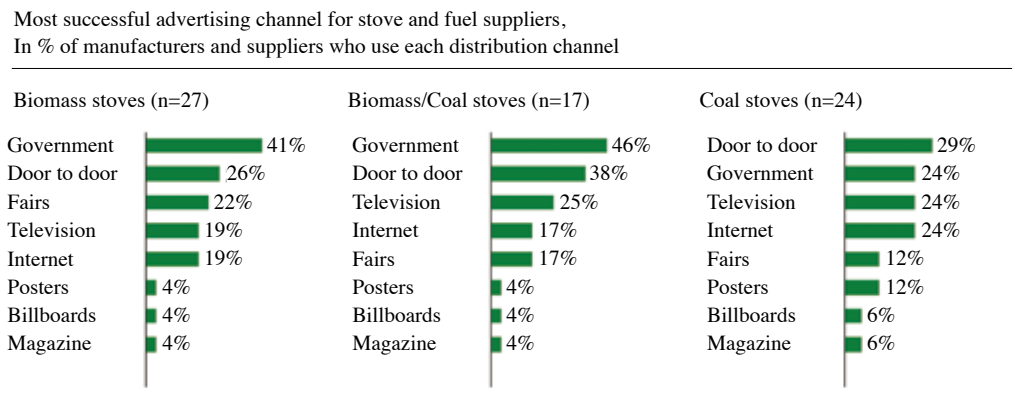


Figure 63 Stove manufacturer perceptions on most successful advertising channels

Stove Manufacturer Advertising

Manufacturers utilize a wide variety of methods and mediums to advertise their products. Billboards are the most popular means of communication, but only a minority of manufacturers think it is actually successful. Fairs, posters, Internet, door-to-door, and government promotions are also fairly popular means of advertising. Out of all these methods, government and door-to-door are believed to be the most effective. There is a significant gap between what is done and what manufacturers believe is effective, leaving room for improvement in advertising and promoting stoves.

Fuel Producer Distribution

There are two major distribution channels for fuel producers: door-to-door and wholesale. Wholesale is the most popular for pellet producers, whereas almost all coal briquette producers utilize the door-to-door approach. Similarly to stove manufacturers, the Internet is significant for pellet producers, with 15% of producers distributing online.

Fuel Producer Advertising

Biomass pellet producers utilize more mediums to get the word out in comparison with coal briquette producers. This makes sense as pellets are less established than coal briquettes and, therefore, more advertising is needed. Coal briquette producers predominantly advertise door-to-door and through billboards. In their view, door-to-door is by far the most successful medium. Pellet producers similarly agree that door-to-door is the most successful medium, and rate the Internet as the next best medium. Therefore, greater focus on the Internet as a means of advertising should be considered in future promotion campaigns.

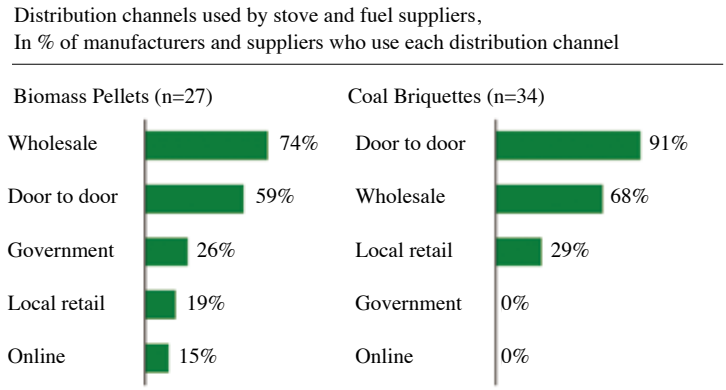


Figure 64 Fuel producer distribution channels

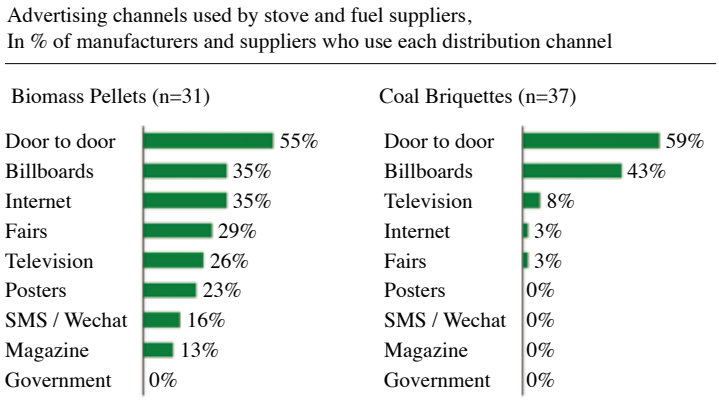


Figure 65 Fuel producer advertising channels

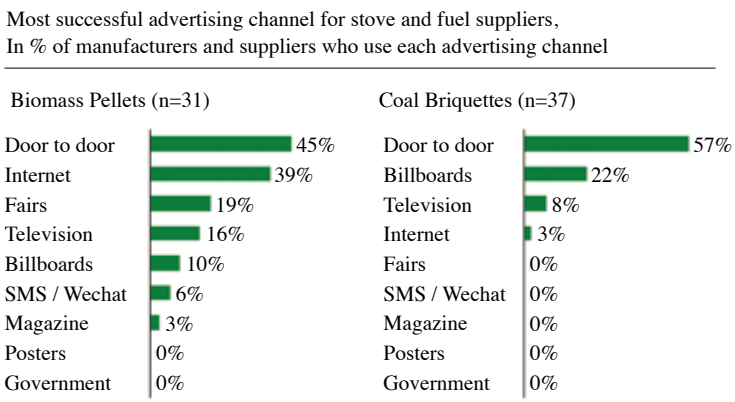


Figure 66 Fuel producer perceptions on most successful advertising channels

3.2 The first major challenge: inconsistent quality due to lack of standards and market fragmentation

Barriers to entry are low, due to the lack of standards and monitoring in the biomass and coal industry. As a result, many small players enter the market with varying levels of quality production. The market is highly fragmented, with a long tail of producers, seen in the figures 67, where most producers in each industry produce less than 10,000 units per year.

This long tail of small-scale players is the result of the industry not yet benefitting from economies of scale. In addition, smaller players do not typically have the funds needed to invest in research and development, leading to greater levels of quality inconsistency, and missed opportunities for innovation. National and provincial leaders in the six provinces confirmed these problems.

There are standards that have been developed in China and internationally. However, they are not applied and enforced, due to lack of coordination between standards developers and regulatory organizations. Provincial leaders cited quality problems and the lack of standards

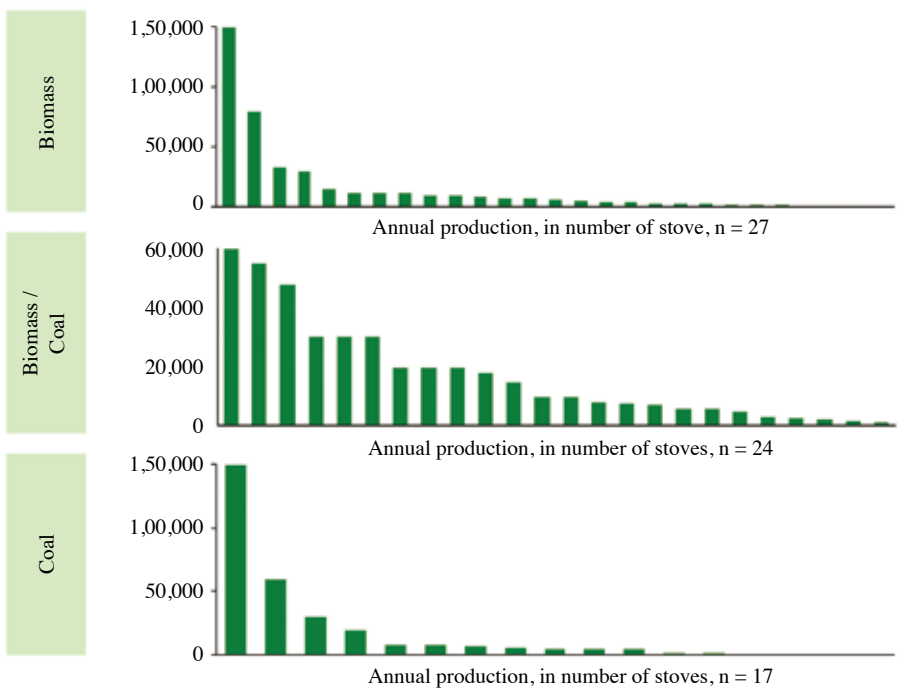


Figure 67 Long tail of production: stove manufacturers

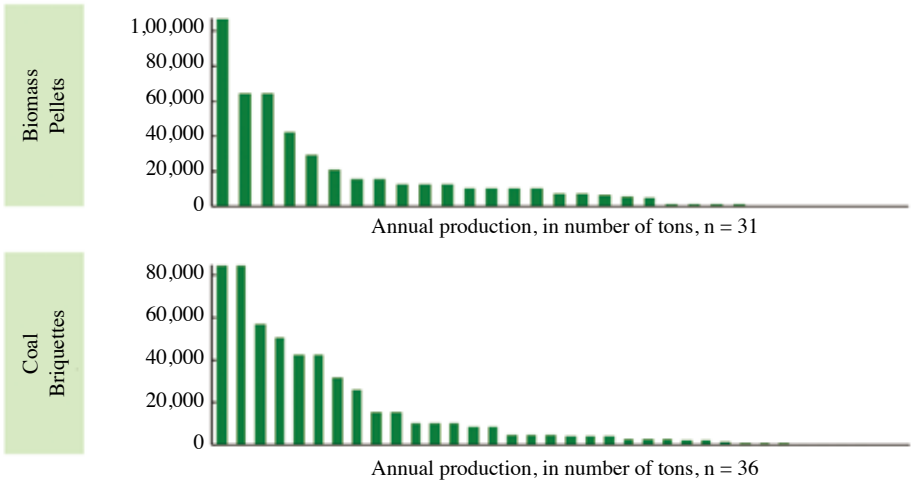


Figure 68 Long tail of production: fuel producers

implementation as one of the major reasons constraining the biomass and coal stove market from independently thriving. Across the country, the lack of standards has led to the production of counterfeit products, which have cheated consumers, discouraging consumer demand and willingness to pay for improved biomass stoves and fuels. In particular, there have been a number of reported fraudulent businesses making straw gasification stoves, decreasing consumer confidence in the technology.

In the absence of implemented standards and brands, rural consumers make purchase decisions based on the outward appearance of stoves and the up-front prices, since they cannot reliably judge other short and long-term benefits. Without promotional efforts and clear standards, many rural consumers in China are highly likely to remain uneducated as to why certain stoves are better than others, especially when it comes to energy efficiency and health.

3.3 The second major challenge: cost inefficiencies due to current subsidy programs

Biomass stove and fuel suppliers make economic choices based on current subsidy policies and dynamics. While subsidies do help rural households afford new and better stoves and fuels, they also play an inhibiting role relative to industry-level scale and stability.

Interviews revealed that manufacturers have designed their business models to respond to subsidy programs rather than to markets. Rather than engineer production and go to market aiming for scale and reach with consumers, they manage and market to meet irregular and batch-oriented government procurement.

Figure 69 below captures the dynamics created through existing subsidy programs as described in field interviews. Together, these dynamics have created a "stop-and-go" market, which limits the ability of suppliers to build scale and efficiency. In other words, subsidy programs have had an unintended consequence of holding back the industry.

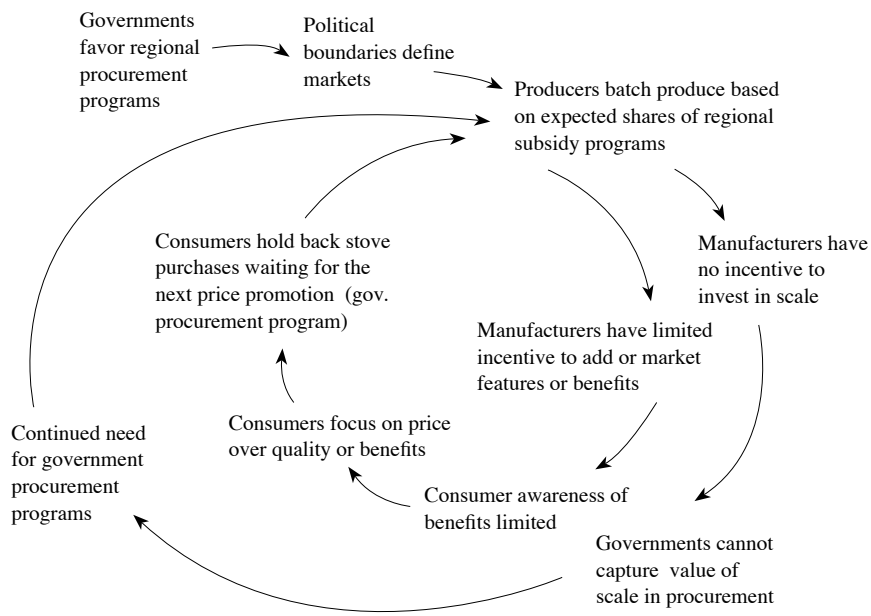


Figure 69 Dynamics driven by current subsidy program: stove products stuck in "stop-and-go" market dynamics

The cost structures for the sample of biomass, biomass/coal, and coal stove manufacturers in the survey similarly suggest that subsidies are constraining the incentive to lower cost of production. Figures 70, 71 and 72 represent the cost curves of the manufacturers surveyed. Each grey column represents one manufacturer surveyed. The width of the column represents the units of stove production per year, while the height of the column represents the unit cost of producing one unit for that manufacturer.

The analysis shows that:

• There are three types of markets in stove production: a basic market, mass market, and a differentiated market. This can be seen based on the relative "tiers" of cost of production in the cost curves.

• There appears to be no clear "winners" in each stove market. The lowest-cost producers are not the largest in size. In typical white goods industries, healthy industries concentrate the majority of sales in the top group of producers. This suggests that current subsidies are constraining the incentive to lower cost of production, potentially due to the lack of a level playing field (inconsistent application of subsidies.)

In production cost (RMB), production (units per year), n = 24 manufacturers

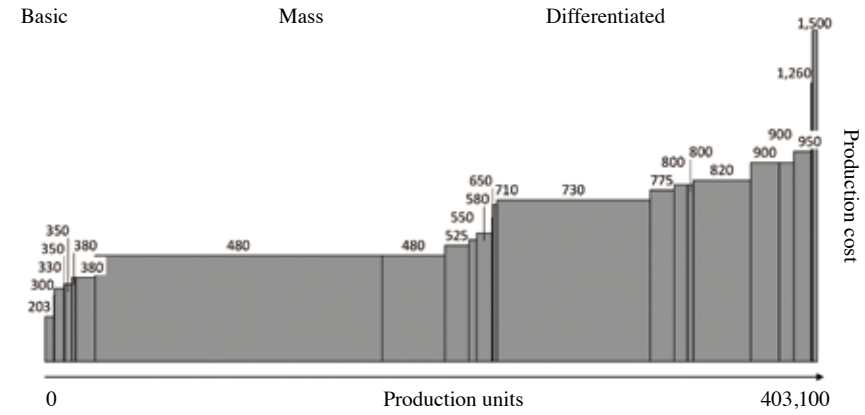


Figure 70 Biomass stove industry cost curve

In production cost (RMB), production (units per year), n = 22 manufacturers

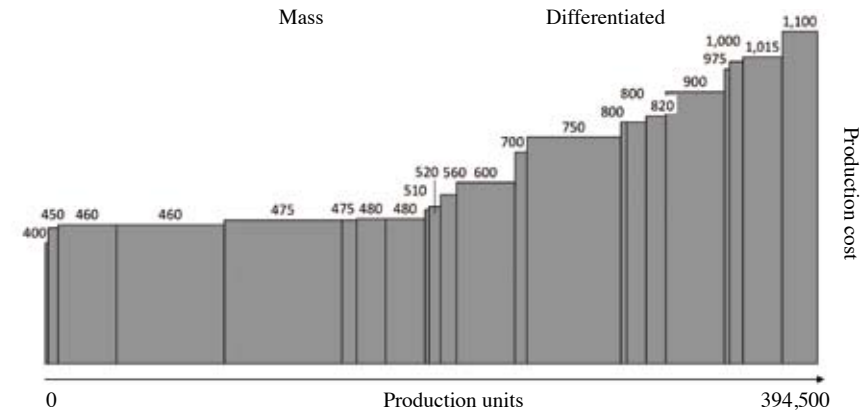


Figure 71 Biomass/coal stove industry cost curve

In production cost (RMB), production (units per year), n = 15 manufacturers

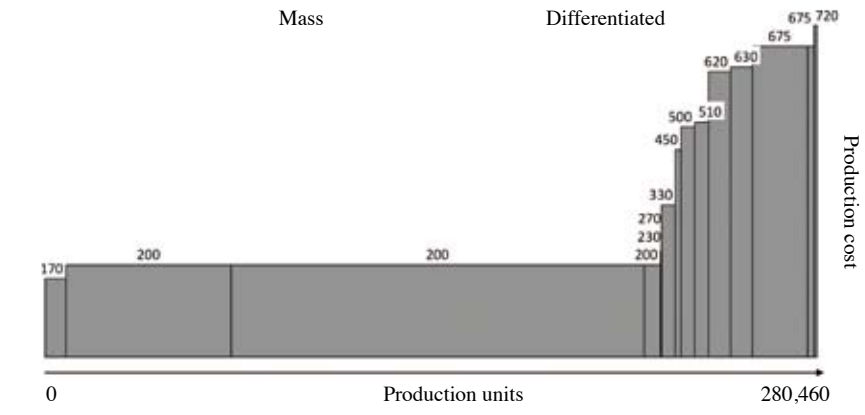


Figure 72 Coal stove industry cost curve

Supply / demand curves for the fuel industry:

Fuels (biomass pellets or coal briquettes) are commodity products, and therefore, the cost curve analysis for fuels is effectively the industry's supply curve, and the sales curve data collected is the industry's demand curve.

The supply/demand curves in figures 73 and 74 below show how existing subsidy programs for biomass pellets are inhibiting scale and creating cost inefficiencies[①]. Typically, in a competitive commodity market (such as the market for coal briquettes in Figure 73 below), one expects a large flat supply curve, which represents market pressure on costs-after fully competition, most manufactures will reach nearly the same and lowest cost in a industry. Contrast this picture with Figure 74, the subsidized market for biomass pellets, where the exhibit shows the market currently allows for many different cost structures and scales of production.

This is the result of varying subsidy levels (Figure 75) that allow varying levels of manufacturer efficiency to exist. As a result, market pressure on costs is lacking and there is little incentive for low-cost producers to scale.

Importantly, the analysis does not advocate for the removal of subsidies. Instead, the analysis argues that subsidies, in order to be effective, should be designed to catalyze scale and efficiency, and not create dependency and fragmentation.

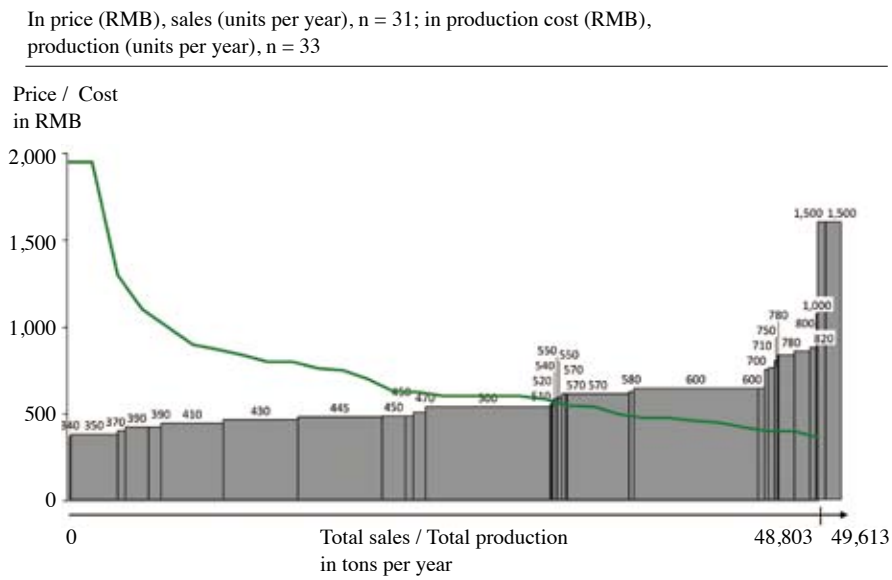


Figure 73 Coal briquette industry demand/supply/cost curves

① The authors recognize that costs of production can differ due to different collection models, transportation and logistics and electricity rates; however, these factors do not explain why the range of costs is so large (where the highest cost biomass pellet producer (at 980 RMB per ton) produces at a cost base five times higher than the lowest cost producer (at 200 RMB per ton).

In price (RMB), sales (units per year), n = 26; in production cost (RMB), production (units per year), n = 28

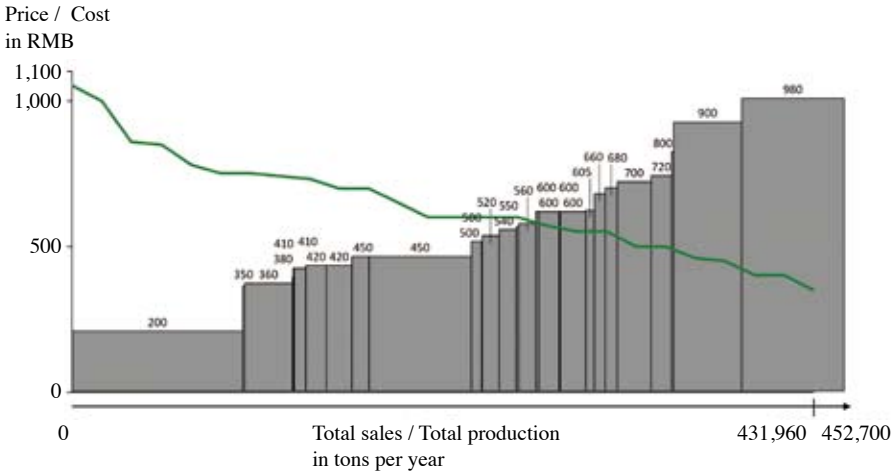
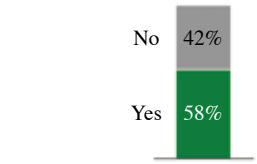


Figure 74 Biomass pellet industry demand/supply/cost curves



Subsidy received, in number of manufacturers, n = 31

Average subsidy revenue (%)	19%
Subsidy range (%)	5%-60%

Figure 75 Biomass pellet subsidy data (repeated from Figure 60)

4. Strategies for the next national program

This report has discussed the opportunity for another national program to target cleaner stoves and fuels in depth. The analysis presented has deepened an understanding of rural demand in China, as well as outlined challenges in the quality and cost of supply.

Now, building on past success, the next national program should focus on four actions that will address the barriers and opportunities described in this report. The program should 1) strengthen focus toward increasing the affordability and accessibility of cleaner fuels, not just cleaner stoves; 2) address stove quality and cost issues by refining existing standards and implementing them at the national level and by re-designing existing manufacturer subsidy programs; 3) accelerate consumer awareness of the health and environmental value of reducing solid fuel burning, through consumer labels and targeted awareness campaigns; and 4) utilize consumer segmentation as an input into designing and prioritizing policy actions and practitioner strategies.

4.1 Economic growth alone is not enough to transition rural China's energy mix from dependency on solid fuels

This section outlines the key recommendations based on the analysis in this report. This first section (4.1) outlines the baseline scenario of what is likely to happen to China's rural energy mix and CO_2 emissions from solid fuel usage without any further government intervention; it also outlines the options for reducing solid fuel burning by region across the nation, providing an overview of the four actions recommended for the next national program. The final four sections (4.2 to 4.5) discuss the four actions in detail, estimating impact where possible.

Baseline scenario, without intervention:

The baseline scenario, without any further intervention or government program, is estimated to reduce solid fuel reliance by 9%, resulting in an overall reliance on solid fuels of 69% for rural China in 2020. In other words, without intervention, it is expected that the majority of rural consumers in China will still primarily use solid fuels. As a result, China's prevailing high reliance on solid fuels will continue to negatively impact the environment and public health.

As discussed in chapter 1, the government has plans in place to address these issues; for example, the 12th Five-Year Plan announced to reduce carbon emissions per unit of GDP by 17%; also in the 12th Five-Year Plan the government released the Air Pollution Prevention and Control Action Plan. This report suggests that cleaner cooking and heating in China's rural areas can contribute to this goal and the broader agenda to address China's environmental and health issues. However, the baseline impact driven by economic growth alone will not be enough.

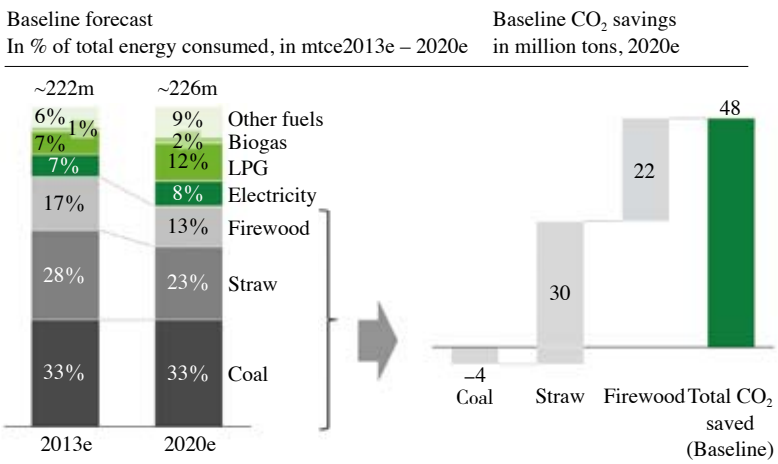


Figure 76 Estimated baseline impact on CO_2 emissions[34]

Note: The model does not account for the additional CO_2 emissions from energy production – it only accounts for CO_2 emissions from energy use.

The model shown in Figure 76 estimates the baseline contribution of CO_2 savings to be approximately 48m tons. While this represents less than 1% of China's total estimated 6,000m tons of CO_2 emissions[①], it represents a significant portion of the gains possible from addressing rural cooking and heating. Furthermore, as shown in chapter 1, recent studies have shown that residential coal and biomass burning is a large contributor to China's PM2.5 emissions (~34%) and black carbon (~50%-70%). Therefore, this is an important source of emissions for the government to address, and with intervention, it is believed the emissions savings could be significantly greater.

The opportunity for intervention:

Intervention is needed, therefore, to create greater impact through cleaner cooking and heating in rural China. Improving the efficiency of solid fuel burning and even reducing solid fuel usage happens in two ways:

- Fuel switching to cleaner substitutes;
- Stove switching to higher quality, more efficient, cleaner stoves.

The opportunity for fuel switching in China principally lies in promoting cleaner, accessible fuel substitutes for space-heating stoves. Figure 76 shows that economic growth drove CO_2 emissions savings in straw and firewood, but not in coal. Reliance on coal remained flat at 33% and CO_2 emissions from coal increased by an estimated 4m tons (given the estimated increase in overall energy consumption from 222m to 226m). Coal remains popular in large part due to its attractiveness and accessibility for space heating. Therefore, in order to reduce coal usage, cleaner, affordable coal substitutes for space heating are needed. Wealthy consumers may switch to electricity or gas for space heating; however, most consumers will not be able to afford electricity and gas. Therefore, there is an opportunity for biomass pellets (produced at scale, and more accessible and affordable) to substitute coal usage across rural China. This is discussed in greater detail in 4.2.

The opportunity for stove switching is across the board and involves improving the quality and efficiency of stoves across the nation. In particular, there is significant opportunity to focus on solid fuel stoves due to their reliance on subsidies and the quality and cost efficiency issues raised in Chapter 3.

Figure 77 summarizes these opportunities by region, integrating insights from the survey and segmentation analyses to tailor opportunities to the needs of each region.

A national program to capture the opportunities:

Another national program, centrally coordinated and managed, can successfully capture these opportunities.

① World Bank Databank 2010.

Building on past successes, the program would need to:

1) Strengthen focus toward increasing the affordability and accessibility of cleaner fuels, not just cleaner stoves;

2) Address stove quality and cost issues by implementing national standards and by re-designing subsidy programs;

3) Accelerate consumer awareness of the health and environmental value of reducing solid fuel burning, through consumer labels and targeted awareness campaigns;

4) Utilize consumer segmentation as an input into designing and prioritizing policy actions and practitioner strategies.

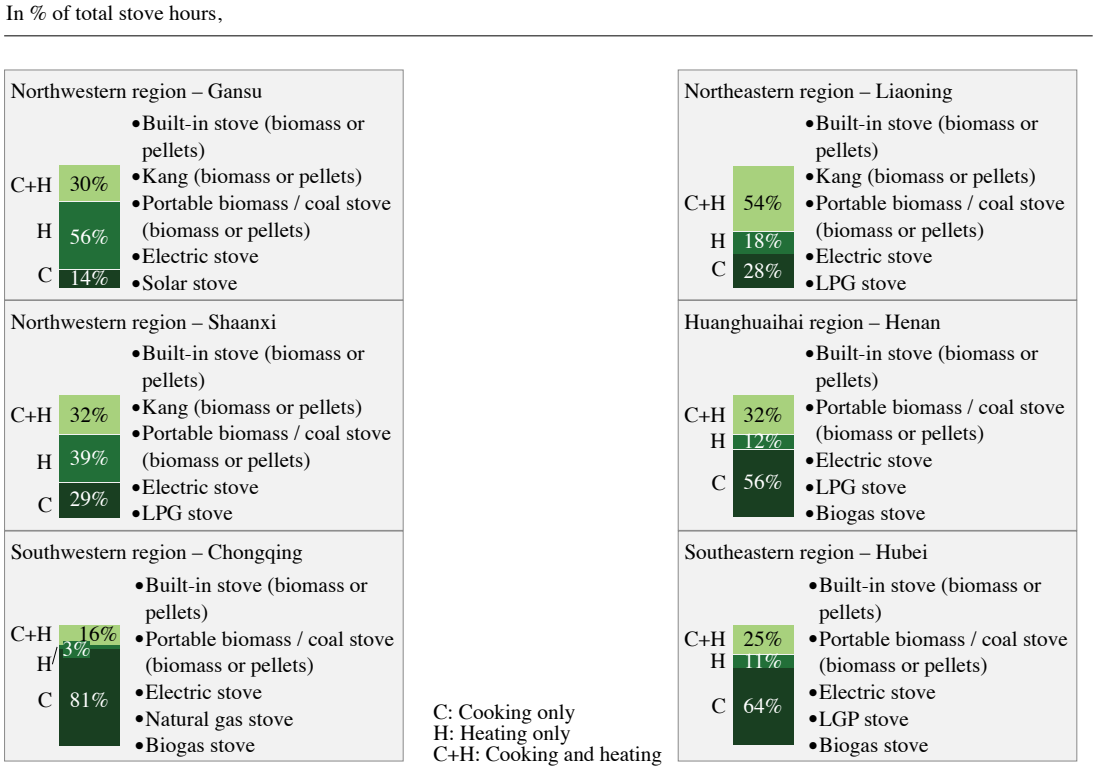


Figure 77 Map of possible stove/fuel combinations to promote a reduction in solid fuel burning at national level

Figure 78 summarizes the recommendations for the national program, as well as the likely targeted household (HH) impact of each policy suggestion. The policies have the potential to directly impact between 22 million to 67 million households, depending on the extent of household overlap in policy implementation.

The following sections outline each of these four actions in more detail.

Recommendations		Likely targeted HH	Rationale:
1. Strengthen focus toward cleaner fuels, not just cleaner stoves	• Promote scale-up of biomass pellet industry	~22m	• Strategy affects wealthier segments due to higher ability to pay. 30% penetration assumed for coal users and 20% penetration assumed for biomass users, as pellets are more attractive substitutes for coal
2. Address quality and cost issues by implementing national standards and redesigning subsidies	• Implement national standards on portable biomass / coal stoves	~11-12m*	• Standards much more easily implementable on factory-manufactured stoves vs. built-in. Standards improve quality of portable biomass / coal stoves which affects buyers of these stoves. Buyers are typically wealthier segments, representing 12%-13% of these segments
	• Re-design subsidy programs for biomass stoves	~11m	• Bottom 10% of low income segments to be targeted for subsidy programs
3. Accelerate consumer awareness through consumer labels and targeted awareness campaigns	• Implement consumer labels on portable biomass / coal stoves	~11-12m*	• Same rationale standards, as labels correspond with stoves that meet standards
	• Conduct targeted awareness campaigns	~22m	• Consumer awareness campaigns to target wealthier segments as they have higher ability to pay / respond to campaigns. Target 25% of segment for targeted campaigns
4. Utilize consumer segmentation to inform policy and practitioner strategies	• Improve targeting and promotions for all recommendations	N/A	

Figure 78 Overview of recommendations

4.2 Strengthen focus toward cleaner fuels, not just cleaner stoves

There is immense value in focusing subsidy investment on scaling cleaner fuels, beyond subsidizing stoves. The rationale for focusing primarily on fuels is threefold:

• Fuel economics drive consumer choice. Households manage "portfolios" of stoves for fuel flexibility, balancing cost and convenience. Households purchase stoves based on the attractiveness of the related fuel. Therefore, increased demand for cleaner fuels results in demand for cleaner stoves.

• Switching to cleaner fuels has had, on average, a greater impact on emissions than stove switching.

• Developing policy to target fuels is more pragmatic than targeting stoves. Fuels, unlike stoves, are commodities, making policies more practical and standardized.

The greatest opportunity in scaling cleaner fuels is in the biomass pellet industry for several reasons:

• Biomass pellets are cleaner than coal and other solid fuels. Biomass pellets could significantly improve efficiency and emissions impact if pellets were more price-competitive.

• However, pellets are not yet price competitive, as scale benefits are yet to be captured. The industry for biomass pellets is operating sub-scale and production costs are inefficient: pellets

cost roughly twice as much as coal.

The challenge to scaling pellet production is the lack of incentive to process raw biomass, given how plentiful biomass residue is across the nation. China annually produces 1 billion tons of biomass residues, more than is needed to satisfy all of rural China's cooking energy needs.

However, as demonstrated in Chapter 3 of this report, current subsidies to biomass pellets are constraining scale of the biomass pellet industry.

• Current subsidy amounts are highly varied and inconsistent, ranging from 5%-60% of revenue, for different fuel producers.

• As a result, current subsidies do not create a level playing field (producers receive different subsidy values regardless of production cost). The implication is a lack of incentive for producers to reduce costs and maximize efficiency. Overall, this results in a sub-scale market.

To address the issue, subsidies need to be re-designed to create a level playing field (offering the same value subsidy for all producers), while still delivering an efficient social subsidy. The target effect of re-designed subsidies for biomass pellets would be to create clear incentives for the lowest-cost producer to scale. This would result over time in a shift of the biomass pellet supply curve toward a much more efficient shape, as exhibited in Figure 79.

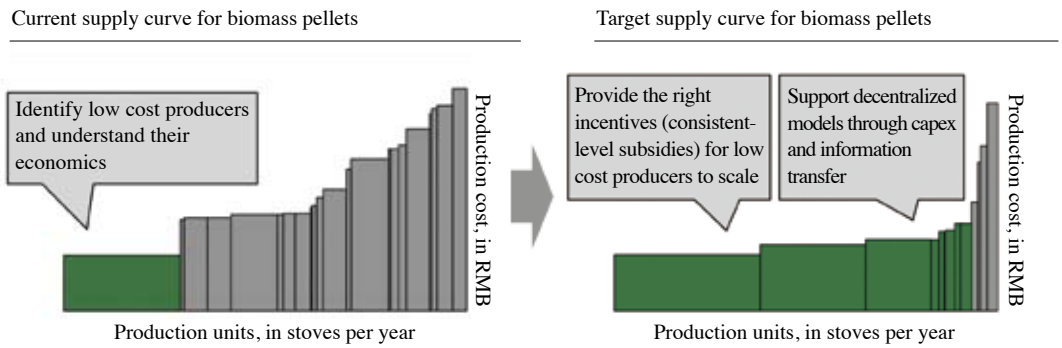


Figure 79 Current vs. target supply curve for biomass pellets

In addition to subsidies to centralized pellet producers, attention should also be given to opportunities to encourage the replication of small-scale village-level models. In Liaoning, for example, there have been village-level pelletizer business models, which create incentives for villagers to trade raw materials for processed goods. In some cases, this model encourages villagers to bring peanut shells to the pelletizer entrepreneur. The shells are processed; the peanuts go to the villagers and the waste gets turned into pellets and retained by the pelletizer business. Villagers receive a free service to process their peanuts, and pelletizer businesses solve the collection problem by creating incentive for villagers to bring the raw materials to them.

The challenge with these models is the capital expenditure required for the pelletizer. To encourage the spread of pellets, a subsidy on the pelletizer capital expenditure can be considered.

Possible impact of pellet strategy on rural households and emissions:

The strategy to scale pellet production could have a significant impact on millions of rural Chinese households, as well as on overall emissions reduction. It is estimated that it is likely for the pellet strategy to impact ~20m-25m households as well as replace ~1.5bn hours of biomass cooking and ~5bn hours of coal cooking. The assumptions for the estimates include the following:

- The likely consumers for pellets are wealthier consumers, with either high coal usage or high biomass usage. In particular, coal users are more likely to switch hours than biomass users, as pellets are a stronger substitute for coal given their heat efficiency.
- It is assumed that with economies of scale, the price of pellets will become competitive with the price of coal, including accounting for the relative differences in fuel efficiency.

Consumer-based subsidy programs to upgrade existing stoves will still be needed, especially for low-income consumer segments:

The above strategy for promoting pellets and pellet stoves will not be attractive and economically valuable to all consumer segments. In particular, poorer consumer segments (especially those still mostly dependent on collection of solid fuels in low-coal-reliance provinces), will find the economic cost of ownership unattractive.

Therefore, for these segments, reducing solid fuel burning may still require stove subsidy programs to encourage use of more efficient biomass stoves. These stoves could include improved built-in stoves, Kangs and/or portable biomass and coal stoves, depending on the region where these segments exist (see Figure 77).

4.3 Address quality and cost issues by implementing national standards and re-designing subsidies

Implementing national standards:

The solid fuels stove industry in China would greatly benefit from the implementation and enforcement of a national standard, building from the existing Chinese local and sectoral standards and the IWA documents that have been developed by a group of international experts, a process led by the Alliance and ISO. The enforcement of standards protects consumers, incentivizes competition and ensures quality supply.

Enforcing consistent standards in conjunction with government procurement/subsidy programs will consolidate the industry in the long run, leading to more efficient industry cost structures and greater levels of market competitiveness. Low-quality, inefficient producers would be pushed out of the market, or forced to increase their efficiency or quality.

Currently, there is an expert team led by MOA drafting a national standard for the biomass

clean stove. There needs to be a coordinated effort between MOA, the National Energy Administration (NEA) and the Standardization Administration of China (SAC) to improve the development processes of clean stoves standards and testing protocols, establish a systematical certification and evaluation regime, as well as look into how this can be integrated into international standards. However, while there is progress, clarity on standards and processes for monitoring and enforcement on the ground have yet to be executed consistently.

Possible household impact of implementing national standards:

Implementing standards is more feasible on centrally manufactured stoves (portable biomass and biomass/coal stoves), given that manufacturers are more likely to have the incentives to meet standards, and the monitoring and evaluation effort required. As a result, standards are likely to only improve the quality of portable biomass and biomass/coal stoves. Currently, the penetration rate of these stoves is between 12%-13%, most typically purchased by wealthier segments that prefer the convenience of these stoves.

Based on these assumptions, it is estimated that the likely household impact will be wealthier segments that are likely to purchase these stoves. This represents approximately 11m-12m households.

Re-designing manufacturer subsidies:

Figure 80 summarizes the dynamics introduced in Figure 69 in Chapter 3 and re-emphasizes the issue with current subsidy programs. Government procurement cycles create "stop-and-go" markets where manufacturers design their business models and production based on their expected share of government subsidies, rather than market demand. On the demand side, consumers have also come to expect subsidy cycles, and therefore, they plan their purchases and price expectations based on historical government programs.

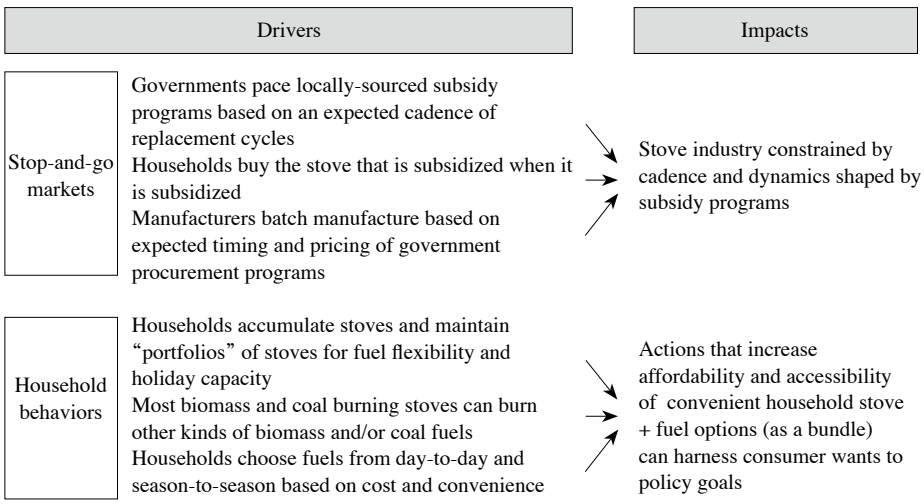


Figure 80 Drivers of current market dynamics: stop-and-go markets and household behaviors

There is a large opportunity to re-design manufacturer subsidies so as to allow market forces to work more efficiently. For example, the government could consider re-designing subsidies in the form of consumer rebates. Subsidies are paid on the basis of market sales. As a result, the market will set demand for production, rather than government procurement decisions.

In doing so, market forces will provide clearer and more equal incentives for lowest-cost manufacturers to scale. By creating an even playing field and strengthening market signals, manufacturers are more likely to reach economies of scale. As scale economies are captured, biomass stoves will become more affordable as costs decrease. The likely overall effect of making biomass stoves more affordable is a significant increase in demand for them.

Figure 81 summarizes the value of national standards and re-designing manufacturer subsidies in reversing existing dynamics created by politically designed "stop-and-go" markets. Effective implementation of standards and consumer or retailer rebates will have the longer-term effect of promoting a more market-based system.

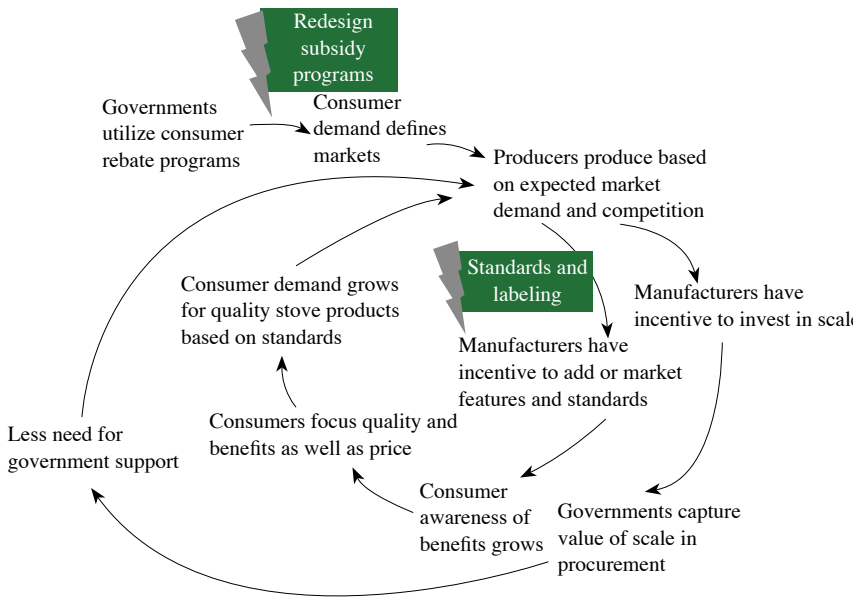


Figure 81 Strategic interventions to reverse industry dynamics and promote a more market-based system

Possible household impact of re-designing subsidies

Re-designing subsidies as consumer rebates allows the government to target specific consumer segments with its rebate policy. For example, consumer rebates can be used to "tip" poorer consumers into participating in the market, by making rebates only available to consumers who can prove low household income.

Assuming the bottom 10% of the poorer consumer segments are targeted for these rebates, the impact of this policy would be approximately ~11m households.

4.4 Accelerate consumer awareness through consumer labels and targeted awareness campaigns

The value of consumer labels:

Standards create pressure on the supply side, while consumer labeling can act as a powerful demand-side reinforcing mechanism. This is also shown in Figure 81 on the previous page. Labels educate consumers and create greater transparency on product quality, which can lead to higher demand for cleaner, more improved stoves and increased consumer confidence.

However, similar to standards, implementing consumer labels is also quite complex. Historically, labeling has been reserved for much larger markets such as refrigerators and air conditioners. The value of labeling in these markets has been to increase industry value through more efficient competition, where the benefits of doing so are weighed against the cost of implementation.

The smaller market value for solid fuel stoves means that it has not historically been seen as economically valuable to implement consumer labeling. However, in the current political context, the value of implementing consumer labels should be reconsidered. In September 2014, the government reiterated its intention of creating a national carbon market by 2017, to reduce China's overall CO_2 emissions. Solid fuel burning through inefficient stoves is a major contributor to CO_2 emissions, and as a result, linking consumer labels to CO_2 financing could provide a much stronger business case for the value of implementing consumer labels in stoves.

For example, a consumer would be able to directly see that by buying a stove that has high levels of efficiency, he or she is implicitly receiving a carbon subsidy, raising the perceived value for the stove.

We recommend further research be done on this in light of recent trends towards a carbon market for China by 2017. The impact of labeling is estimated to be similar to the impact of standards as these two recommendations go hand in hand.

Targeted consumer awareness campaigns:

In addition to consumer labels, targeted consumer awareness campaigns are necessary to help consumers make a socially optimal choice. Very few stove users during the field visits demonstrated real knowledge or concern about the health effects from indoor air pollution caused by poor-quality stoves. While campaigns have been run in the past, these may need to be more localized to account for the substantial variance in usage of stoves.

Implementation of these campaigns should strongly utilize product demonstrations at the village level, as well as Internet communications. Village demonstrations or "fairs" were cited both in interviews and in the manufacturer survey as one of the most effective methods

of advertising. Rural consumers are highly practical and prefer to see concrete evidence of value before purchase. In addition, village demonstrations encourage a positive network effect. Many rural consumers find out about new products by visiting other houses in their village. By demonstrating in each village, effective campaigns can create excitement across the whole village.

If 25% of the wealthier consumer segments were targeted for these awareness campaigns, then the campaigns would impact approximately 22 million rural Chinese households. Targeting wealthier households makes sense due to the value of appealing to the aspirational nature of these households, as well as taking advantage of their higher ability to pay.

In addition to village demonstrations and "fairs," the use of the Internet was also cited as an increasingly important channel for advertising and sales. Future awareness campaigns should consider utilizing the Internet and social media applications such as Weibo and WeChat to get the word out.

4.5 Utilize consumer segmentation to inform policy and practitioner strategies

Institutionalizing consumer segmentation and a data-driven approach in developing national and provincial policy will equip leaders to smartly invest in programs that carry the highest benefit for the money invested. This will be especially applicable when thinking through where to apply specific stove and fuel strategies (such as the promotion of biomass pellets), and how to influence and shift consumer behavior and awareness, as discussed above.

In practice, this means understanding the drivers behind segmentation and the implications for how to target different consumer segments. Segmentation analyses for rural China showed that the three most powerful explainers of behavioral differences among rural consumers were: 1) whether the household was situated in a province with high or low access to coal; 2) whether the household was situated in a remote location (far from town and/or in a mountainous/hilly terrain) or was close to town; and 3) whether the household had low or high income.

These drivers were used in Chapter 2 to group consumers into eight segments that had different behavioral preferences towards their stove and fuel usage and purchase. As a result, understanding these differences has clear implications for the effectiveness of policies and marketing strategies on different consumer segments.

This analysis in combination with the earlier analysis in Chapter 1 on total stove hours by stove purpose and fuel type can be powerful tools for policy makers to stress test their strategies. They provide a useful guide to understand the diversity of behaviors within a given province and/or region, as well as the relative contribution of each consumer segment to the overall problem of solid fuel dependency. Figure I below shows an example of how segments can be prioritized based on 1) their contribution to solid fuel usage (the y axis); 2) their ability to pay (the x axis); and 3) the relative population of each segment (the size of the bubble).

For example, in the analysis below, the "close-to-town, low-medium income coal user" is both a large segment and burns significant average hours of solid fuel. Strategies targeting this segment would be particularly effective in reducing overall solid fuel burning. Importantly, priority segments will differ from province to province based on this analysis. Policy makers should understand the relative sizes and demands of consumer segments in their province, in order to better target their interventions.

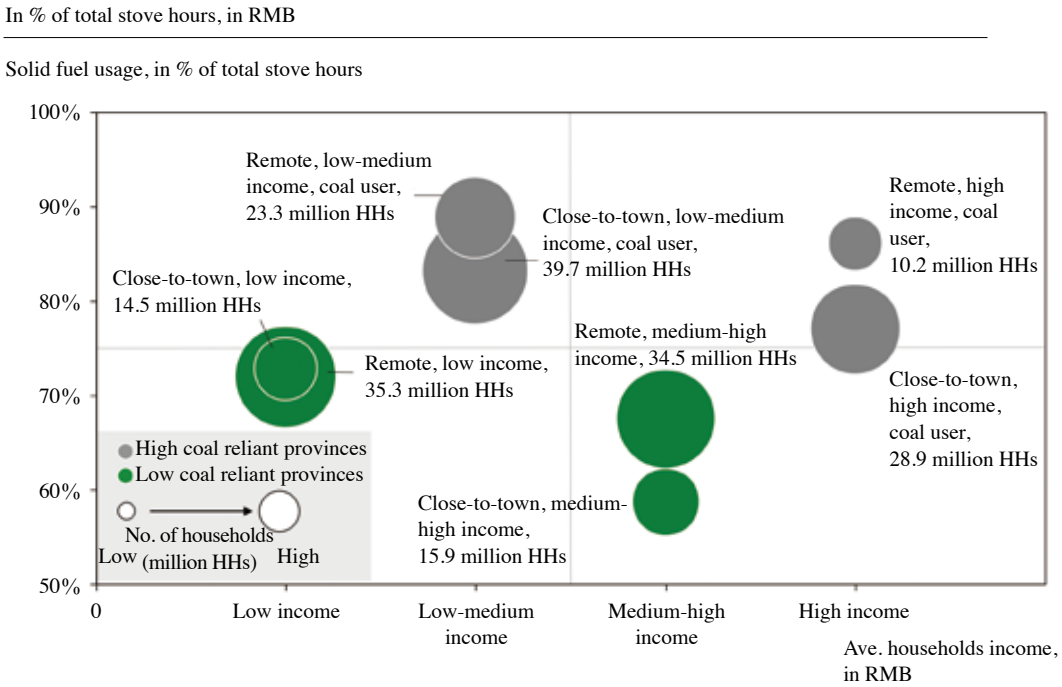


Figure 82 Consumer segmentation prioritization matrix

This report develops only some of the consumer insights and potential policy innovations suggested by the data collected. Both policy makers and manufacturers stand to gain by continuing to invest in understanding consumer segments. The appendix contains more information related to the segmentation analysis. Policy makers and practitioners are encouraged to review this analysis for implications on their strategies going forward.

4.6 The second national stoves program: a top–down approach in contribution to achieve China's climate goals

Although about 180 million homes were reached during the first national program (NISP) in the 1980s-1990s, most of them are not considered "clean" with today's criteria and some of them are not in use now. As mentioned in previous chapter, as of 2013 the current market penetration for

clean cookstoves is 25% and it will only come to 31% by 2020 under the baseline scenario which assumes clean adoption is only driven by economic growth alone and no further interventions (business as usual). The Ministry of Agriculture and the Alliance announced in 2014 a target of 40 million clean and efficient stoves adopted by 2020, if achieved will drive the penetration to 49%. This will only be achieved with strong political will and government policy support.

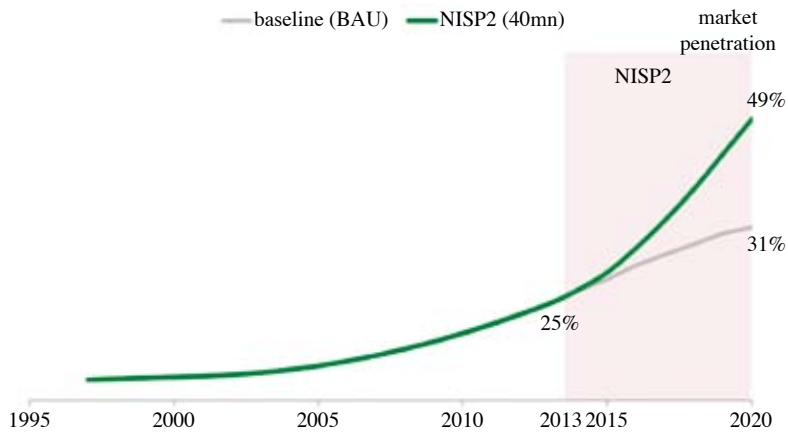


Figure 83 Clean adoption scenarios by 2020

The 18th National Congress of the Communist Party of China announced achieving ecological progress and building a beautiful China as national priorities and the key to lasting and sustainable development of the Chinese nation. Energy conservation, emission reduction and ecological progress were integrated into national priorities by the Party Central Committee and the State Council and were identified as key to national economy and people's livelihood, synergy between social, resource and environment, and a pathway to sustainability. Promoting clean and efficient stoves is consistent with this national strategy and will contribute to China's emission reduction goals in the rural sector.

In order to achieve the 40 million target, a new national program of clean stoves launched by the central government is recommended. This large-scale, top-down program should focus on four principles, "localized, leveraging, innovation and action-driven" and the technology deployment can be on a village basis focusing on not only clean stoves and fuels but also broader household clean energy solutions to bring environment, livelihood, energy, carbon, ecological benefits. As a first step, 500 demonstration villages will be built during the 13th Five-Year Plan from 2016-2020, 100 each year. The new national program will boost innovation on clean stoves and biomass pellets technology and explore a new public-private partnership in distributing clean stoves which is government-led, manufacture-driven, market-based and consumer-involved. It will also drive rural energy infrastructure upgrade and a win-win of economic-environmental benefits. The model and results of these demonstration villages will be duplicated in surrounding

areas and scale up to entire provinces to reach 40 million homes eventually. As estimated, 186 million RMB is needed upfront to jump start this program and 62 million RMB will be subsidized by central finance. The new national stove program will save 60,000 tons of coal equivalent annually, 180,000 tons of coal equivalent CO_2 and SO_2 combined.

4.7 Start with a pilot effort in five regions to launch new interventions

As mentioned in Chapter 2, China is highly diverse and stove demand is largely driven by regional difference in climate, fuel availability and local food and cooking habits. Therefore, tailored and localized solutions are more effective and should launch in multiple locations for comparison. In the next step, the Alliance and REEA plan to launch 1-2 pilot projects in each of the typical Five Regions applying data, tools and recommendations, especially the segmentation analysis, from this assessment to adopt a market-based approach in promoting clean stoves and fuels and using subsidies more efficiently before completely eliminated. Specific interventions during the pilot program include fuels-driven strategy (build the distributed biomass pellets infrastructure), microfinance, new marketing and distribution strategy, incentives programs (rewards, voucher).

The following locations have been chosen for the pilot projects: Beizhen county of Liaoning province for the Northeastern Plain region, Liquan county of Shaanxi province and Yuzhong county of Gansu province for the Northwestern Arid region, Qinhuangdao county of Hebei province and Xixia county of Henan province for the Huang-huai Sea Plain region, Pengshui county of Chongqing city for the Southwestern Plateau Mountainous region, and Xuan'en county of Hubei province for the Southeastern Hills region. In biomass rich areas such as Hebei, Liaoning, Henan, Hubei, Chongqing and Sichuan, the Alliance and REEA will have a focus on fuel interventions including incubating small scale biomass pellets entrepreneurs and factories.

In response to the Air Pollution Prevention and Control Action Plan, Heibei provincial government distributed 1.32 million stoves in 2014, of which 450,000 clean stoves were distributed through government subsidy programs. The program saved 657,500 tons of coal and produced 1.6 million tons of biomass pellets. Given its success, the government is planning to expend the program in 2015—2017 with a target of 6 millions of clean adoption in three years. The priority areas include 510 villages in 9 districts, 7934 villages in the capital beltway area and the villages in modern agricultural industrial park zone. Incentives will be provided for coal-switching to cleaner fuels such as biomass pellets, electricity and solar. This renewed program will bring clean stove penetration to over 80% in this province, at least 1 million homes adopting biomass pellets, replacing 15 million tons of coal which is 37.5% of total coal consumption in Hebei, reducing 500,000 tons of SO_2 and 500,000 tons of particulate matter.

5. Conclusion

This report has provided an in-depth market assessment of stoves and fuels for rural China. It has identified the barriers and challenges to catalyzing greater adoption of cleaner cooking and heating, through a detailed analysis of demand and supply. Four specific actions were recommended, as part of a second national program, to address the current challenges and promote cleaner cooking and heating.

Implementation of these recommendations going forward will require collaboration. The implications of stove and fuel policy cuts across issues affecting health, agriculture, energy, women, and environmental protection. As a result, there will need to be continued dialogue and coordination among relevant government agencies.

In collaboration with the Alliance, the Chinese government is committed to promote adoption of clean stoves and fuels in 40 million households by the year 2020. Together, the Alliance and REEA have committed to a pilot effort during Alliance Phase II from 2015 to test and refine the recommendations in this report. The results of the pilot will then inform a scaled national program to be implemented in 2016—2020.

The pilot phase will need to be supported by targeted research and analysis to further strengthen and adapt the recommendations to local contexts. There are three specific opportunities for next-stage research:

1) Determining the right level of subsidy allocation and pricing based on the revised approaches to subsidy policy as outlined in Chapter 4;

2) Estimating the impact of the recommendations and strategies on environmental impacts, and in particular carbon dioxide and PM2.5 emissions;

3) Exploring mechanisms and interventions for market-based approach;

4) Developing stronger links to capture the opportunity in China's new domestic carbon markets.

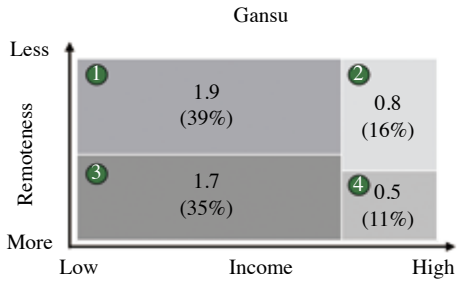
Planning for these pilots and next-stage research with national, provincial and local governments has already begun. The Alliance looks forward to working with all stakeholders in China and a detailed work plan for China will be released in due course.

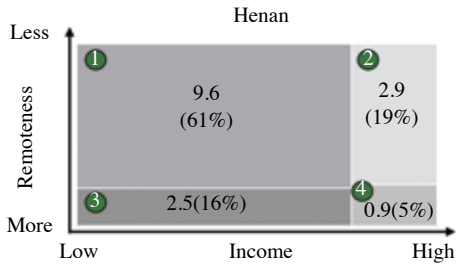
As a final remark, there is an opportunity not just to improve China's domestic goals through the second national program, but also to show international leadership in clean cookstoves through South-South cooperation. China could play a global role as a center for research, and an exporter of quality stoves and effective policies for clean cooking around the world.

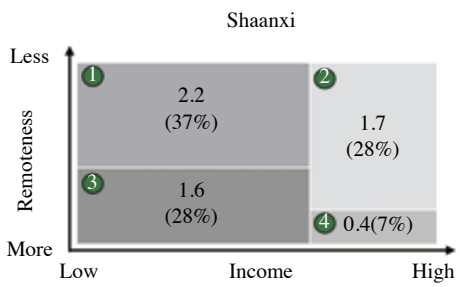
Appendices

Appendix I Sizing consumer segments

This section contains the market size of consumer segments for the 6 priority provinces.







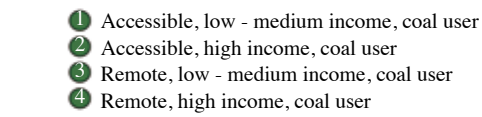
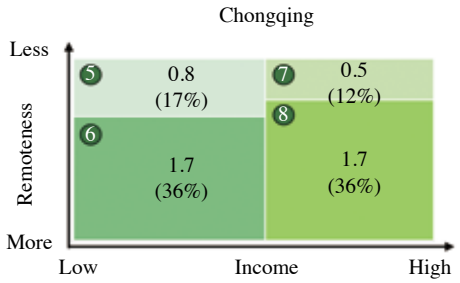
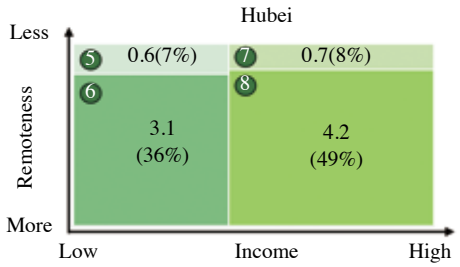
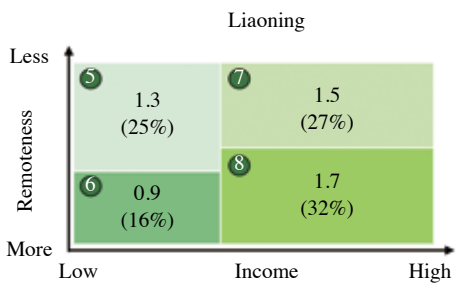


Figure 1 Consumer segments in provinces with higher reliance on coal







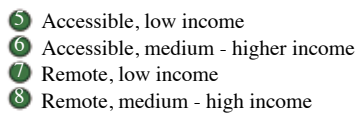


Figure 2 Consumer segments in provinces with lower reliance on coal

Appendix II Toolkit for provincial policy setting

For each of the 6 priority provinces this section contains key analyses for the first two of the three questions addressed in the toolkit for provincial leaders.

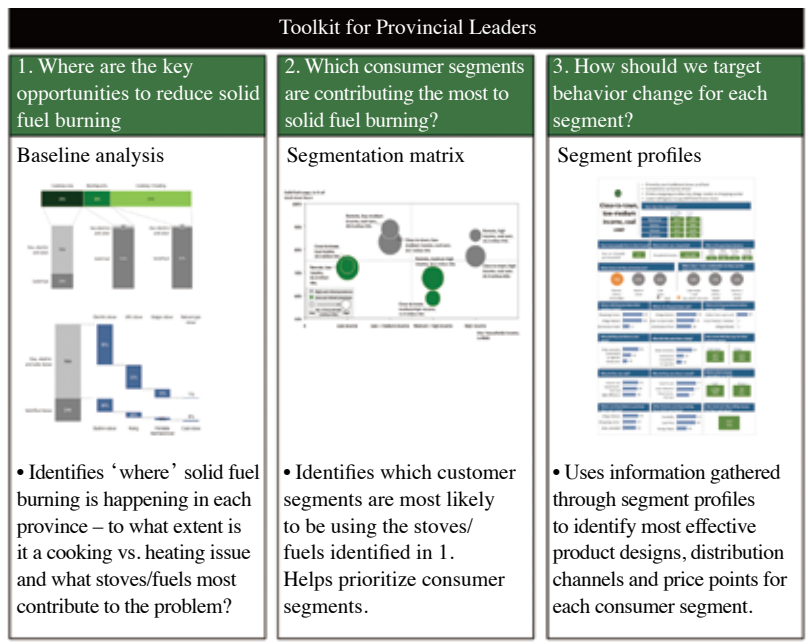


Figure 3 Toolkit for Provincial leaders

1. Chongqing

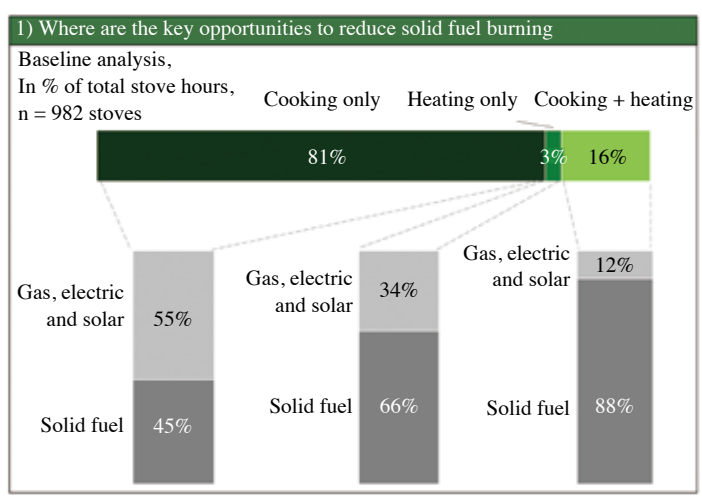


Figure 4 Baseline analysis for Chongqing

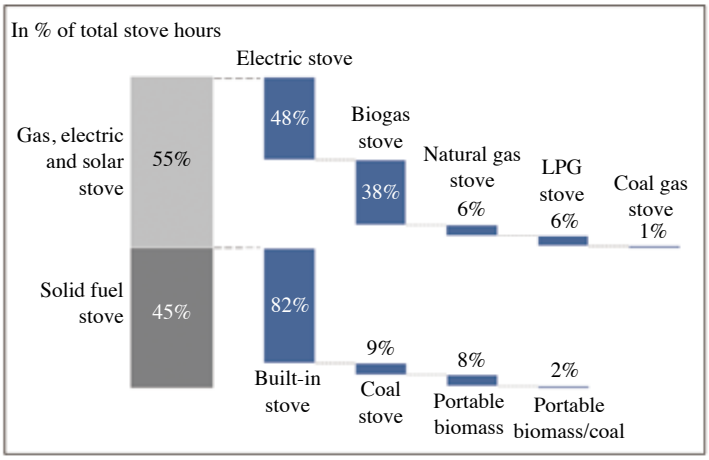


Figure 5 Breakdown of stove type for cooking only stoves in Chongqing

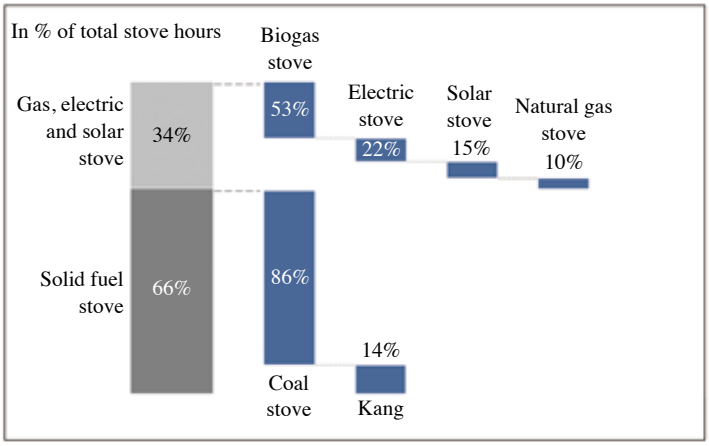


Figure 6 Breakdown of stove type for heating only stoves in Chongqing

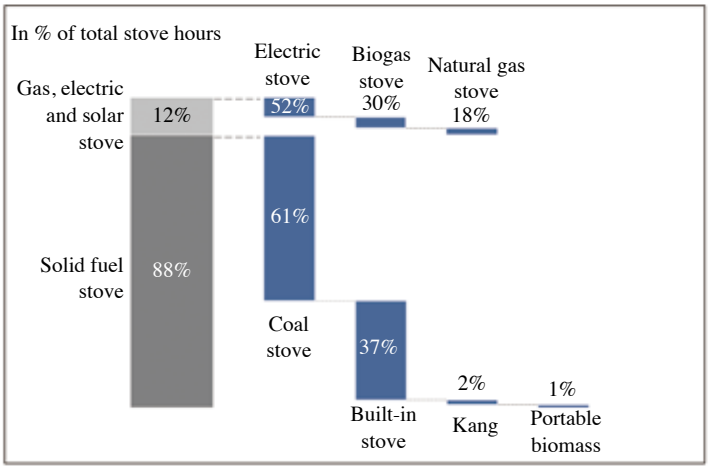


Figure 7 Breakdown of stove type for cooking + heating stoves in Chongqing

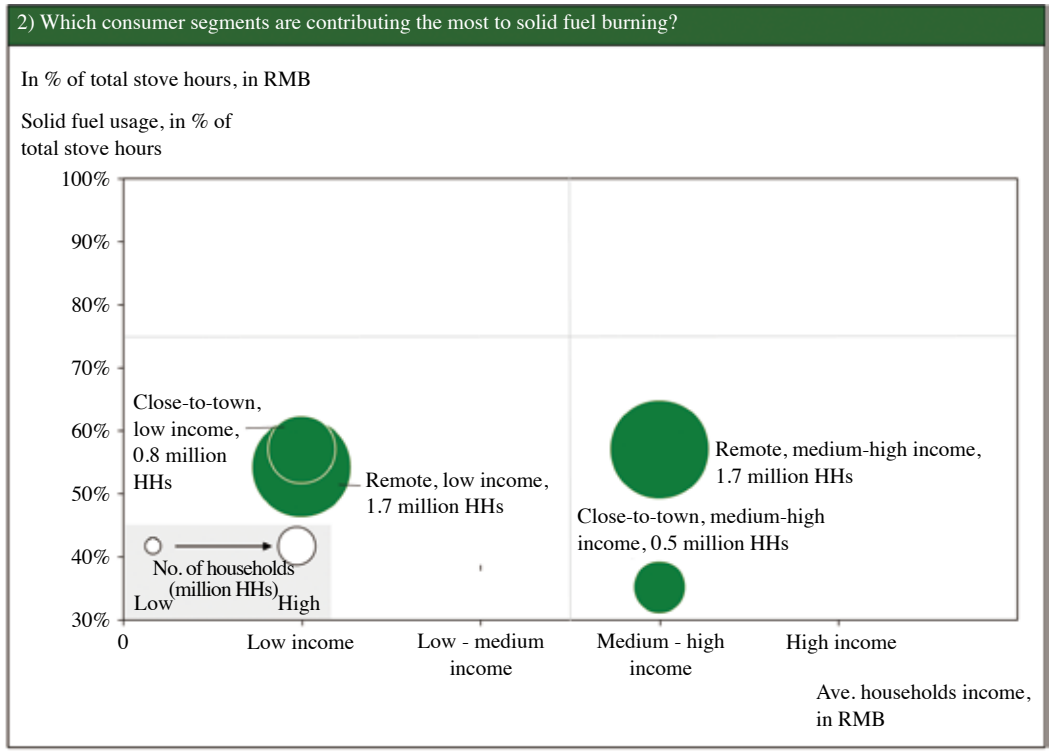


Figure 8 Segment Prioritization matrix for Chongqing

2. Gansu

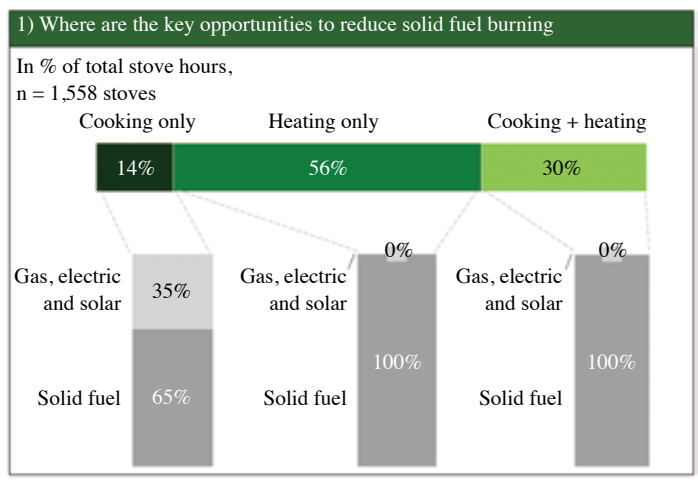


Figure 9 Baseline analysis for Gansu

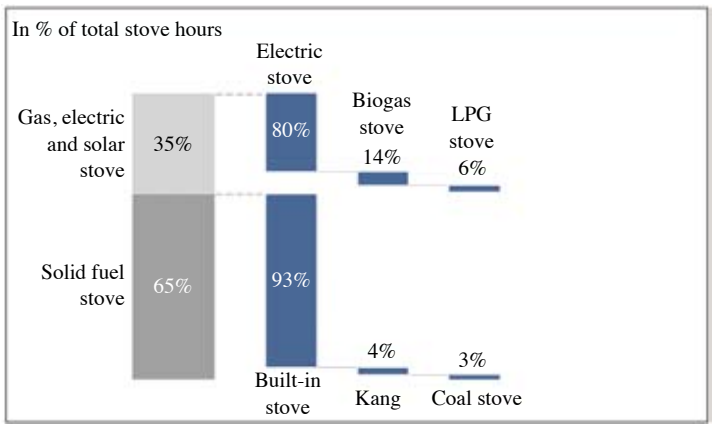


Figure 10 Breakdown of stove type for cooking only stoves in Gansu

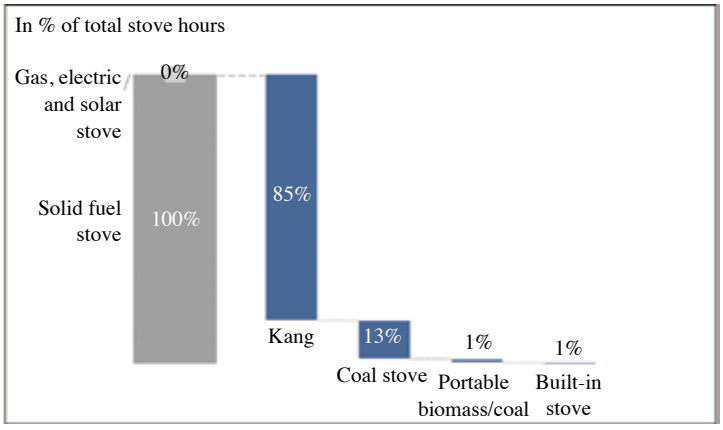


Figure 11 Breakdown of stove type for heating only stoves in Gansu

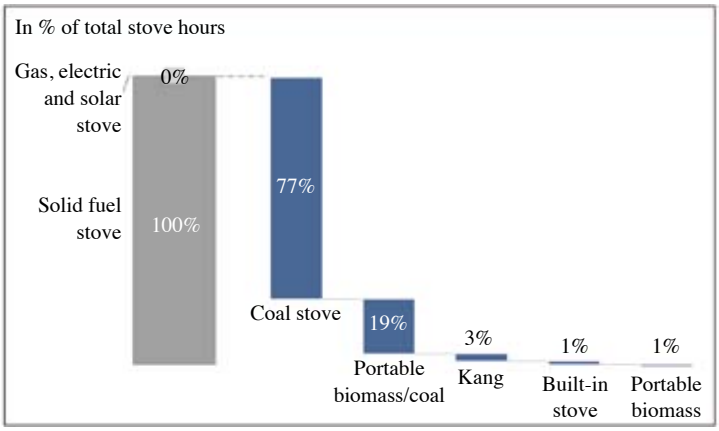


Figure 12 Breakdown of stove type for cooking + heating stoves in Gansu

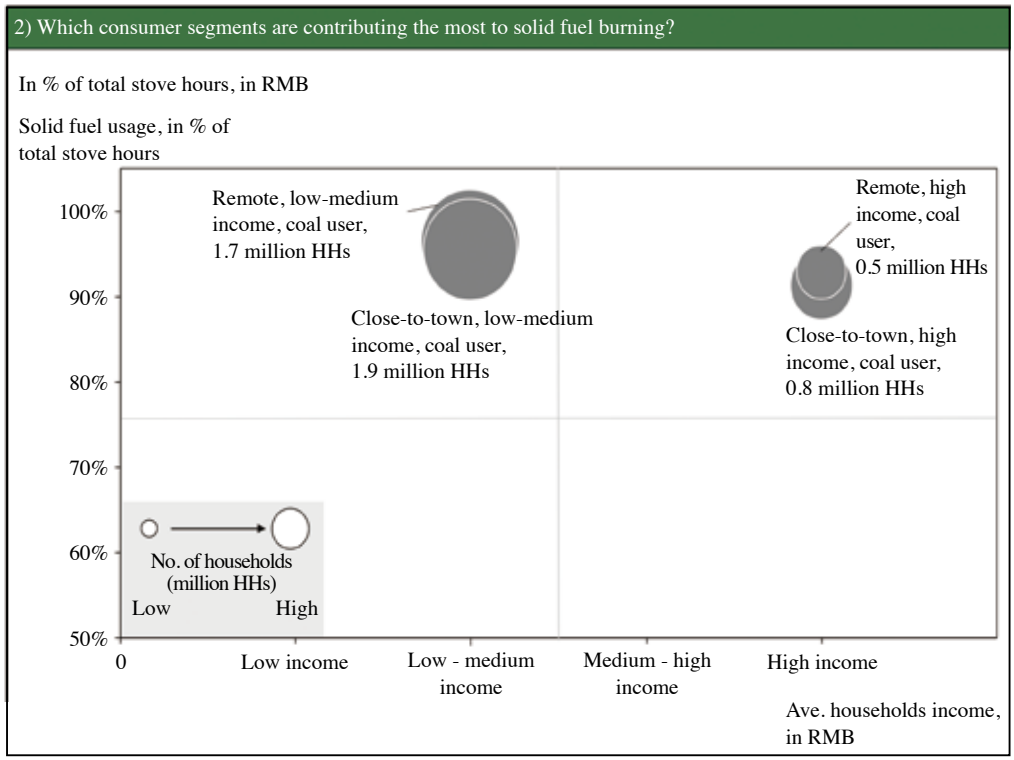


Figure 13 Segment Prioritization matrix for Gansu

3. Henan

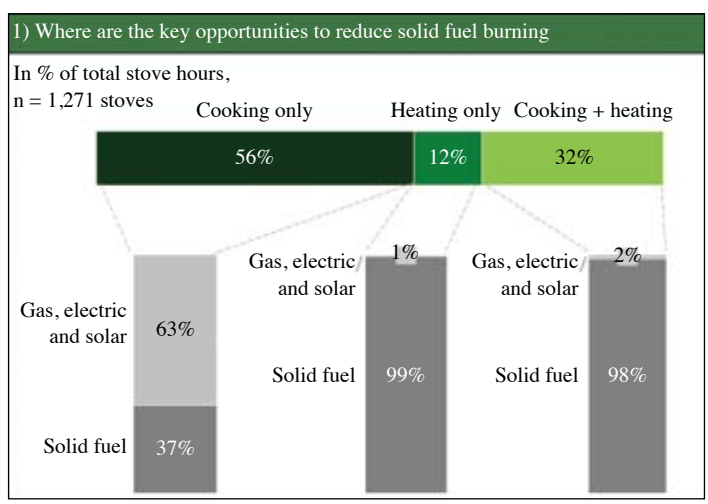


Figure 14 Baseline analysis for Henan

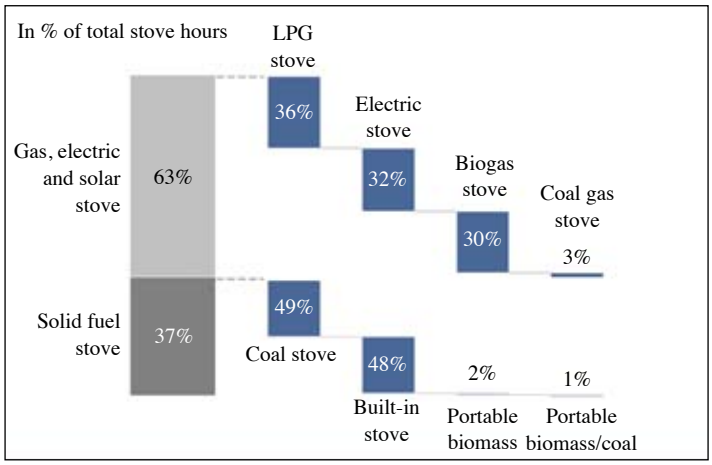


Figure 15 Breakdown of stove type for cooking only stoves in Henan

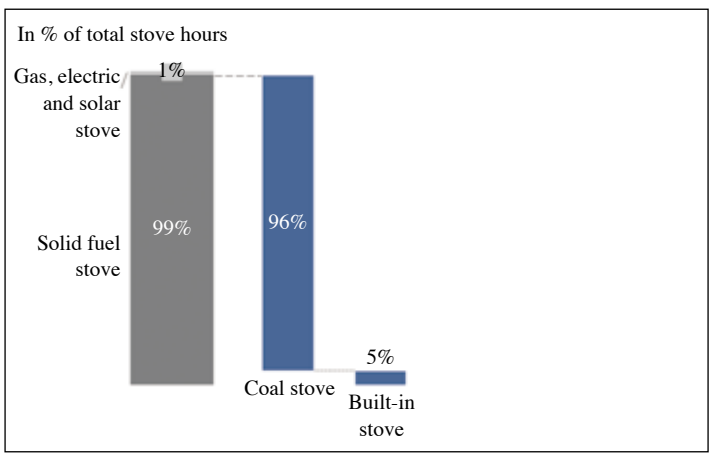


Figure 16 Breakdown of stove type for heating only stoves in Henan

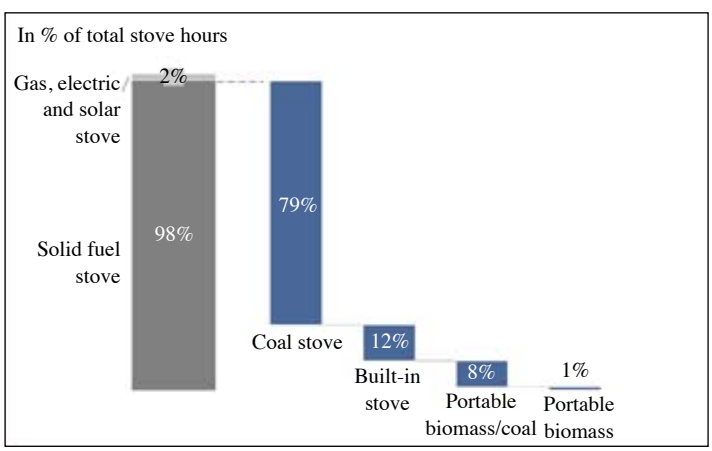


Figure 17 Breakdown of stove type for cooking + heating stoves in Henan

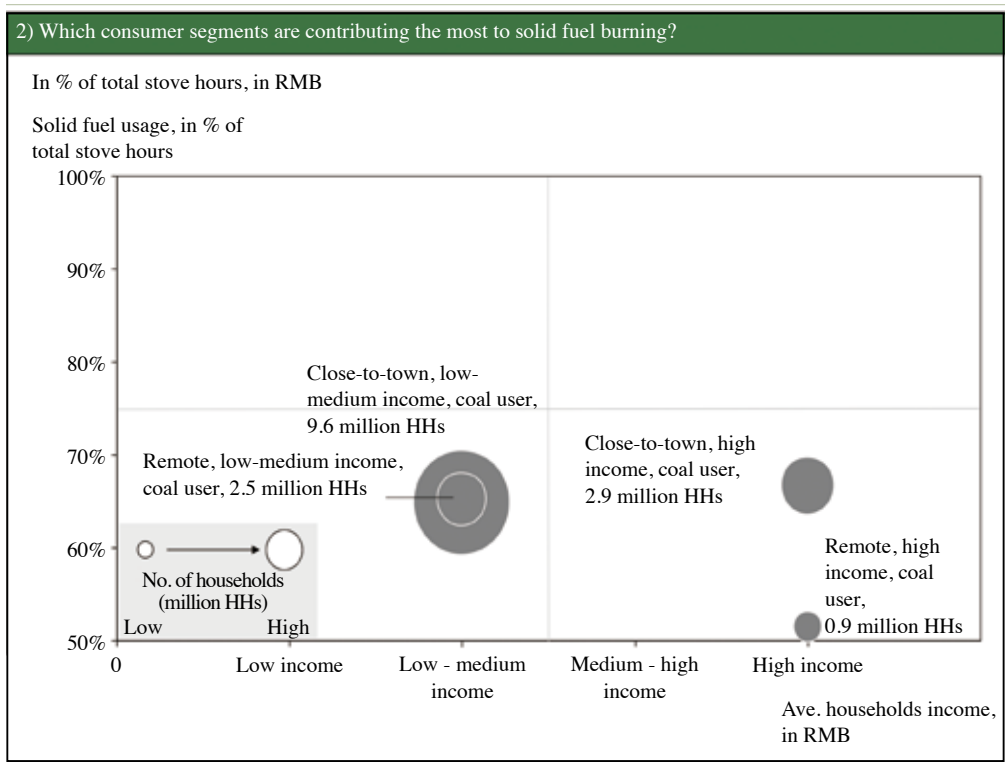


Figure 18 Segment Prioritization matrix for Henan

4. Hubei

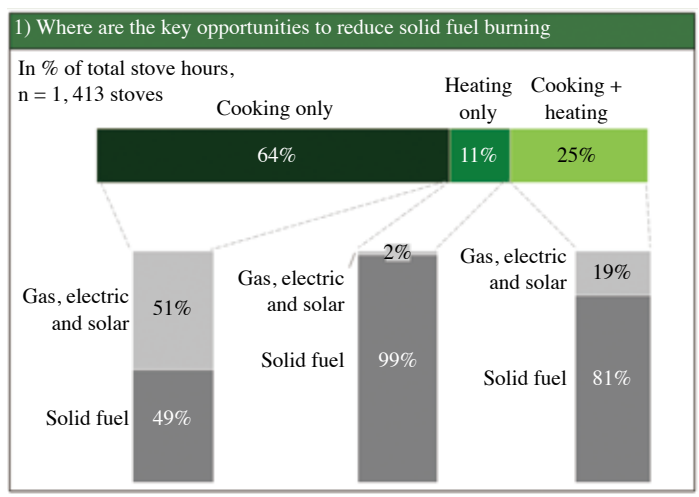


Figure 19 Baseline analysis for Hubei

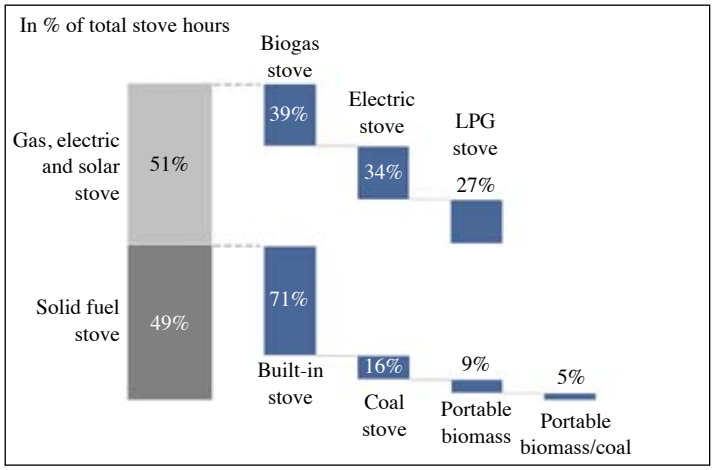


Figure 20 Breakdown of stove type for cooking only stoves in Hubei

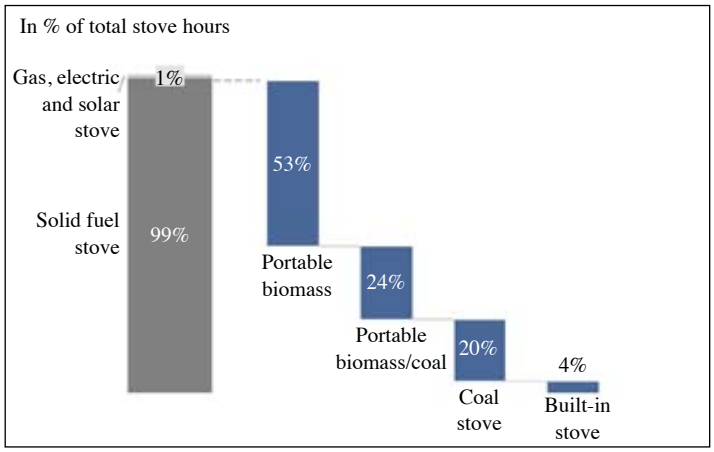


Figure 21 Breakdown of stove type for heating only stoves in Hubei

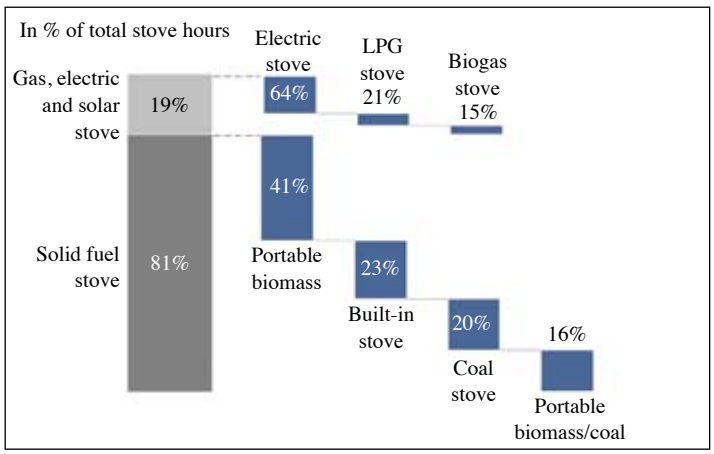


Figure 22 Breakdown of stove type for cooking + heating stoves in Hubei

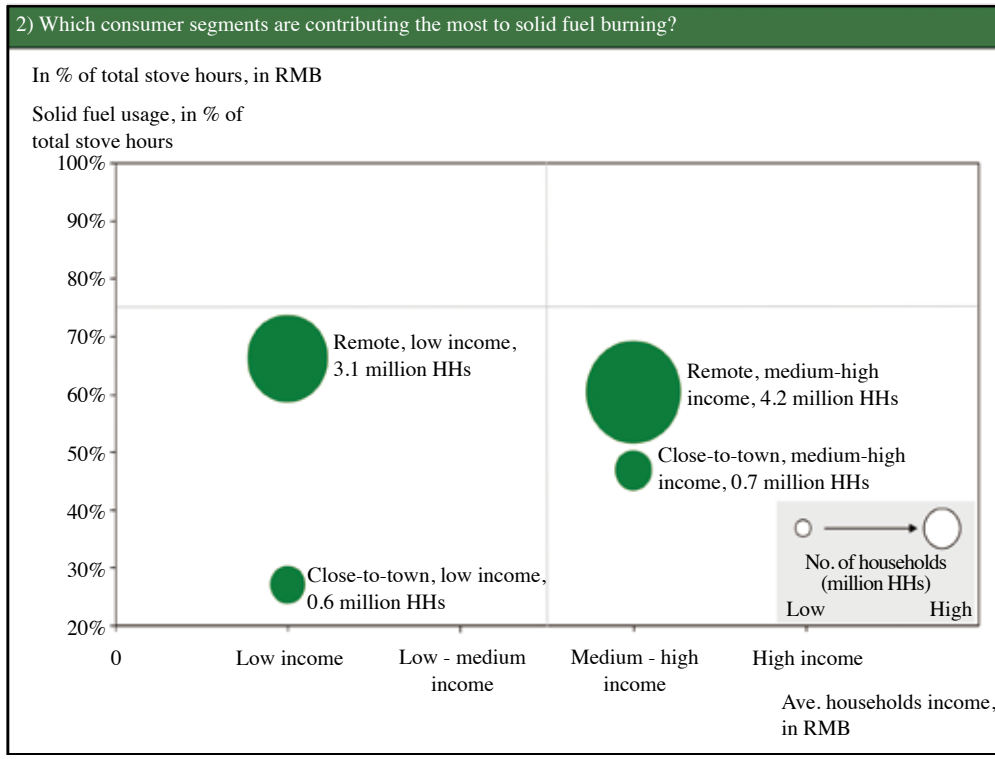


Figure 23 Segment Prioritization matrix for Hubei

5. Liaoning

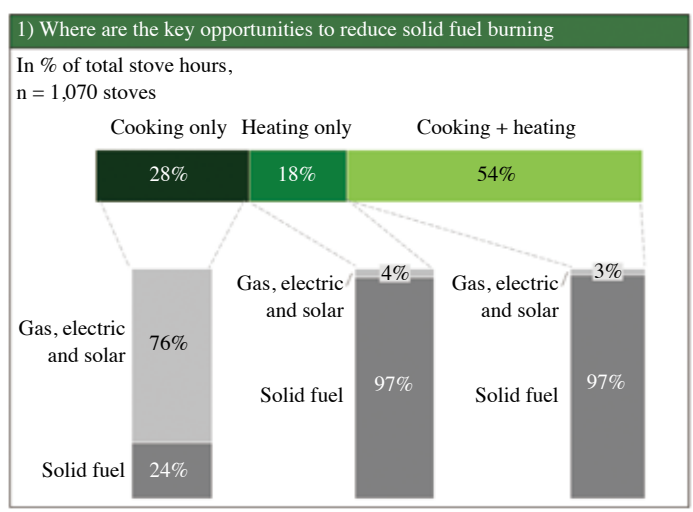


Figure 24 Baseline analysis for Liaoning

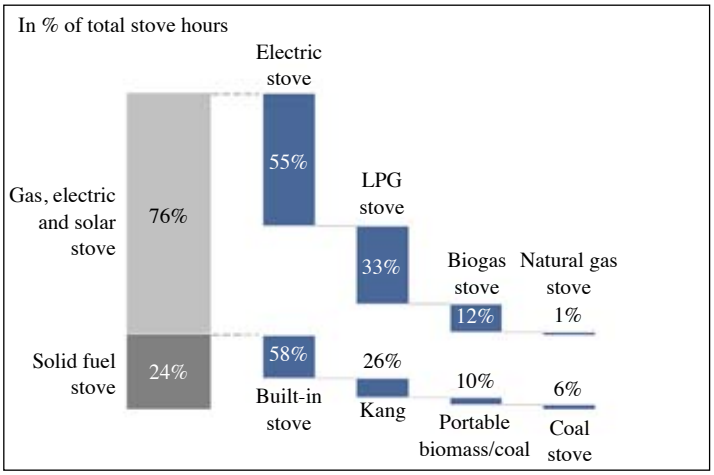


Figure 25 Breakdown of stove type for cooking only stoves in Liaoning

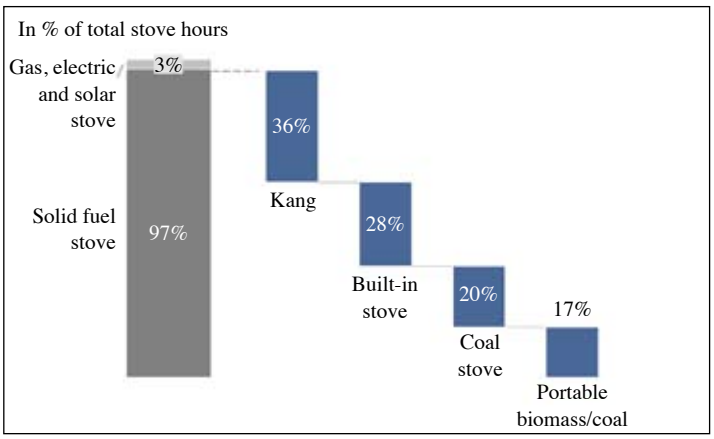


Figure 26 Breakdown of stove type for heating only stoves in Liaoning

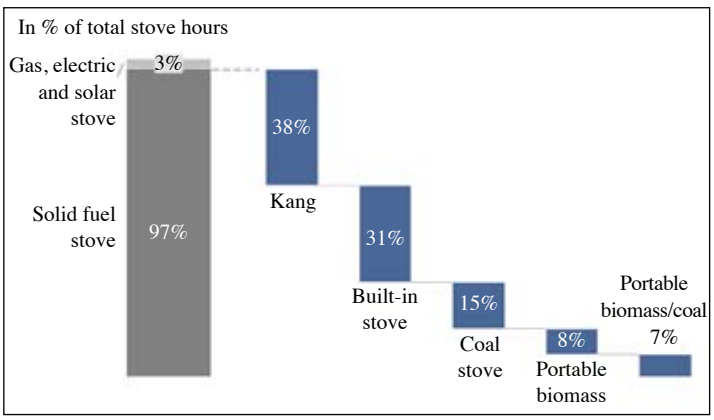


Figure 27 Breakdown of stove type for cooking + heating stoves in Liaoning

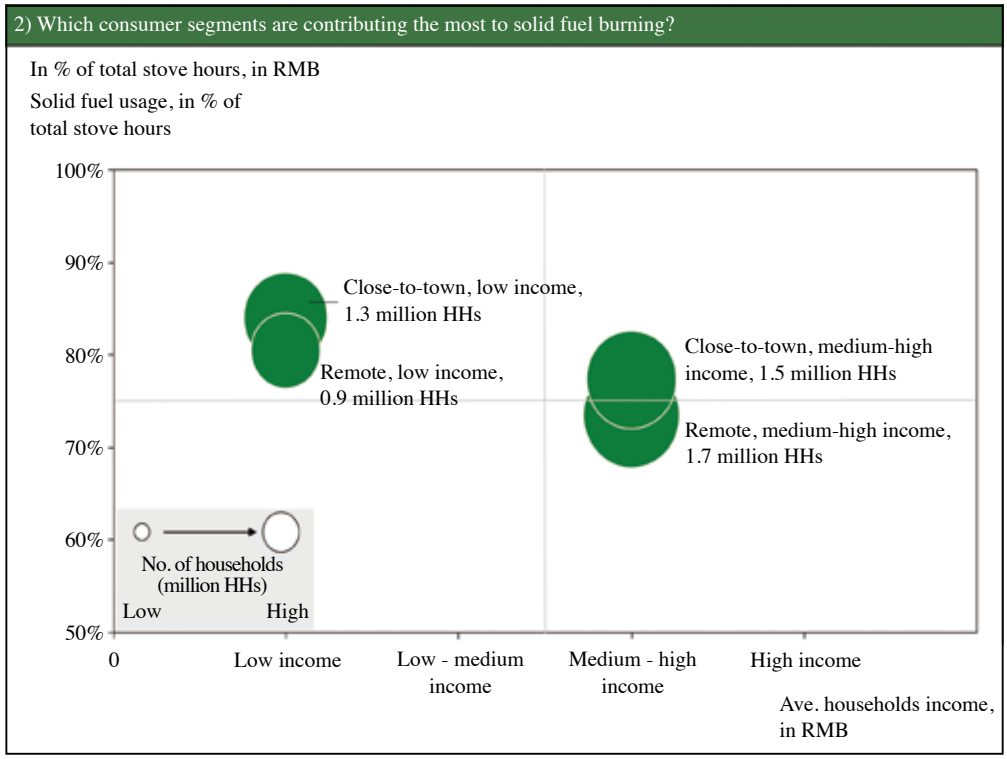


Figure 28 Segment Prioritization matrix for Liaoning

6. Shaanxi

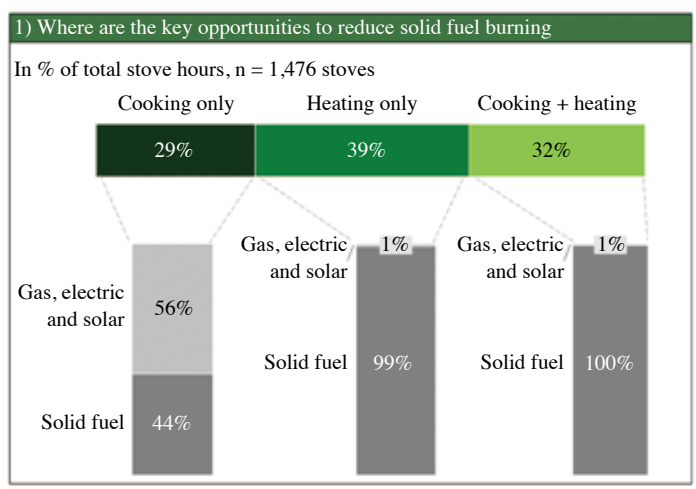


Figure 29 Baseline analysis for Shaanxi

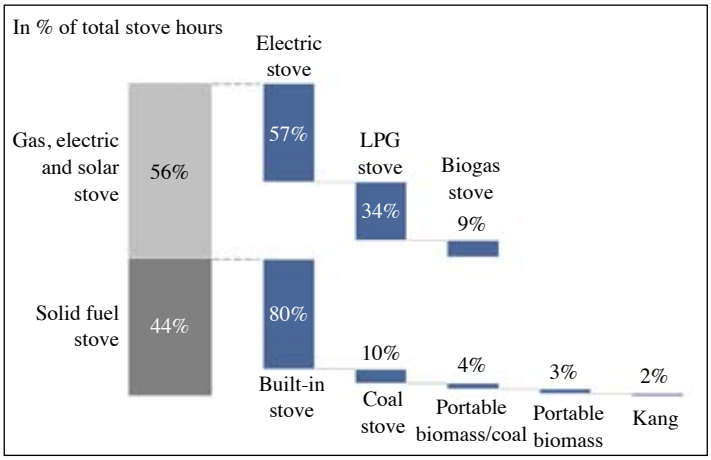


Figure 30 Breakdown of stove type for cooking only stoves in Shaanxi

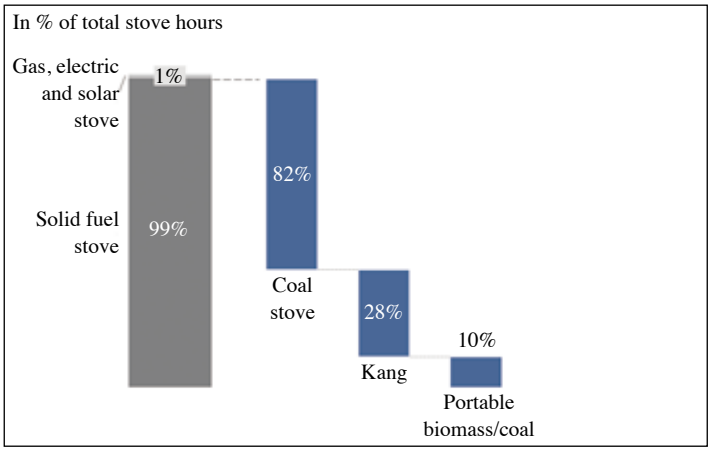


Figure 31 Breakdown of stove type for heating only stoves in Shaanxi

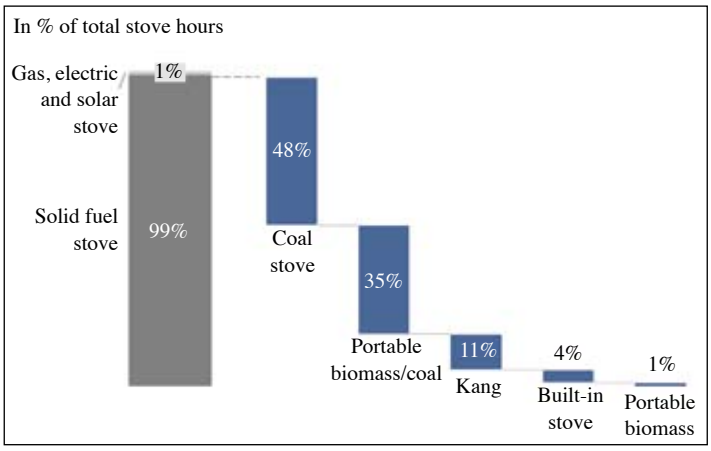


Figure 32 Breakdown of stove type for cooking + heating stoves in Shaanxi

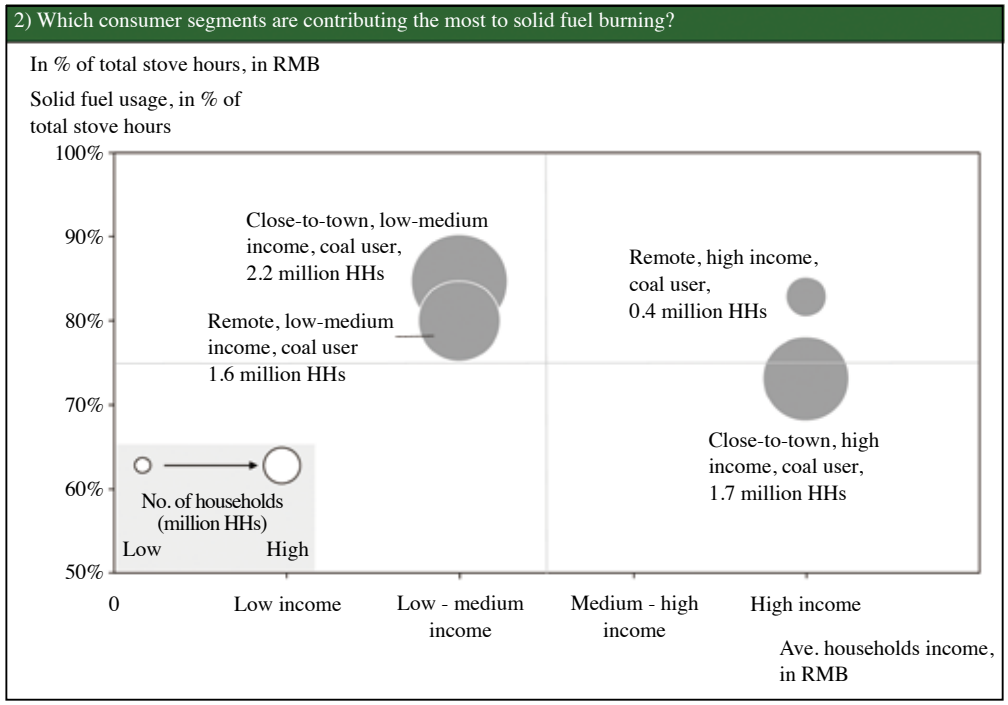


Figure 33 Segment Prioritization matrix for Shaanxi

Appendix III　Stove and Fuel Opportunity Maps

1. Chongqing

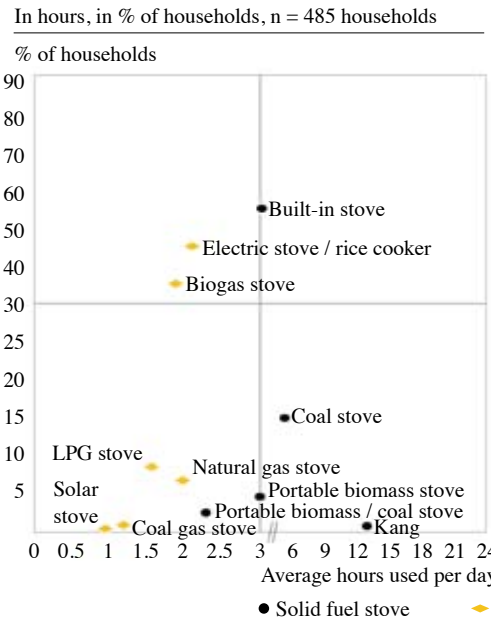


Figure 34　Chongqing's stove map in winter months

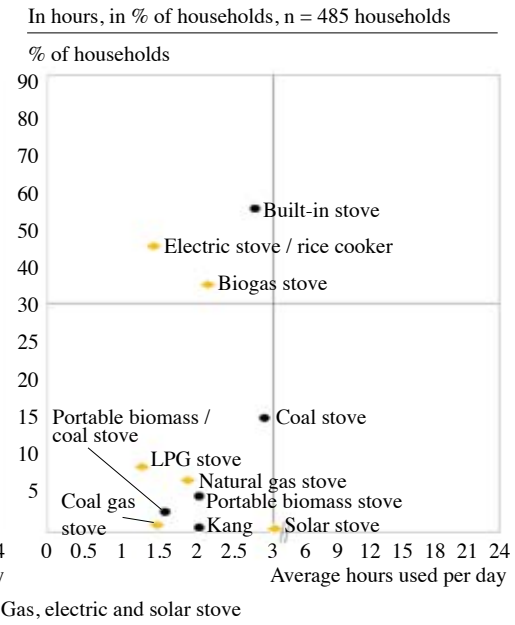


Figure 35　Chongqing's stove map in non-winter months

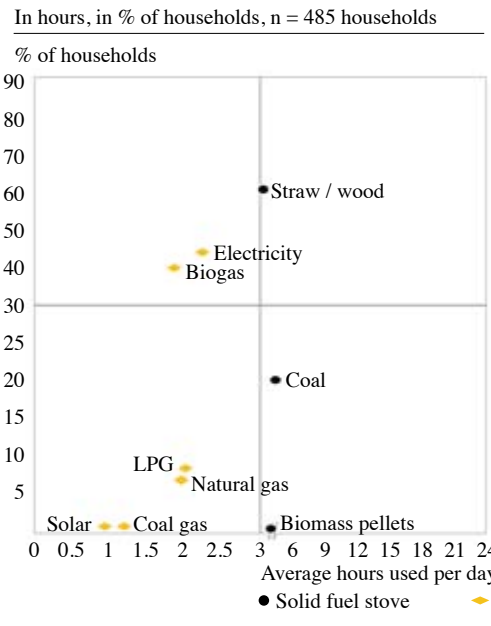


Figure 36　Chongqing's fuel map in winter months

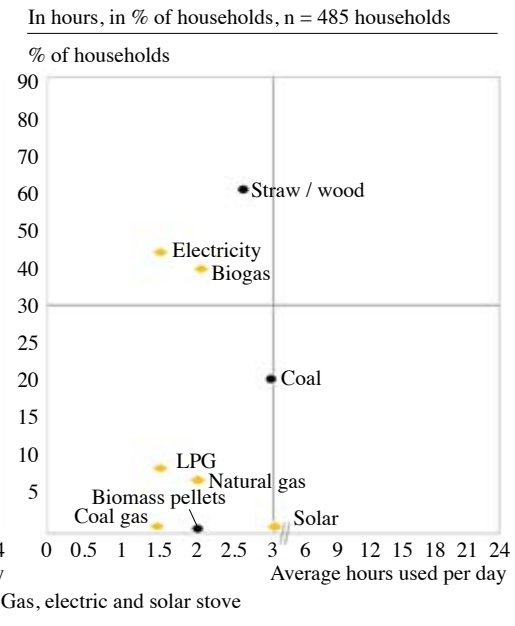


Figure 37　Chongqing's fuel map in non-winter months

2. Gansu

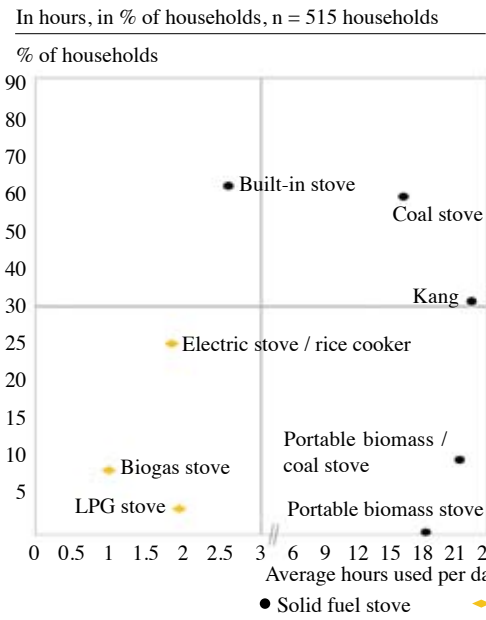


Figure 38 Gansu's stove map in winter months

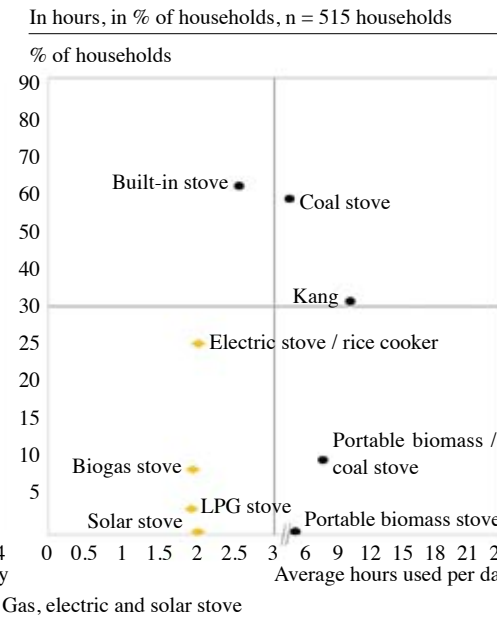


Figure 39 Gansu's stove map in non-winter months

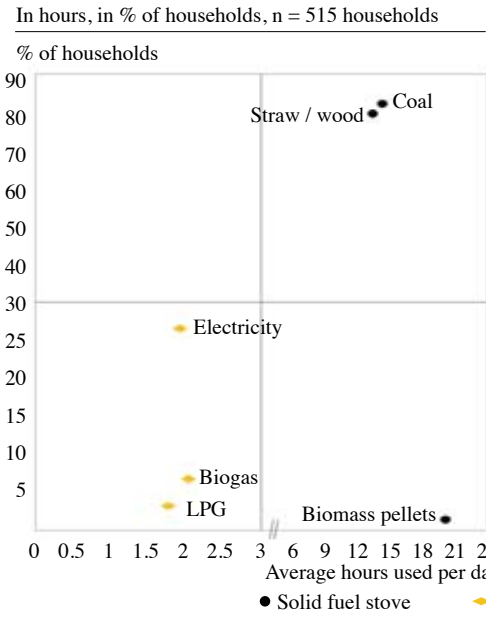


Figure 40 Gansu's fuel map in winter months

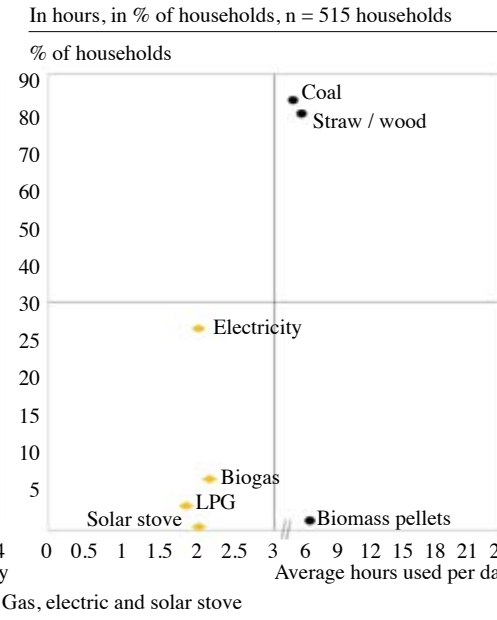


Figure 41 Gansu's fuel map in non-winter months

3. Henan

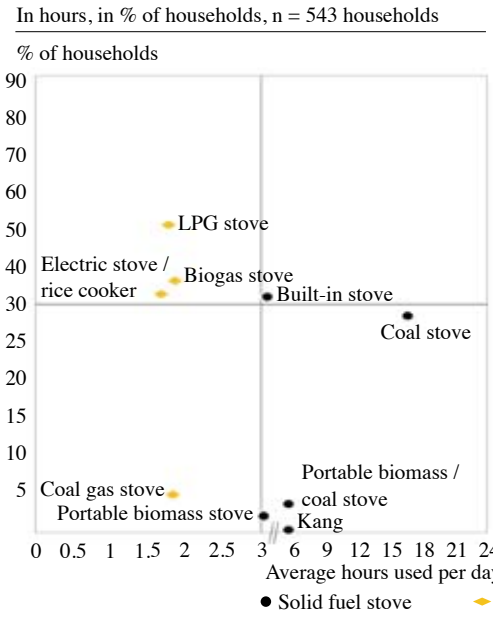


Figure 42 Henan's stove map in winter months

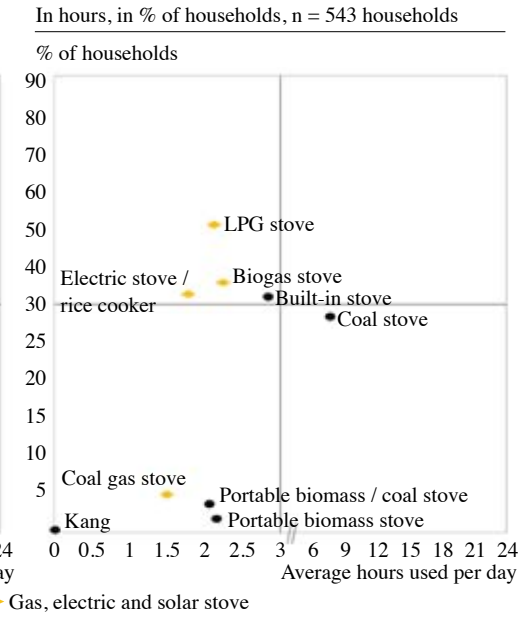


Figure 43 Henan's stove map in non-winter months

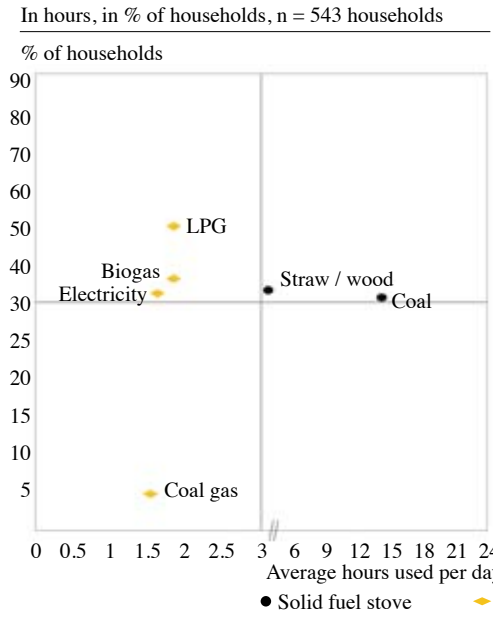


Figure 44 Henan's fuel map in winter months

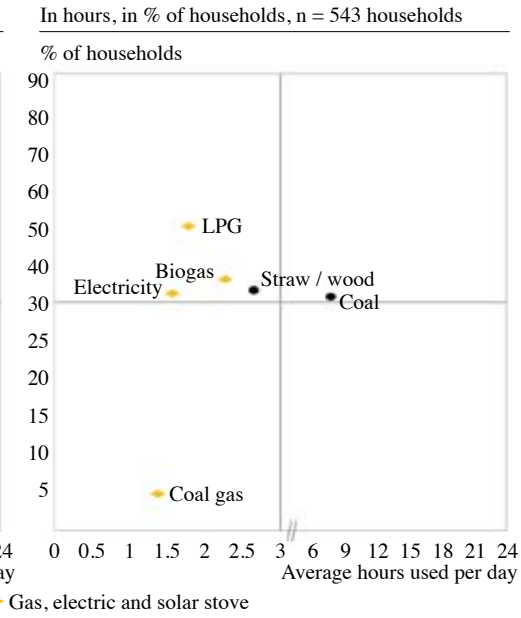


Figure 45 Henan's fuel map in non-winter months

4. Hubei

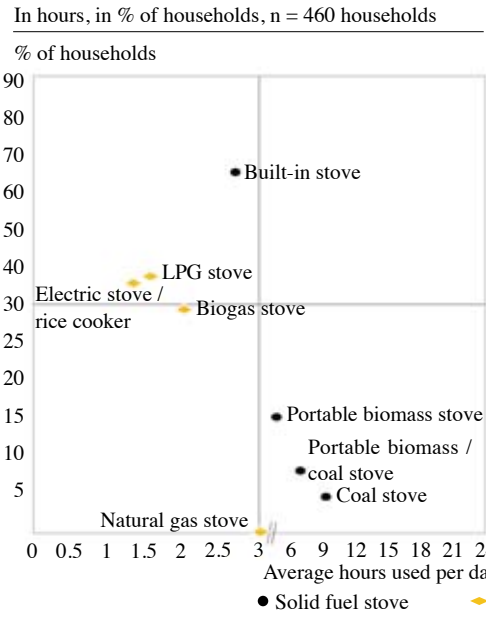


Figure 46 Hubei's stove map in winter months

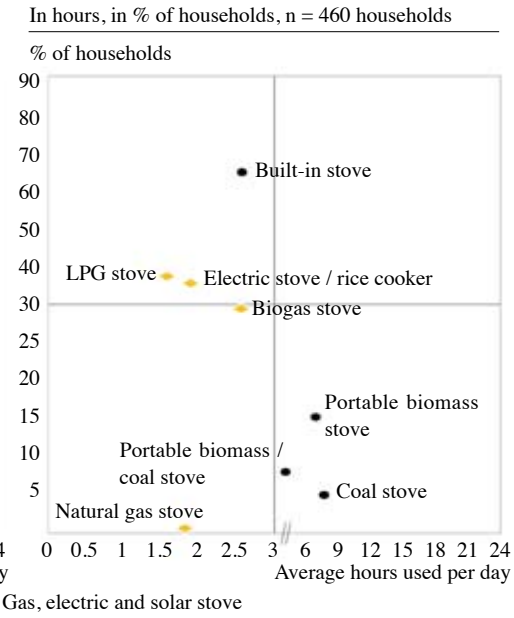


Figure 47 Hubei's stove map in non-winter months

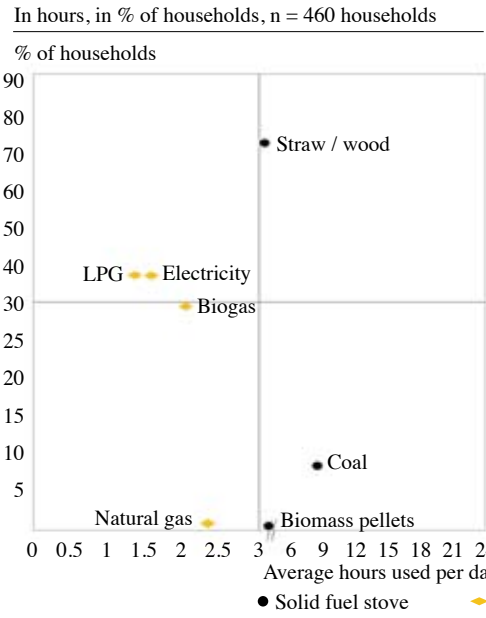


Figure 48 Hubei's fuel map in winter months

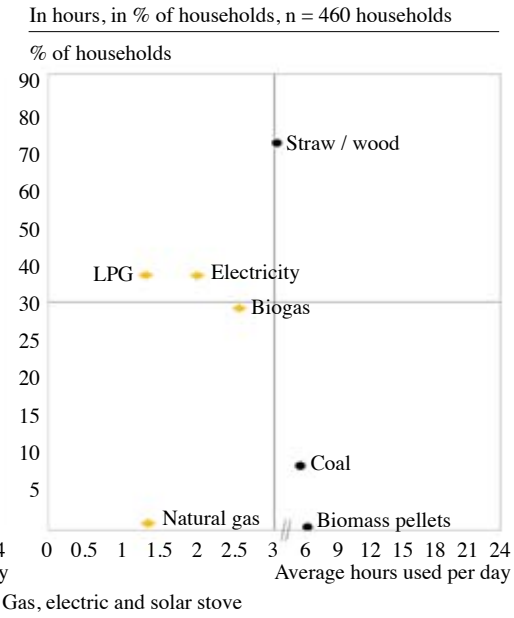


Figure 49 Hubei's fuel map in non-winter months

5. Liaoning

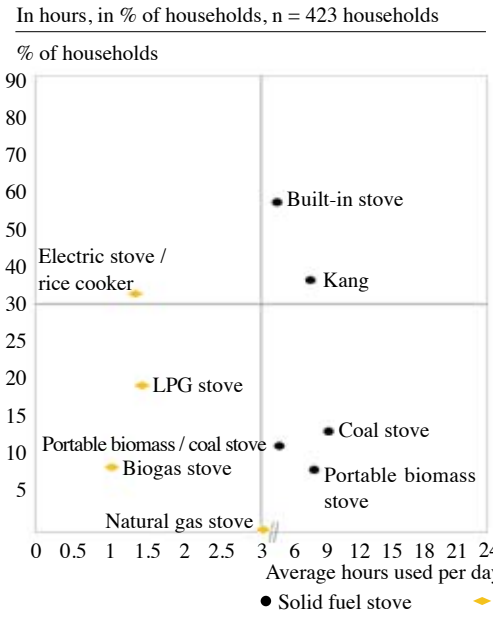


Figure 50 Liaoning's stove map in winter months

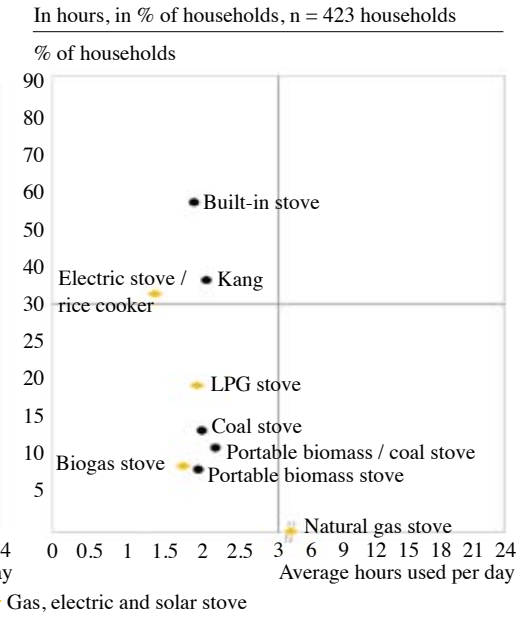


Figure 51 Liaoning's stove map in non-winter months

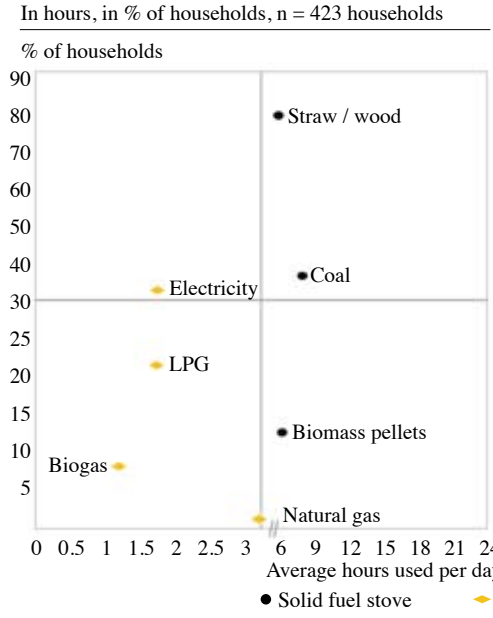


Figure 52 Liaoning's fuel map in winter months

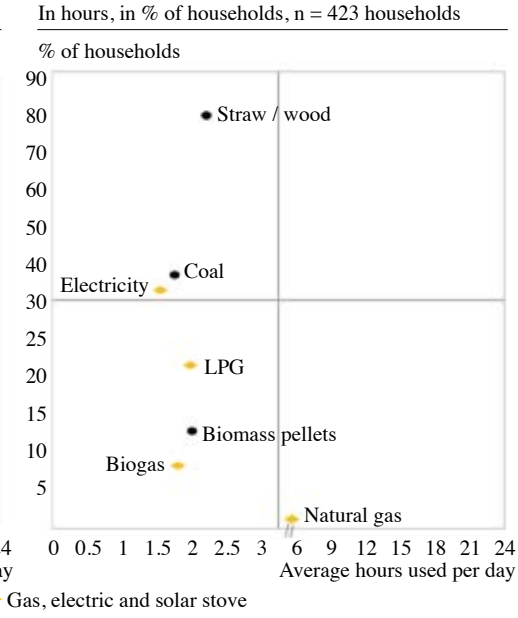


Figure 53 Liaoning's fuel map in non-winter months

6. Shanxi

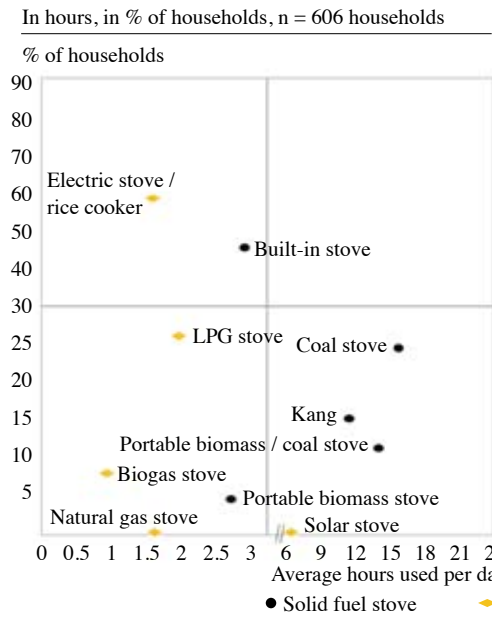


Figure 54 Shaanxi's stove map in winter months

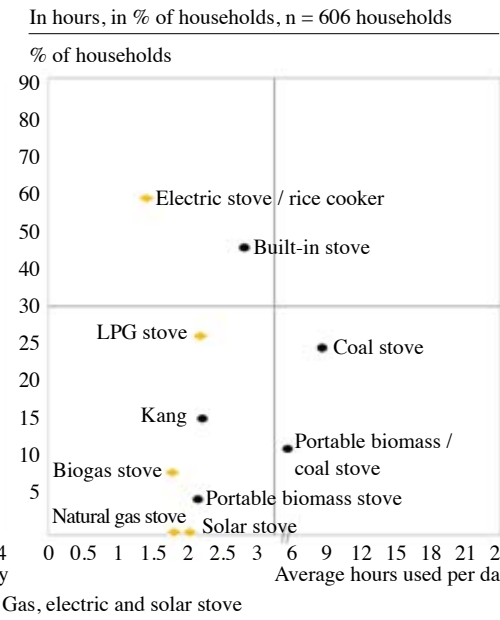


Figure 55 Shaanxi's stove map in non-winter months

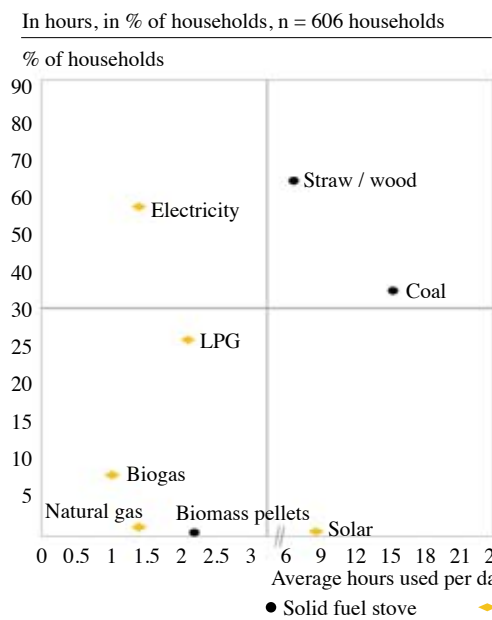


Figure 56 Shaanxi's fuel map in winter months

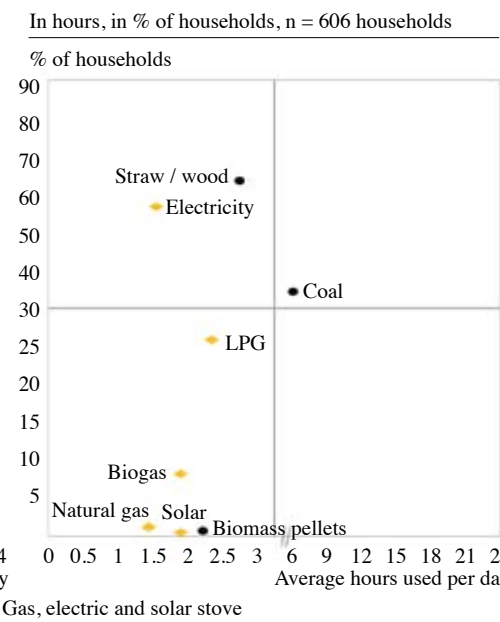


Figure 57 Shaanxi's fuel map in non-winter months

Appendix IV Survey Questionnaires

1. Rural Household Survey Questionnaire

Surveyor name:_____ Surveyor contact phone number:_____ Survey Date:_____

I. Basic survey location information

County (city) name:_____ Town name:_____ Official Village:_____

Landscape: ☐ Plain ☐ Mountainous ☐ Hills Elevation:_____Meters

Distance to the nearest town/city center____Kilometers

Winter heating time:____Months Lowest temperature in winter:____ Celcius

II. Basic respondent information

Name: _____Age:_____ Gender:_____

Employment status: ☐ Farming ☐ Labourq Business ☐ Retired ☐ Unemployed ☐ Other__

III. Household information

1. How many people live in your home?___

Age	Gender	Number
< 10 years	male	
	female	
10 - 18 years	male	
	female	
18 - 60 years	male	
	female	
> 60 years	male	
	female	

2. How many household members earn income through working and living long-term outside of home (from a job or business)?___ (Long-term outside the home means more than half a year away from home county)

3. In the last three years, what was your average annual net household income? (circle one)

a.	<10000 元
b.	10000 - 20000 元
c.	20000 - 30000 元
d.	30000 - 40000 元
e.	40000 - 60000 元
f.	>60000 元

4. What are the primary and secondary sources of RMB income of your household?

Primary	Secondary
a. Farming	a. Farming
b. Outside of home village labor (non-farming)	b. Outside of home village labor(non-farming)
c. Commercial business (local non-farming labour、shop owner、land/house rental)	c. Commercial business (local non-farming labour、shop owner、land/house rental)
d.Remittances (money sent by a friend or relative)	d. Remittances (money sent by a friend or relative)
e. Other_____	e. Other _____

IV.Current household stove and fuel usage

5. At present, what fuels do you use in your household (Select the type of fuel first and then answer the questions associated)

Sr.	Type	Method to obtain	Price/amount	Why would you choose this fuel？	Purchase channel
a.	Straw/wood	Buy	Price_____元/year	①Stove only burns this fuel ②Fuel has high efficiency ③Less smoke, little odor, clean ④Easy to use ⑤Low fuel price ⑥Easy to buy/accessible ⑦Does not affect food taste ⑧Other_____	①Village market ②Door to door sales ③From friends or relatives ④Other_____
		Own collection	Time spent collecting____ days/year (1 day=8 hours)		①Straw/wood collection from own land ②Collection in the mountains/forest
b.	Biomass Pellet	Buy	Price_____元/year	①Stove only burns this fuel ②Fuel has high efficiency ③Less smoke, little odor, clean ④Easy to use ⑤Low fuel price ⑥Easy to buy/accessible ⑦Does not affect food taste ⑧Other_____	①Village market ②Door to door sales ③Distribution point ④Internet ⑤Government program ⑥Other_____

(continued)

Sr.	Type	Method to obtain	Price/amount	Why would you choose this fuel ?	Purchase channel
c.	Coal	Buy	Price_____元/year	① Stove only burns this fuel ② Fuel has high efficiency ③ Less smoke, little odor, clean ④ Easy to use ⑤ Low fuel price ⑥ Easy to buy/ accessible ⑦ Does not affect food taste ⑧ Other_____	① Village market ② Door to door sales ③ Distribution point ④ Internet ⑤ Government program ⑥ Other_____
d.	Biogas	Buy	Price_____元/year	① Stove only burns this fuel ② Fuel has high efficiency ③ Less smoke, little odor, clean ④ Easy to use ⑤ Low fuel price ⑥ Easy to buy/ accessible ⑦ Does not affect food taste ⑧ Other_____	① Gas station ② Direct sale to front door ③ Other_____
		Own collection	Time spent collecting____ days/year (1 day=8 hours)		① Own household biogas ② Joint-household biogas ③ Other_____
			If you collect from a diges-ter managed by someone else, how much do you pay them (management fee)? Price____元/year		
e.	LPG	Buy	Price_____元/year	① Stove only burns this fuel ② Fuel has high efficiency ③ Less smoke, little odor, clean ④ Easy to use ⑤ Low fuel price ⑥ Easy to buy/ accessible ⑦ Does not affect food taste ⑧ Other_____	① Village market ② Door to door sales ③ Distribution point ④ Government program ⑤ Other_____

(continued)

Sr.	Type	Method to obtain	Price/amount	Why would you choose this fuel?	Purchase channel
f.	Natural gas	Buy	Price_____元/year	①Stove only burns this fuel ②Fuel has high efficiency ③Less smoke, little odor, clean ④Easy to use ⑤Low fuel price ⑥Easy to buy/accessible ⑦Does not affect food taste ⑧Other_____	①Home Pipeline ②Government program ③Other_____
g.	Coal gas	Buy	Price_____元/year	①Stove only burns this fuel ②Fuel has high efficiency ③Less smoke, little odor, clean ④Easy to use ⑤Low fuel price ⑥Easy to buy/accessible ⑦Does not affect food taste ⑧Other_____	①Home Pipeline ②Village market ③Door to door sales ④Distribution point ⑤Government program ⑥Other_____
h.	Electricity for daily use	Buy	Price_____元/year	①Stove only burns this fuel ②Fuel has high efficiency ③Less smoke, little odor, clean ④Easy to use ⑤Low fuel price ⑥Easy to buy/accessible ⑦Does not affect food taste ⑧Other_____	①Electricity metering service ②Other_____

(continued)

Sr.	Type	Method to obtain	Price/amount	Why would you choose this fuel?	Purchase channel
i.	Solar	Own-collection	How many days do you use? __days/year	① Stove only burns this fuel ② Fuel has high efficiency ③ Less smoke, little odor, clean ④ Easy to use ⑤ Low fuel price ⑥ Easy to buy/accessible ⑦ Does not affect food taste ⑧ Other_____	
j.	Other: _____	Buy	Price_____元/year	① Stove only burns this fuel ② Fuel has high efficiency ③ Less smoke, little odor, clean ④ Easy to use ⑤ Low fuel price ⑥ Easy to buy/accessible ⑦ Does not affect food taste ⑧ Other_____	① Village market ② Shopping center ③ Door to door sales ④ Distribution point ⑤ Internet ⑥ Government program ⑦ Other_____
		Self-collection	Time spent____ days/year (1 day=8 hours)		

6. How many stoves do you own?

Biomass/Coal stove:__# Biomass stove: ___# Coal stove:___# "Zao":____#

Kang:___# Natural Gas Stove:___# Coal gas stove: ___# LPG stove:___#

Biogas stove:__# Electric stove/rice cooker:___# Solar stove:___#

Most used 2-3 stoves	#1 _____	#2 _____	#3 _____
Stove type/construction (circle)	① Stone, built-in ② Metal, built-in ③ Metal, mobile	① Stone, built-in ② Metal, built-in ③ Metal, mobile	① Stone, built-in ② Metal, built-in ③ Metal, mobile
Chimney (circle)	① Yes ② No	① Yes ② No	① Yes ② No
Purpose of use (select multiple)	① Cooking ② Heating a. water heating b. fire heating	① Cooking ② Heating a. water heating b. fire heating	① Cooking ② Heating a. water heating b. fire heating

(continued)

Most used 2–3 stoves	#1 _____	#2 _____	#3 _____
Fuel(s) used (circle)	① Straw/wood ② Biomass pellets ③ Coal ④ Biogas ⑤ LPG ⑥ Coal gas ⑦ Natural gas ⑧ Electricity ⑨ Other	① Straw/wood ② Biomass pellets ③ Coal ④ Biogas ⑤ LPG ⑥ Coal gas ⑦ Natural gas ⑧ Electricity ⑨ Other	① Straw/wood ② Biomass pellets ③ Coal ④ Biogas ⑤ LPG ⑥ Coal gas ⑦ Natural gas ⑧ Electricity ⑨ Other
Average hours used per day (winter/heating season)			
Average hours used per day (non-winter/non-heating season)			
How long you have used the stove (years)			
Initial cost of stove or cost of construction (元)			
If there was government subsidy, how much was the subsidy? (元)			
Where purchased (circle one)	① Village market ② Shopping center ③ Door to door sales ④ Distribution point ⑤ Mechanic construction site ⑥ Internet ⑦ Government program ⑧ Other_____	① Village market ② Shopping center ③ Door to door sales ④ Distribution point ⑤ Mechanic construction site ⑥ Internet ⑦ Government program ⑧ Other_____	① Village market ② Shopping center ③ Door to door sales ④ Distribution point ⑤ Mechanic construction site ⑥ Internet ⑦ Government program ⑧ Other_____
Purchase decision-maker (circle one)	① Elder man ② Elder woman ③ Young man ④ Young woman	① Elder man ② Elder woman ③ Young man ④ Young woman	① Elder man ② Elder woman ③ Young man ④ Young woman

(continued)

Most used 2–3 stoves	#1 ______________	#2 ______________	#3 ______________
What are the two most important reasons for your purchase and/or the use of this particular stove?	① Daily necessity ② Fuel–switching (e.g coal to electricity) ③ Government project ④ Good price ⑤ Reduce pollution ⑥ Convenient to operate ⑦ Appearance is nicer ⑧ Flame is stronger ⑨ Other________	① Daily necessity ② Fuel–switching (e.g coal to electricity) ③ Government project ④ Good price ⑤ Reduce pollution ⑥ Convenient to operate ⑦ Appearance is nicer ⑧ Flame is stronger ⑨ Other________	① Daily necessity ② Fuel–switching (e.g coal to electricity) ③ Government project ④ Good price ⑤ Reduce pollution ⑥ Convenient to operate ⑦ Appearance is nicer ⑧ Flame is stronger ⑨ Other________
Most unsatisfactory aspects (circle all possible)	① Inconvenient to operate ② Inconvenient and high cost to maintain ③ Not good–looking ④ High purchase price ⑤ Fuel consuming ⑥ Heave smoke ⑦ Affects food taste ⑧ High fuel price ⑨ Fuel is inconvenient due to additional processing needed ⑩ Other__________	① Inconvenient to operate ② Inconvenient and high cost to maintain ③ Not good–looking ④ High purchase price ⑤ Fuel consuming ⑥ Heave smoke ⑦ Affects food taste ⑧ High fuel price ⑨ Fuel is inconvenient due to additional processing needed ⑩ Other__________	① Inconvenient to operate ② Inconvenient and high cost to maintain ③ Not good–looking ④ High purchase price ⑤ Fuel consuming ⑥ Heave smoke ⑦ Affects food taste ⑧ High fuel price ⑨ Fuel is inconvenient due to additional processing needed ⑩ Other__________
☐ There is no unsatisfactory aspects	☐ There are no unsatisfactory aspects about this stove	☐ There are no unsatisfactory aspects about this stove	☐ There are no unsatisfactory aspects about this stove

V. Future stove plans

7. Are you considering buying a new stove? a.Yes b. No c. I don’t know

8. If you are going to buy a new stove, how much money do you plan to spend?__Yuan

Within in what timeframe do you plan on buying it?

a. within < 1 month b. 1-3 months c. 3-6 months d. 6 months>

9. If are going to buy a new stove, what three features are most appealing? Please rank select:

a)_____ b)_____ c)_____

1.	Low price	7.	Multi-functionality(e.g. cooking and heating, etc)
2.	Government subsidy	8.	Low smoke, less pollution
3.	Durability	9.	Appearance
4.	Fuel type suitability	10.	Long warranty
5.	Strong flame	11.	Other_____
6.	Easy to operate		

10. If you are going to buy a new stove, what purchase channels would you most likely use? Please rank select:

a)_____ b)_____

1.	Government provided
2.	Local marketplace
3.	Shopping center
4.	Small shop
5.	Door to door sales
6.	Internet
7.	Other_____

11. Where do you usually buy your household appliances and electronics, such as TV?

a.	Door to door sales
b.	Local marketplace
c.	Small shop
d.	Shopping center
e.	Internet
f.	Other_____

This is the end of the survey, Thank you for your support!

2. Stove Manufacturer Survey Questionnaire

Surveyor name:_____ Surveyor contact phone number:_____ Survey Date:_____

I. General information

Company name: _____ Address: _____

Name of respondent: _____ Contact number: _____ Email: _____

II. Current sales and operations

1. How long have you been manufacturing stoves?

a. <1 year b. 1-3 years c. 3-5 years d. more than 5 years (removed e.)

2. How many employees do you have?

a. 0-20 b. 20-50 c. 50-100 d. more than 100 (removed e.)

3. Please fill in the company's different business activities (such as stove manufacturing, fuel production, radiator manufacturing, etc.) and percentage of total capacity

Business activities	Percentage of total business capacity

4. In 2013, what is your total stove production capacity___# and actual total production___# How many total production facilities do you have___#? Where are you production facilities located and what is each locations' production capacity and actual production (in # of stoves)

Location (city/province)	Production capacity (# of stoves)	Actual production (# of stoves)

5. Please provide annual production, sales (domestic and exported), and average price and production cost details for each type of stove you produce

(Both charts are to be completed; where at least, the situation resembling most closely to the company's production should be completed)

a. Based on stove type (functionality), what are the company's annual production & sale capacities, and price details?

Functionality	Annual production capacity (stove #)	Annual sales domestic (stove #)	Annual sales exported (stove #)	Average price (元/stove)	Average production cost (元/stove)	Fuel used for this type of stove (can write more than 1)
Cooking						
Heating						
Cooking + open fire heating						
Cooking + water heating						
Other_____						

b. Based on stove type (fuels), what is the company's production & sale capacities, and price details?

Fuel	Annual production (stove #)	Annual Sales domestic (stove #)	Annual Sales exported (stove #)	Average price (元/stove)	Average production cost (元/stove)
Biomass stove					
Coals stove					
Biomass / coal stove dual					
Biogas stove					
LPG stove					
Natural gas stove					
Coal gas stove					
Electric stove					
Solar stove					
Other _____					

6. If you export, what are the main countries do you export to?

_____、_____、_____、_____、_____、_____、_____.

7. What measures do you take to improve the product quality? (multiple responses possible)

a. Application of new technology b. R&D improvement

c. Improve quality control measures d. Other_____

III. Current customers

8. What are the company's sales percentages based on home province v. other provinces, the

specific provinces represented in each, and the # of counties covered?

Sales location	% of sales	Province(incl. Municipality、Autonomous region)	Number of counties covered (#)
Home province			
Other province			

9. What sales methods does your company mostly use? (multiple responses possible)
a. Government programs b. Door to door sales c. Online
d. Wholesale e. Local retail stores f. Other_____

10. What has been the most successful way for the sale of stoves?
a. Government programs b. Door to door sales c. Online
d. Wholesale e. Local retail stores f. Other_____

11. What mediums for advertising stoves do you use? (multiple responses possible)
a. TV advertising b. Billboards c. Posters d. Magazine advertising
e. Door to door promotion f. Internet g. Expositions/fairs h. SMS/Wechat
i. Government j. Other_____

12. What has been the most successful stove selling channel?
a. TV advertising b. Billboards c. Posters d. Magazine advertising
e. Door to door promotion f. Internet g. Expositions/fairs h. SMS/Wechat
i. Government j. Other_____

13. Who are your target customers? (multiple responses possible)
a. Farmer b. Enterprise (e.g. restaurants, shops, farmhouse) c. School
d. Bank e. Other_____

14. Do you market or advertise differently to different types of customers? (If "yes" please respond to Q15)
a. Yes b. No

15. How do you distinguish between the different types of customers? (multiple responses possible)
a. Income b. Occupation c. Location d. Other_____

16. What are the top three reasons why do you think your customers purchase your product?
a. Low price b. Fuel type c. Post-sale service d. Brand

e. Durability f. High efficiency g. Less smoke h. Ease of use/operation
i. Other_____

17. Which aspects do you most consider when you set prices? (multiple responses possible)
a. Profit targets b. Production costs c. Competitor's pricing
d. Government regulations e. Other _____

18. Which aspects do you most consider when you set product development priorities? (multiple responses possible)
a. Consumer feedback b. Dealer feedback c. Post-sales service
d. Government demand e. Other _____

19. Do you conduct any form of consumer research? (If "yes" please respond to Q20)
a. Yes b. No

20. In what ways have you conducted consumer research?
_____

IV. Government regulations and support

21. Do you receive a subsidy under the government subsidy program? (If "yes" please respond to Q22)
a. Yes b. No

22. For which stove types do you receive a government subsidy? (multiple responses possible)
a. Biomass stove b. Coal stove c. Biomass / coal stove dual d. Biogas stove
e. LPG stove f. Natural gas stove g. Electric stove h. Solar stove
i. Other_____

23. Between the different stove types, what subsidy amounts, in percentages of stove prices, have you received from the government?

Stove type	% of stove price
Biomass stove	
Coals stove	
Biomass / coal stove dual	
Biogas stove	
LPG stove	
Natural gas stove	
Electric stove	
Solar stove	

Other _____	

24. Would you continue manufacturing if you weren't receiving a subsidy from the government?

(If "no" please respond to Q25)

a. Yes b. No

25. What is the lowest percentage of government subsidy you are willing to accept _____%

26. What quality standards does your company apply in stove production?

a. National/government standards b. Local standards c. Industry standards

d. Enterprise standards

27. Do you think there are any existing standards which are unreasonable?

a. Yes, Please explain_____ b. No

28. Have your stoves passed compliance with quality standards by the government, industry, and/or an association?

a. Passed national/government standards b. Passed other industry standards

c. Passed other association standards d. Not been tested

V. Competition in the industry

29. Is competition in the industry a big concern for you?

a.Yes b.No

30. In which of the following aspects of your business is there the most competition?

a. Sales b. Technology c. Cost d. Exterior Appearance e. Tenders

f. Other____

31. What advantages differentiate you from your competitors? Circle three choices

a. Price b. Durability c. After-sale service d. Stove efficiency

e. Brand f. Exterior appearance g. Stove type h. Ease of use

i. Delivery services j. Distribution network k. Other _____

VI. Future plans and current barriers

32. What are the main factors influencing your market sales? _____

33. How are you planning to grow your business? (multiple responses possible)

a. M&A/Collaboration b. New sales methods c. Open in new markets

d. Develop new products e. Other _____

34. Presently, what percent of your operations revenues do you invest in R&D? _____%

35. Looking to the future, what type of stove for cooking and heating has the greatest market prospect? (multiple responses possible)

a. Biomass stove b. Coal stove c. Biomass / coal stove dual d. Biogas stove

e. LPG stove f. Natural gas stove g. Electric stove h. Solar stove

i. Other_____

36. Do you have any growth targets / objectives?

a. Yes b. No

37. If yes, what are your specific growth targets / objectives?

_____

38. What are the key constraints you are facing?

Rate in order of importance below (1 = insignificant constraint, 3 = significant constraint)

Primary constraint	Rating
Insufficient funds to scale operations	1 2 3
Insufficient technology	1 2 3
Lack of labor	1 2 3
Fluctuations in the cost of production	1 2 3
Unstable market demand	1 2 3
Stove fuel supply problems	1 2 3
Limited distribution channels and logistics support	1 2 3
Other _____	1 2 3
Other _____	1 2 3
Other _____	

39. What will help overcome these key constraints?

_____

_____

_____

40. What policy measures will help you overcome these constraints?

_____

_____

_____

This is the end of the survey, thank you for your support!

3. Fuel Producer Survey Questionnaire

Surveyor name:_____ Surveyor contact phone number:_____ Survey Date:_____

I. General information

Company name: _____ Address: _____

Name of respondent: _____ Contact number: _____ Email: _____

II. Current sales and operations

1. How long have you been engaged in fuel production?

a. <1 year b. 1-3 years c. 3-5 years d. more than 5 years

2. How many employees do you have?

a. 0-20 b. 20-50 c. 50-100 d. more than 100

3. Please fill in the company's different business activities (e.g. fuel canisters) and percentage of total capacity

Business activities	Percentage of total business capacity

4. In 2013, what is your total fuel production capacity: _____ tons, what is your actual production___tons. Where are your production facilities located and what is each locations' production capacity and actual production (in tons)

Location	Total fuel production capacity(tons)	Total actual fuel production (tons)

5. Please provide annual production, sales (domestic and exported), and average fuel price and production cost details for each type of fuel you produce

Based on fuel type, what are the company's annual production & sale capacities, and price details?

Fuel type	Source of Fuel (i.e. gathered/ bought)	Annual production capacity (tons)	Annual sales domestic (tons)	Annual sales exported (tons)	Average price (RMB)	Average production cost (元/ton)
Biomass Pellets						
Coal Briquettes						
Other_____						

6. Your company's fuel production is mainly exported to which countries?

_____、_____、_____、_____、_____、_____、_____.

7. What measures do you take to improve the product quality? (multiple select)

a. Application of new technology b. R&D improvement

c. Improve quality control measures d. Other_____

III. Current customers

8. What are the company's sales percentages based on home province v. other province, the specific counties represented in each, and the # of counties covered?

Sales location	% of sales	County(Municipality、Autonomous region)	Number of counties covered (#)
Home province			
Other province			

9. What sales methods does your company mostly use? (multiple select)

a. Government programs b. Door to door sales c. Online

d. Wholesale e. Local retail stores f. Other_____

10. What has been the most successful way for the sale of stoves?

a. Government programs b. Door to door sales c. Online

d. Wholesale e. Local retail stores f. Other_____

11. What mediums for advertising stoves do you use? (multiple select)

a. TV advertising b. Billboards c. Posters d. Magazine advertising

e. Door to door promotion f. Internet g. Expositions/fairs h. SMS/Wechat

i. Other_____

12. What has been the most successful fuel selling channels?

a. TV advertising b. Billboards c. Posters d. Magazine advertising

e. Door to door promotion f. Internet g. Expositions/fairs h. SMS/Wechat

i. Other_____

13. Who are your target customers?

a. Farmer b. Enterprise (e.g. restaurants, shops, farmhouse) c. School d. Bank
e. Other_____

14. Do you market or advertise differently to different types of customers?

a. Yes b. No

15. If yes, how do you distinguish between the different types of customers?

a. Income b. Occupation c. Location d. Other_____

16. What are the top three reasons why do you think your customers purchase your fuel product? (multiple responses possible)

a. Low price b. Efficiency c. Fuel quality d. Brand
e. Post-sales service f. Less pollution g. Ease of use/operation h. Other_____

17. Which aspect do you most consider when you set prices? (multiple select)

a. Profit targets b. Production costs c. Competitor's pricing
d. Government regulations e. Other _____

18. Which aspect do you most consider when you set product development priorities? (multiple select)

a. Consumer feedback b. Dealer feedback c. Post-sales service
d. Government demand e. Other _____

19. Do you conduct any form of consumer research? (If yes, please respond to question 20)

a. Yes b. No

20. In what ways have you conducted consumer research?

_____

IV. Government regulations and support

21. Do you receive a subsidy under the government subsidy program? (If "yes", please answer Q22)

a. Yes b. No

22. For which fuel types do you receive a government subsidy? (multiple select)

a. Biomass pellet b. Coal briquette c. Other_____

23. Between the different fuel product types, what subsidy amounts, in percentages of fuel prices, have you received from the government?

Fuel type	% of fuel price
Biomass pellet	
Coals briquette	
Other_____	

24. Would you continue producing fuel if you were not receiving a subsidy from the government? If "No", please answer Q25

a. Yes b. No

25. What is the lowest percentage of government subsidy you are willing to accept _____%

26. What quality standards does your company apply in fuel production? (multiple select)

a. National/government standards b. Local standards c. Industry standards

d. Enterprise standards

27. Do you think there are any existing standards which are unreasonable?

a. Yes, Please explain_____ b. No

28. Have your fuel products passed compliance with quality standards by the government, industry, and/or an association? (multiple select)

a. Passed national/government standards b. Passed other industry standards

c. Passed other association standards d. Not been tested

V. Competition in the industry

29. Is competition in the industry a big concern for you?

a.Yes b.No

30. In which of the following aspects of your business is there the most competition?

a. Sales b. Technology c. Cost d. Exterior Appearance

e. Tenders f. Other____

31. What advantages differentiate you from your competitors? Circle three choices

a. Price b. Service c. Fuel quality d. Brand e. Appearance

f. Ease of use g. Delivery services h. Distribution network i. Other _____

VI. Future plans and current barriers

32. How are you planning to grow your business? (multiple select)

a. M&A/Collaboration b. New sales methods c. Open in new markets

d. Develop new products e. Other _____

33. Presently, what percent of your operations revenues do you invest in R&D? _____%

34. Looking to the future, what type of fuel for cooking and heating has the greatest market prospect? (multiple select)

a. Biomass pellets b. Coal briquettes c. Biogas d. LPG e. Natural gas

f. Electric stove g. Solar h. Other_____

35. Do you have any growth targets / objectives? (If "yes" please answer 36)

a. Yes b. No

36. What are your specific growth targets / objectives?

_____

37. What are the key constraints you are facing?

Rate in order of importance below (1 = insignificant constraint, 3 = significant constraint)

Primary constraint	Rating
Insufficient funds to scale operations	1 2 3
Insufficient technology	1 2 3
Lack of labor	1 2 3
Fluctuations in the cost of production	1 2 3
Unstable market demand	1 2 3
Limited distribution channels and logistics support	1 2 3
Unstable resource supply	1 2 3
Low customer confidence	1 2 3
Other _____	1 2 3

38. What will help overcome these key constraints?

_____

_____

_____

39. What policy measures will help you overcome these constraints?

_____

_____

_____

This is the end of the survey, thank you for your support!

Appendix V Methodologies

1. Stove Hour Methodology

"Stove Hours" is a comparative index created in this report to distinguish the relative usage of fuels and stoves based on average hours per day as collected in the GACC Survey 2014. This index is more advantageous than simply looking at 'primary use' of stoves and fuels as it accounts for stacking (as it measures relative usage across all fuel/stove combinations), and therefore provides a greater base for comparing and understanding emissions impact and overall consumer behavior.

Stove hours was calculated using the following steps:

1) Clean raw data from GACC Survey 2014: In the survey, average hours per day in the winter and non winter is collected for every households' most used, second most used and third most used stove/fuel combination.

2) Calculate average hours per day for both winter and non winter months for each stove/fuel combination. For each stove/fuel combination, the responses for the number of hours of use per day were added and divided by the total number of users, to attain the average hours per day for each stove/fuel combination in the winter and in the non-winter.

3) Calculate a weighted average hours per day for the year instead of splitting by winter/non winter: Assuming four winter months, and eight non-winter months, an average hours per day was calculated for each stove/fuel combination across a full year rather than by winter/non winter.

4) Calculate stove hour index: To get to total stove hours, the average hours per day was multiplied by the total number of users for each given stove/fuel combination. This total stove hours (per day) was then used to create indexes to compare at different levels of analysis. In the report, this index is used to compare usage by stove purpose (cooking, heating and cooking and heating) and by stove/fuel combination.

2. Estimating baseline impact on CO_2 emissions

Estimating CO_2 emissions is important to understand the impact of a cleaner more efficient fuel mix. The following steps were taken to conduct this analysis:

1) Estimate baseline impact on fuel mix based on economic growth: Using historical correlations between GDP per capita and each fuel type, estimates for each fuel type contribution was estimated based on forecasted GDP per capita growth (based on government targets).

2) Calculate the differences in fuel mix for each fuel type: The differences were calculated by subtracting the forecast year (2020) from the base year (2013). This results in millions of tons coal equivalent of impact split by different fuel types.

3) Calculate emissions impact by multiplying differences by emissions factors: An average

emissions factor was used for each broad fuel type. These emissions factors were multiplied by the tons of coal equivalent to determine tons of CO_2 emissions.