A rough guide to clean cookstoves

Takeaways

Biomass is still the only available energy source for 2.7 billion people. Inefficient biomass cookstoves, commonly based on firewood or charcoal, increase de-forestation and CO_2 emissions. In addition, they emit smoke containing carbon monoxide (CO) and particulate matter (PM), which cause respiratory diseases leading to 1.6 million deaths each year.

The most important factor for the adoption and salability of clean cookstoves is reduced fuel consumption. Field studies show that the most critical factors for the adoption and salability of clean cookstoves are 1) reduced fuel consumption, 2) reduced cooking time, 3) similar or improved functionality. Giving away the stoves for free, which previously was the strategy of development and aid agencies, is proven not to be a viable path.

Field testing of cookstoves is costly and time consuming, but necessary. Testing cookstoves in the field is extremely important as laboratory tests are unable to predict cookstove performance in real life. Laboratory testing should, however, still be conducted as a first step to determine whether or not it is worthwhile to engage in expensive field testing.

The clean cookstoves industry is becoming increasingly commercialized. The importance of customer satisfaction and need-based product development is finally being understood by the clean cookstoves industry. The one-size-fits-all approach has been abandoned, and several new models and designs tailored to specific groups and markets have been launched.

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What's cooking?

According to the International Energy Agency, 2.7 billion people lack access to clean cooking facilities, of which 1.9 billion are based in Asia, 657 million in Africa, and 85 million in Latin America. These people still depend on biomass as their main source of energy, and are forced to burn charcoal or wood for cooking, despite its known downsides.

First, the inefficient burning of solid fuels on an open 'three stone fire' or by the use of a traditional cookstove has severe negative health effects. Studies by the World Health Organization (WHO) show that indoor air pollution from cooking contributes to more than 1.6 million deaths globally every year. The daily inhalation of smoke containing carbon monoxide, nitrogen oxides, benzene, sulphur and arsenic amongst others, can be compared to smoking two packets of cigarettes every day, significantly increasing the risk for respiratory diseases.

Second, the inefficient use of solid fuels in households increases deforestation. Deforestation is a large contributor to climate change as it decreases the ability of local forests to absorb greenhouse gases (GHGs). Whilst cleaner fuels exist, they are still unavailable to the world's poor due to high costs. For many the choice is to use firewood or charcoal for cooking, or not have a cooked meal at all. New and improved cooking technology could potentially reduce firewood used for cooking by more than 50% compared to 'three stone fires', and provide savings up to 20% of black carbon emissions.

Third, scarcity of readily available biomass also increases the time spent collecting firewood. In Angola, women and children spend up to 7 hours per day collecting firewood, time that could have been spent on more productive activities. Additionally, women and girls also face increased personal security risk when gathering wood in conflict areas or outside refugee camps.

Traditionally, clean cookstoves have been distributed as part of humanitarian or development aid. Millions of cookstoves have been distributed in Africa and Asia, more or less for free, as they have been heavily subsidized by development agencies. This is all about to change, as the cookstove industry is becoming increasingly commercialized and there is a clear trend away from the development aid based approach.

This Differ report is a rough guide to clean cookstoves and was initiated in the process of evaluating three clean cookstove investment cases. The report provides an overview of clean cookstove types and features, important cookstove attributes, and testing methods for measuring their performance.

Clean cookstoves in short

Clean cooking practices may be divided into three main categories; 1) by the use of an electric cookstove, 2) by the use of a cookstove based on clean fuels (biogas, methane, ethanol, solar), and 3) by the use of a cookstove designed to burn biomass inputs (wood, charcoal, other biomass) more efficiently through cleaner combustion.

Whilst the use of an electric cookstove represents the cleanest alternative for cooking, as it does not have any direct emissions, this technology is rarely used in the developing world, due to the high costs of electricity and limited access in rural areas. The second best alternative, cookstoves based on clean fuels, also offer a large leap in performance compared to cooking on an open fire. Unfortunately, these technologies are also largely unavailable in poor areas, due to the high investment costs and/or fuel prices, as well as their inaccessibility in rural areas.

Efficient biomass cookstoves with improved combustion technology is the third and 'dirtiest' of the clean alternatives, but it is also currently the only available and affordable clean cooking alternative. Efficient biomass cookstoves will therefore be the focus of this report, and will be the technology referred to as 'clean cookstoves' in the rest of this report unless otherwise specified.

Efficient biomass cookstoves

Today, more than 50 types of efficient biomass cookstoves exist. They differ with regard to design, materials used, size, as well as method and location of production. To simplify somewhat, efficient biomass cookstoves may be divided into two main groups (See Table 1):

1) Manufactured rocket stoves
   a. Based on the rocket stove design
   b. Mass-produced in factories
   c. Made from metal and plastic

2) Improved cookstoves
   a. Produced locally
   b. Adopt traditional design
   c. Made from locally available materials such as ceramics, clay and bricks
   d. May adopt 'rocket stove' design elements

The manufactured stoves originally came as a one-size-fits-all. Over the past few years, several new models of various sizes and market-specific versions have been launched. The durability of these manufactured stoves range from 2 to 5 years and several producers also offer warrantees of varying length. The main drawback of this type of cookstove is that it can be relatively expensive for the bottom-of-the-pyramid customers, and that it may not be suitable for all markets due to the standardized design.

The improved cookstoves are made locally, often by artisans. This reduces the need for transportation, and lower production costs, and consequently also retail costs. Designs range from small portable ceramic bowls to large installations with permanently fitted chimneys. The durability of these cookstoves varies from one year for the simplest versions to over ten years for the permanent cookstoves. The price varies correspondingly, from around USD 1 to more than USD 90, depending on the design.

Table 1: Efficient biomass cookstove design features.
Efficient biomass cookstoves sorted in two main groups based on design, manufacturing, materials and technical approach.

Variables	Manufactured cookstoves	Improved cookstoves
Fuels	Wood, charcoal, pellets, other biofuels	Wood, charcoal, pellets, other biofuels
Materials	Metal, plastic	Ceramic, clay, bricks, dung, metal
Durability	2-5 years	1-10 years
Warranty	0-5 years	Depends on the producer
Price	USD 10-80 (Average retail price: USD 30)	USD 1-100
Production	Manufactured off-site in factories	Built directly on-site or produced locally by artisans
Size/ mobility	From small and portable household stoves to large institutional cookstoves	From portable ceramic cookers weighing around 5 kg to permanently built-in brick ovens
Chimneys	Can be fitted with a chimney	Can be built with a chimney
Customers	Households, institutions (schools, hospitals), refugee camps	Rural areas (households, refugee camps), urban areas (restaurants, institutions)
Areas	Rural areas (households, refugee camps), urban areas (restaurants, institutions)	Rural areas (households, refugee camps), urban areas (restaurants, institutions)

Locally produced semi-industrial improved cookstoves are becoming increasingly popular as these are cheaper than manufactured stoves. Cookstove components are often imported, whilst production and assembly of stoves is performed locally, which reduces transport and production costs. Further cost reductions are possible as production volumes can easily be increased due to centralized production.

Standardized single-sized clean cookstoves for households, based on the portable rocket stove design have been used in humanitarian and development aid projects for more than 30 years. Today, the cookstove industry is becoming increasingly market driven. Designers of both manufactured and improved cookstoves therefore take into account customer needs and preferences to a much larger extent. An example of this is the two-pot cookstove, which allows for cooking several dishes at the same time. Cookstoves designed for roasting, in addition to boiling, is another new development gaining popularity.

Cookstove developers also identify new consumer segments and adapt their products to meet these segments' needs to increase the market potential. An example of this is institutional cookstoves. They are based on the same technological principles as household stoves, but come in larger sizes, specifically designed for cooking larger quantities of food. Potential customers include kitchens where food is cooked in large quantities over several hours of the day, such as schools and hospitals in rural areas, but also restaurants located in cities.

Given the various features and many designs of contemporary clean cookstoves, which attributes does a clean cookstove need in order to be adopted, saleable, and commercially viable?

Performance indicators

Early clean cookstoves, distributed through development aid organisations, have been criticised for underperforming compared to the 'three stone fire'. Despite stoves being handed out for free, the increased cooking time, user-hostile features and impractical designs, made users quickly abandon the clean cookstoves and return to their traditional cooking methods. These experiences also showed that giving away stoves for free can lead to a lack of ownership, which shortens the lifetime of stoves and significantly reduces the intended benefits.

To secure the financial viability and maximize potential revenue streams, technical cookstove performance needs to be optimised, alongside factors that ensure cookstove adoption and use. Today, the technical performance of clean cookstoves is thoroughly tested in laboratories before selected stoves are further subjected to rigorous field testing. In the field, user surveys are more commonly used to map important attributes that can ensure cookstove adoption and salability.

Critical clean cookstove attributes

Field studies on improved cookstoves in India, Kenya, Uganda and Tanzania all show that the following attributes are the most important for user satisfaction, and hence, critical to ensure adoption of the cookstove:

1. Reduced fuel consumption
2. Reduced cooking time
3. Practical design aspects
    a. Size
    b. Usability
    c. Functionality

Reduced fuel consumption lowers the cost of cooking, and/or frees up time for alternative activities (see Table 2). This increases customer satisfaction and affects purchasing power directly. To be salable, the cookstoves' cooking time needs to be shorter, or at least the same as traditional cooking practices. If cooking time is increased, users will not buy the cookstove, or buy it, then quickly return to their old cooking practices. For example, although a solar cooker needs no fuels and emits no CO or PM emissions, a boiling time of 70 minutes, nearly twice as long as the three stone fire, renders it uncompetitive in many instances.

Stove size, flexibility and user-friendliness are also critical cookstove attributes. Stoves that are too large or small to cook traditional dishes, are difficult to handle or stir, or do not offer the same or improved functionality compared to traditional stoves, stand little chance of being adopted. Users also tend to prefer clean cookstoves that have designs resembling their traditional cookstoves.

Reductions in carbon monoxide (CO) and particulate matter (PM) emissions are appreciated by users, but are not main drivers for consumer satisfaction. However, such considerations motivate stove demand from development aid projects and health organisations. Cookstoves' contribution to avoided deforestation and lower CO_2 emissions from fuel consumption are the most important for those seeking carbon credits.

The first step towards profitability for investors interested in clean cookstove technologies, or project developers wishing to manufacture, distribute and/or sell clean

Table 2: Key factors and methods for evaluating clean cookstove performance and salability
Key factors rated by importance for adoption and salability, health and environmental benefits. Identified 'must have' factors and recommended testing method for the various key factors..
Rating: 1: High importance, 3: Low importance. Testing methods: L = Laboratory, F = Field, S = Survey

Key factors	Adoption & salability	Health benefits	Environmental benefits	'Must have' factors	Testing method
Fuel reduction	1	2	1	X	L, F
CO reduction	2	1	1	X	L, F
PM reduction	2	1	1	X	L, F
Reduced/similar cooking time	1	2	2	X	L, F
CO2 reduction	3	2	1	X	L, F
Long lifetime	2	3	3		F
Low breakage rate	3	3	3		F
Improved safety	2	1	3	X	F, S
Improved cleanliness	3	3	3		F, S
User friendly size/usability/functionality	1	3	3	X	F, S
Affordable price	2	3	3		S

cookstoves, is 'getting the right product'. By this we mean a cookstove which ensures both economic, health and environmental benefits. The 'high importance' key factors, listed under 'Adoption & salability' in Table 2, are therefore the most critical, as these increase profitability, but also overall benefits as a direct consequence of continued and frequent cookstove use. Once the clean cookstoves have been adopted and are used, profitability may be increased by additional revenue streams from, for example, international carbon credit schemes. So how can we test which cookstove will be the most salable in a given market and maximize revenue streams and profits?

How to measure the key factors

The common trait of all clean cookstoves, regardless of mobility, size or shape, is that the technology used should ensure reduced fuel use, combined with cleaner combustion. Cleaner combustion reduces CO and PM emissions, whilst lower fuel consumption reduces costs and/or time spent on collecting firewood, in addition to deforestation.

So far, no international benchmark for rating clean cookstoves has been agreed upon. However, the First ISO International Workshop on Clean and Improved Cookstoves has recently taken place, and this will hopefully lay the foundations for developing a globally recognized standard for laboratory testing of cookstoves.

Meanwhile, some specific tests have been developed and are employed to measure the key performance factors. For instance, The Water Boiling Test' is a commonly used laboratory test for clean cookstoves, and has been suggested as a benchmark (see Table 3). The test includes three parameters: 1) Fuel efficiency, 2) Emissions of carbon monoxide and 3) Emissions of particulate matter (soot), associated with boiling 5 liters of water and keeping it simmer for an hour.

Table 3: Water Boiling Test.
Benchmark for fuel consumption and emissions associated with boiling 5 liters of water and keeping it simmer for an hour. Source: Shell Foundation/Aprovecho Research Centre/Partnership for Clean Indoor Air.

Characteristic	Three stone fire	Benchmark	Reduction
Fuel consumption (g)	2000	850	-60%
Carbon monoxide (g)	100	20	-80%
Particulate matter (g)	4800	1500	-69%

Table 4: Controlled Cooking Test.
Time used to boil 5 liters of water by selected clean cookstove types, including a solar cooker. Source: Aprovecho Research Centre.

Characteristic	Three stone fire	Rocket stove	Institutional stove	Solar cooker
Time to boil	38	38	32	70

The proposed fuel consumption benchmark is set 60% below the fuel consumption of an open fire. CO emissions should be reduced by 80%, whilst PM should be reduced by nearly 70% compared to the benchmark.

Technical aspects of clean cookstoves are also commonly evaluated according to the 'Controlled Cooking Test'. This extended version of the abovementioned Water Boiling Test includes a fourth parameter, 'Time to boil', which measures the time it takes to boil 5 liters of water (see Table 4).

Perhaps as important as the technical laboratory testing, is testing the practical features of the stove and the stove's actual performance in the field. From 2003 to 2010, the Partnership for Clean Indoor Air (PCIA) tested 18 clean cookstoves in the laboratory and the field. Field and laboratory results differed considerably, with field tests showing a significantly lower cookstove performance. Whilst pure technical testing is suitable for side-by-side comparison of stoves, laboratory results cannot be used to predict cookstove performance in the field.

In a recent field study in rural Sub-Saharan Africa by The International Energy Initiative (IEI), testing was taken a step further by also including user surveys. The testing was done in rural kitchens in households in Uganda and Tanzania, by local women cooking traditional meals in real quantities. The study included technical and practial testing and user surveys measuring user satisfaction, preferences and willingness to pay.

The results from Uganda show that 96% of the participants preferred the manufactured rocket stove over the improved rocket stove and the three stone fire (see Table 5). The stove reduced fuel consumption by 40% whilst adding only one minute of cooking time. It also proved to have the most appropriate size for this market. At USD 5, 88% of the participants would like to purchase the stove, whilst 33% would also be interested at the high price of USD 17.5.

Table 5: Key findings from Uganda.
The manufactured stove was ranked highest due to reduced fuel consumption, appropriate cookstove size and no increase in cooking time. (-) indicates that no data was available. Source: International Energy Initiative (2010).

	Indicators	Improved stove	Manufactured stove
Technical	Fuel reduction	-46%	-38%
	CO reduction	-60%	-46%
	PM reduction	-	-56%
	Cooking time	+22 min	+1 min
	CO2 savings	-54%	-
	Price	USD 20-22	USD 20-22
Practical	Durability	3 years	2 years
	Size	Too big	Appropriate size
	Safety	-	-
	Cleanliness	-	Improved
	Unfavorable traits	Long cooking time	Difficult to light
Preferences	Ranking	Ranked last (42%)	Ranked first (96%)
	Willingness to pay	% of respondents	
	- USD 5	62	88
	- USD 10	39	59
	- USD 17.5	21	33

42% of the participants ranked the improved stove lower than the three stone fire, implying little possibilities for adoption and low salability. The main reason for this was the long cooking time and the inappropriate size of the stove. The willingness to pay was more than 30% higher for the manufactured cookstove than for the improved biomass stove. However, 20% of the participants still indicated a willingness to pay for the improved stove at the high price of USD 17.5.

This is only one example of clean cookstove testing and the results cannot be generalized. Contradictory to other studies, the improved cookstove got the lowest rank in this study. Improved cookstoves are often preferred over manufactured stoves as their designs resemble the traditional cookstoves which facilitates adaption. The improved stove tested here was based on the rocket stove design and enjoyed none such advantages. Perhaps the most important point to be taken away from this study is that although fuel reduction is the most important factor of a clean cookstove, both user satisfaction and willingness to pay is greatly reduced if cooking time is significantly increased.

Cooking continued

To achieve health benefits, improved living standards and reduced deforestation through a sustained and long-term use of clean cookstoves, thorough testing both in laboratories and in the field is necessary. Just as important is the inclusion of user preferences when designing the stove. Getting the cookstove ‘right’ is expensive, which combined with these consumers’ low willingness to pay, have so far impeded large scale commercialization.

A fully commercialized market for clean cookstoves is still some way off, both due to remaining short-comings in user-friendly product performances, and to the ability and willingness to pay for these products. However, recent developments in public-private partnerships, new ways of subsidizing clean cookstove projects, as well as additional financing from international carbon markets, are likely to contribute to meeting these issues and thereby improve the financial viability of clean cookstoves.

Our next analysis on this issue will take a closer look at potential markets for clean cookstoves and identify main actors in the field. It will discuss the clean cookstove value chain from manufacturing to distribution and marketing, and identify and analyse the most important factors for the profitability of clean cookstove projects.

About

Differ (www.differgroup.com)

Differ's business idea is to help scale up small-scale carbon reduction technologies (e.g. renewable energy and energy efficiency) in selected developing countries through i) providing free in-depth analysis on e.g. market conditions, feed-in-tariffs, financing and business opportunities, ii) advising project developers, project owners, investors and other decision makers, iii) developing our own concepts and companies and iv) investing in start-ups.

Differ was founded in November 2010 by entrepreneurs that previously have started and developed companies like Renewable Energy Corporation (REC) and Point Carbon.

Differ Analysis series

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