The Ashden Awards for sustainable energy

2009 Ashden Awards case study
Aprovecho Research Center (ARC) and Shengzhou Stove Manufacturer (SSM)

Finalist's work:	**Mass production of improved wood-burning cooking stoves**
Organisation:	**ARC: non-profit established in 1976. Annual turnover of £118k and five staff (2008) SSM: private business, annual turnover of £1.3m and 100 staff (2008)**
Location:	**USA and China, worldwide sales**

Summary

Many people in developing countries cook with biomass, using open fires or traditional stoves. The resulting emissions leads to serious health problems and additional deaths, mainly children and women, and contribute to climate change. The use of wood often contributes to deforestation and collecting it is a demanding chore, usually for women. There are many excellent stove projects around the world, but several billion people have still not benefited. To rapidly increase the availability of improved stoves, the Aprovecho Research Center (ARC) has collaborated with the Shengzhou Stove Manufacturer (SSM) in China, to design and mass-produce efficient stoves for burning fuelwood and charcoal.

- Initial stove designs developed by ARC, developed for mass production with SSM. Customer feedback has assisted the development of stove designs.
- SSM designed and set up the new factory production line in 2007.
- 'Rocket' design concept uses precise internal dimensions to control the flow of air, in order to burn the wood cleanly and transfer heat efficiently to the cooking pot.
- Stove combustion chambers are made from an extrusion of clay, which is fired to produce a light weight, durable, insulating ceramic material.
- Three main models developed so far, price ex-factory from US$3.50 to US$12.
- SSM has sold 60,000 stoves since 2008. Production capacity now 50,000/month.
- Over 90% of sales have been to Envirofit International, a US-based non-profit which markets the stoves in India supported by the Shell Foundation. Also sold to distributers in South Africa, Tanzania, Madagascar, Argentina, Chile, and the Marshall Islands.
- Laboratory and field tests show savings of 40% of fuelwood (50% if a pot skirt is used); 50 to 70% of particulate emissions; and 50 to 60% of carbon monoxide emissions, compared to three-stone fires.
- Typical saving of 1 to 2 tonnes/year CO_2 (equivalent) per stove.
- Users benefit through improved health (from reduced indoor air pollution); less time spent collecting wood and cooking; and saving money from buying fuel.
- SSM has recruited twenty additional staff to manufacture these stoves, and two new ARC staff work on marketing. Many more employed in the distribution chains.
- SSM hopes to sell between 200,000 and 300,000 stoves during 2009/10.

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Context

Over three billion people worldwide cook with wood, animal dung, coal and other solid fuels on open fires or traditional stoves.[1] This causes indoor air pollution which is responsible for more than 1.5 million deaths per year due to respiratory diseases – most of whom are young children and their mothers. Fuelwood is often collected by women, which is time-consuming and tiring and may expose them to abuse. Collectively open fires and traditional stoves consume large quantities of fuelwood and charcoal which can contribute to deforestation and erosion unless new trees are planted. The inefficient burning of biomass contributes to climate change, through emissions of carbon dioxide, methane and nitrous oxide (the Kyoto greenhouse gases) and also other emissions like black carbon, whose climate-change impact is of increasing concern.

The use of improved fuelwood cooking stoves can help with these problems, and also bring important secondary benefits such as reduced risk of burns, time-saving, income saving and cleaner homes. Programmes have run in many countries to make improved stoves available and affordable for many years. However, most programmes have a local focus, using local artisan-based production methods, and the vast majority of potential users have still not been reached.

The Aprovecho Research Center (ARC), based in Oregon USA, has pioneered the design of efficient stoves since the 1970s, and provided consultancy to many stove programmes. To help achieve a radical increase in the number of people with access to improved stoves, they wanted to establish factory-based mass-production of them. In 2006, ARC found the ideal partner to do this in the Shengzhou Stove Manufacturers (SSM), in Zhejiang province, China. SSM is the largest manufacturer of domestic coal stoves and combustion chambers in China, and has particular expertise in making light-weight ceramic components for stoves. The new range of stoves developed by ARC in partnership with SSM was launched in September 2007.

Technology and use

Design

The ARC/SSM design is based on the well-known 'rocket' concept, developed by ARC. This uses an internal 'chimney' in the stove which directs air through the burning wood and encourages the mixing of gases and flame above the burning biomass. Precise internal stove dimensions (with tolerances of 1 mm or less) are essential to achieve high combustion efficiency and transfer heat efficiently to the cooking pot. The material of the combustion chamber must have a density of less than 800 kg/m^3 to provide good insulation and low thermal mass, and thus keep carbon monoxide emissions low.

Three different stoves designs have been developed, in consultation with users. All are based on the 'rocket' combustion chamber. The most popular stove burns wood only, and has a single door for adding the wood: this stove is available in different sizes. A similar stove has been developed that burns either wood or charcoal, with a lower door for controlling primary air, and an upper door for fuel entry. These stoves are designed to last between three and five years. The expectation is that the cast iron grate and top will be the first part to need replacing.

A very low cost all-ceramic stove has recently been developed, in response to feedback from GTZ. This stove is supplied without metal parts, so that it can be finished in the country where it will be used.

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[1] World Health Organisation: www.who.int/indoorair/publications/summary/en/

Manufacture
In 2007, SSM designed and started a new production line to manufacture the stoves. The production process starts at the top of the factory and flows downhill. The stove combustion chambers are made from clay mixed with sawdust, which is fired to produce a light-weight, durable, insulating ceramic material, which is resistant to abrasion. The clay is bought from a local mine, about 2 km away from the factory, sorted and mixed. SSM has developed an innovative technique to extrude the clay through a mould, cut it into sections, trim it, cut the door opening and shape the top. The combustion chambers dry under cover at ambient temperature for a few days before being moved into the 15,000-stove capacity drying sheds for up to a week. Here they are dried by waste heat that is pumped through vents in the floor from the ceramic kilns below. Stoves are then moved into the low-smoke ceramic kilns, which are fuelled by coal (about 25%) and sawdust (75%). The fired, ceramic combustion chambers thus produced are tough and resistant to abrasion. They are then ground to precise dimensions and finished.

The stove bodies are made from galvanised, powder-coated sheet steel, which is bought locally. The chambers and the stove bodies are taken to the new assembly and shipping facility, a short distance from the factory. Here the chambers are fitted into the stove bodies, the cast iron tops (designed by ARC/SSM and produced by a local manufacturer) are added, and handles are fixed in place. The refractory cement floor is then cast inside the stove. The outside of the stove is painted to give an attractive finish to the product.

After testing, the stoves are packaged, loaded into shipping containers and transported to the port of Ningbo for export. Stove finishing and packaging can be branded according to the requirements of customers, and instruction manuals can be provided in the local languages where the stoves will be used. An adjustable pot skirt, which improves heat transfer to the cooking pot, can also be included.

ARC has helped SSM to set up a new laboratory at the factory to test the stoves for emissions and fuel efficiency, using internationally approved standard testing protocols. The firewood used is measured, along with carbon monoxide, carbon dioxide and particulate emissions. Durability tests are also carried out to simulate use in the field. Continual laboratory testing assures quality control.

How users pay

The ex-factory price of the complete metal-clad stoves is between US$7 and US$12 depending on the model. The simple all-ceramic stove costs only US$3.50. Most sales to date have been to distributers (including companies, government programmes and NGOs) although some stoves have been sold to individuals. The distributers pay SSM directly, and then use different approaches to provide stoves to users. Sometimes stoves are sold commercially through markets or stores, sometimes subsidies or micro-credit are used, and in refugee camps stoves are provided free to users.

ARC is currently investigating the possibility of carbon finance with CEIHD a non-profit carbon finance organisation. The aim would be to use carbon credits to reduce the sale price of certain types of stove.

Training, support and quality control

SSM is responsible for manufacturing the stoves, and trains all production workers in-house. Only qualified people are recruited into skilled positions such as welders, mechanics and electricians. For general production workers, SSM looks for people with experience in ceramic working, and generally prefers older workers.

ARC made the initial design for the stoves, and invested considerable time in testing and improving before the production model was launched with SSM in September 2007. ARC is also responsible for continuing design development: staff visit the SSM factory every four months to check the production quality and to give technical advice. Some details have been changed as a result of customer feedback. For instance, a door liner was also added for the two-door model in response to feedback from GTZ in South Africa. SSM quality-checks a sample of each batch of stoves, and has won Government quality awards, following regular inspections by the central and local government.

Many stove programmes in different parts of the world have failed because a stove design which worked well under test conditions was not liked by local users. Although ARC and SSM have taken feedback from users in developing their stove, it is inevitable that their small range of designs will not meet all cooking needs. ARC therefore encourages any potential purchaser to market-test a small number of stoves before committing to a large order, and determine the suitability of the generic stove models to local needs. The stoves will then be shipped, with instructions in the local language for the user. Stoves are portable, so no installation is required.

Benefits

Numbers

SSM has sold 60,000 stoves since 2008, over 90% to Envirofit International, a US-based non-profit which markets the stoves in India supported by the Shell Foundation. Other customers are distributers in Argentina, Chile, Ethiopia, Tanzania, Madagascar, the Marshall Islands and South Africa. Sample stoves have also been supplied to potential buyers in more than twenty other places. By February 2009, SSM was shipping an average of 12,000 stoves per month, and has the capacity to produce 50,000 per month.

Because nearly all stoves are sold to distributers, it is not known how many have yet reached users. With typically five people per household, the 60,000 stoves sold to date could potentially benefit about 300,000 people.

Benefits will obviously vary depending on where and how the stove is used. The sections below describe general benefits, with some specific points noted on a visit by one of the Ashden judging team to a stove programme run by GTZ, in South Africa. This programme will make stoves available through retail outlets in urban townships, and through government-supported ‘energy concessions’ in rural areas.

Environmental benefits

One of the main purposes of the stoves is to reduce fuelwood use (although some replace kerosene and electricity) and greenhouse gas emissions. Because cooking practices and the sustainability of wood supply vary between countries and regions, it is not possible to give a single, accurate estimate for the savings achieved. ARC has used several different methods to assess savings, including:

- Laboratory measurements of fuel use and emissions, using the ‘Water boiling test’ which was developed by the Shell Foundation and the University of California, Berkeley (UCB).
- Field tests in India, where 100 women compared the wood needed to cook a meal on a three-stone fire and a Rocket type stove similar to the SSM factory-made stove. This test also included measurements of emissions.
- Cooking tests in a laboratory kitchen, including fuel use and indoor air pollution.
- Daily monitoring of fuel use and indoor air pollution in homes.

- Recent field tests by Columbia University in Uganda of the ARC/SSM One Door stove which evaluated both fuelwood saving and customer preference for different types of stove.

These different methods agree that the stove saves about 40% of fuelwood without the pot skirt. If the skirt is used, this figure increases to about 50%. The stove also reduces particulate emissions by 50 to 70%, and carbon monoxide emissions by 50 to 60%.

The absolute saving of wood depends on how frequently the stove is used, and for what purposes. For example, in the Indian study above, families without improved stoves used an estimated 1.8 tonnes/year fuelwood to cook two meals per day using a three-stone fire. The stove saved 40% of wood use, so about 0.73 tonnes/year per family.

Converting fuelwood savings into greenhouse gas savings depends significantly on the sustainability of the wood source, and also on which emissions are included in the calculation. ARC studies suggest that, if CO_2 and all the other Kyoto greenhouse gases are included, then the savings are between 1 and 2 tonnes/year CO_2(equivalent) per stove.

Social benefits
Users benefit directly because:

- The reduction in indoor air pollution (including particulates and carbon monoxide), results in less respiratory and eye disease. Less smoke in the kitchen often makes life less lonely for the cooks: other family members become willing to spend time there. Cooks in both urban (Alexandra township) and rural (KwaZulu-Natal) parts of South Africa noted that there was smoke when the stove was first lighted, but that it rapidly subsided.
- Where fuelwood is collected, time and effort is saved because less fuel is needed. This was confirmed by a user in KwaZulu-Natal, who previously had to walk for four hours per day to collect wood.
- The stove heats up quickly, so cooking takes less time. The same user in KwaZulu-Natal said that she now had time to cook breakfast for her children before they left for school.
- Where fuelwood, kerosene or charcoal are purchased, money is saved. This was confirmed by a stove user in Alexandra, who used to spend ZAR 14/day (US$1.7/day) on kerosene and now spends ZAR 7/day (US$0.8/day) on fuelwood.
- The risk of burns and house fires is much lower with an improved stove.

Users in Alexandra also commented on the versatility of the stoves: they could be used outside when the weather was hot, but could be brought inside and provide space heating as well as cooking in the winter. They could also be used to heat up a clothes iron, without it getting dirty.

Economic and employment benefits
SSM has taken on about twenty extra staff to manufacture the improved stoves. Many are skilled, and earn typically RMB 1,500 to 2,500 per month (US$220 to 370) but this can increase to RMB 3,000 with over-time. These rates are well above the minimum wage of RMB 600 (US$90) per month. The staff work eight hours per day on six days per week with time off for statutory holidays.

Two new sales and marketing posts have been created at ARC. More employment has been created for sales and distribution staff in the different programmes which are using the stoves.

Potential for growth and replication

The ARC/SSM partnership has shown that it is possible to mass-produce an efficient, durable and affordable fuelwood stove. There is growing interest in the stoves from around the world. The SSM factory could rapidly scale up production to 50,000 per month with further development of the factory. SSM aims to sell 200,000 to 300,000 stoves in 2009/10.

Given that about half the world's population still cook using biomass on open fires or basic stoves, there is a huge potential market for the stoves. There is plenty of opportunity to complement local artisanal stove manufacturers, and not compete with them.

ARC and SSM are working to apply the mass-production approach to other types of pots and stoves, including a fan-assisted stove that burns wood as cleanly as kerosene and greatly reduces greenhouse gas emissions.

Management, finance and partnerships

ARC is a non-profit corporation, managed by Chief Executive, Dean Still. It has been designing stoves since 1976, and has worked with hundreds of partners in many different parts of the world, including Ashden Award winners HELPS (2003) and TWP-AHDESA (2005). ARC won an Ashden Award in 2006 for its work with GTZ on institutional stoves in Southern Africa. ARC provides consultancy and stove-testing services, and also sells stove-testing equipment.

SSM is owned by the Shen family, and since 1995 has been managed by Mr Shen (Chairman), and Mrs Shen (General Manager). Zhao Guoqun manages the overseas department, Liu FaSong is the production director and Qiu Yuejiao is quality control director. SSM is the largest manufacturer of domestic coal stoves in China, around 500,000 ceramic coal stoves (more than twenty models) are produced annually.

ARC and SSM signed a formal partnership agreement to develop and produce the stoves in August 2007. ARC is responsible for design and marketing. SSM is responsible for production and sales. Over the past two years, SSM has invested about RMB 8m (US$1.2m) in the new stove production line, mostly using accumulated profits. ARC has also invested US$145,000.

SSM has sold 60,000 stoves since 2008, over 90% contracted exclusively to US-based non-profit Envirofit International (www.envirofit.org), who helped finalise engineering and testing of these stoves. In partnership with the Shell Foundation, Envirofit has launched the SSM stove and other stoves on the market in India.

A key partner for ARC is the German Development Agency, GTZ (www.gtz.de). GTZ manages two programmes in Southern Africa which are providing stoves for both rural and urban markets. These are the Basic Energy, Climate Change Alleviation Project (BECCAP) which targets South Africa, and the Programme for Biomass Energy Conservation (ProBEC) which focuses on the other countries in the Southern African Development Community. GTZ has made links with the most popular retailers to distribute stoves.

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This report is based on information provided to the Ashden Awards judges Aprovecho Research Center and Shengzhou Stove Manufacturer, and findings from visits by the judging team to see ithe Shengzhou factory work in China and test marketting of stoves by GTZ in South Africa.

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