Master Thesis Energy Science

"Stimulating the transition to low carbon cooking solutions in rural India"

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Abstract

Traditional cooking is done by a large share of the Indian rural population and has many negative impacts. Emissions of PICs cause health problems, high CO_2-emissions contribute to global climate change and the time consumption and drudgery of women from fuel collection and cooking holds back their development.

This thesis is aimed at finding solutions for the rural poor to make a transition towards improved cooking technologies. Several technologies are available to replace the traditional mud stove. Solar cookers require a large shift in culture and biogas stoves require expensive biogas installations, which makes these technologies less suitable for the rural poor in India. Kerosene and LPG stoves are used in larger numbers and have the best performance in terms of indoor air pollution reductions. Improved biomass stoves (IC's) are the best method in terms of cost-benefits and CO_2-emissions, and are available in natural draft stoves and forced draft stoves that include an electric battery.

Financial mechanisms should be in place to realize a transition by the rural poor. Microfinance and credit models provide the opportunity to pay off the high upfront costs in smaller terms. However, the full amount still has to be paid and high interest rates can be charged. Carbon finance can reduce the total costs a household has to pay by selling carbon credits, but has the disadvantage that the time lag between a project's start and the moment of credit issuance is at least two years and extensive monitoring is needed which is time-consuming and costly.

An analysis of general literature on stove programs, literature on past and current programs, interviews of recently developed programs and field interviews was done to find the technology appropriateness, environmental, economic and sociocultural aspects that influence the success or failure of a stove program. This results in a generic framework of success and failure factors for the evaluation of stove programs in India that can be adjusted for worldwide use. Applying this framework to the new Indian stove program, the NCI, it was found that the program has the potential to become successful with large scale coverage if the government does not leave too much of the responsibilities with the industry and state government. If CDM can be realized, carbon credits can replace the initial subsidies from the moment of issuance.

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Acronyms

BIS	Bureau of Indian Standards
BoP	Bottom of the Pyramid
BPL	Below Poverty Line
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CSR	Corporate Social Responsibility
DOE	Department of Energy
ETS	European Trading System
FAO	Food and Agriculture Organization of the United Nations
FCF	Fair Climate Fund
FD	Forced Draft
GS	Gold Standard
IAP	Indoor Air Pollution
IC	Improved biomass cookstove
IEA	International Energy Agency
MDG	Millennium Development Goal
MFI	Microfinance Institution
MNES	Ministry of Non-conventional Energy Sources
MNRE	Ministry of New and Renewable Energy
MPCE	Monthly Per Capita Expenditure
NCI	National biomass Cookstoves Initiative (India)
ND	Natural Draft
NGO	Non-governmental Organization
NISP	National Improved Stove Programme (China)
NPBD	National Program for Biogas Development (India)
NPIC	National Programme for improved Chulhas (India)
NPV	Net Present Value
NSSO	National Sample Survey Organisation
O&M	Operation & Maintenance
PDD	Project Design Document
PDS	Public Distribution System
PIC	Product of Incomplete Combustion
PM	Particulate Matter
PoA	Program of Activities
RSPM	Respirable Suspended Particulate Matter
SHG	Self-help Group
TERI	The Energy and Resources Institute
TSP	Total Suspended Particles
VER	Voluntary Emission Reduction

Currency rates used:

Indian Rupee (INR) - Euro	INR 1	€0.022
US Dollar (US$) - Euro	US$ 1	€1.407

Source: CIA factbook, 6 July 2012

1. Introduction

1.1 Background and problem definition

In developing countries, the main part of household energy demand is provided by traditional, solid fuels such as biomass, animal dung and charcoal. Worldwide, 3 billion people rely on these fuels for cooking (Grieshop et al., 2011). Cooking with these fuels on traditional cooking devices has several negative implications. First of all, large amounts of fuel are needed due to the low efficiency of traditional cookstoves, causing high emissions of greenhouse gases. Also, the indoor air pollution from smoke that is released during cooking has negative impacts on people's health. Because of this indoor air pollution, 500 million cases of illness and 0.5 million deaths occur worldwide each year (UNDP-World Bank, 2003). Moreover, of all the firewood gathered for energy purposes, an estimated 40% is not obtained in a sustainable way, leading to deforestation in many countries (Reddy, 2009). On top of this, women and children spend a lot of time and drudgery gathering the biomass for cooking, which restrains them from spending time on income-earning activities or education and holds back their personal development (Pohekar, 2004; Pachauri et al., 2004).

To achieve the Millennium Development Goals (MDG's) set by the UN to reduce poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women by the year 2015, decreasing the reliance on traditional fuels is a key issue to be addressed (Reddy, 2009). To reach these MDG's, the Government of India set a target to reduce poverty from 22% to 19% by 2015 (Bhide, 2011). Improving the access to modern energy services for low purchasing power people is an important aspect that has to be dealt with to achieve this target. With 24% of the world's yearly biomass consumption, India has a large share in the global use of traditional fuels (International Energy Agency, 2002). Around 625 million people in India have no access to modern cooking fuels and use traditional fuels instead. Especially in rural areas, still 80-90% of the energy used is provided by biomass (Bhide, 2011).

Better solutions are needed to resolve the issues with traditional cooking. Solutions can be based on more efficient and sustainable ways of using traditional fuels, or on a switch to modern cooking fuels and technologies (Foell et al., 2011). So far, a study including both the technological and environmental as well as the financial and social aspects of different cooking solutions is lacking. Such an analysis is needed to provide a complete overview of the fuels and devices available and factors that are important in the transition process towards these low carbon cooking technologies.

In this research, the problems of traditional cooking in India and the improved cooking options that are available are discussed. These options are compared in a quantitative analysis of environmental and financial impacts. Then, a qualitative analysis of stove programs, studies and financial mechanisms is done to create a framework of success and failure factors for the evaluation of stove initiatives based on lessons learned. Finally, this framework is used to evaluate India's new national stove program.

The aim of this is to identify appropriate improved cooking solutions to reduce (1) the emission of greenhouse gas emissions (2) firewood consumption for cooking purposes (3) health impacts from indoor air pollution and (4) the drudgery of women and children, and to identify the factors that can stimulate the implementation of these cooking solutions by the rural poor in India.

1.2 Research question

The following question will be answered in this research:

What factors influence the transition to low carbon cooking technologies for the rural poor in India and how can the implementation of these technologies be stimulated?

The following sub-questions have been set up to be able to answer the research question:

1. What cooking technologies (device-fuel combinations) are available in India?
2. What are the technological, environmental, economic and social barriers and success factors of these technologies?
3. How can lessons learned be applied to policy measures to stimulate the implementation of low carbon cooking technologies for the rural poor in India?

1.3 Boundaries

This research focuses on the rural poor in India. The poverty line, which is the level below which a person is considered to have no adequate income to fulfill basic needs, was decided at its current level of Rs. 672.80 per month per capita for rural India in 2006. In 2009-2010, 33.8 percent of the rural population in India was below this poverty line, so the scope of this research is very large (Planning Commission, 2012). This is in line with the latest data from the National Sample Survey Organisation (NSSO) which states that the 30 percent least affluent of the rural population had an average Monthly Per Capita Expenditure of Rs. 675.35 in 2009-2010 (NSSO, 2011). This least affluent 30 percent of the rural population is the group that is targeted in this research. A term that is often used in literature to address the poor, and that was mentioned in many of the interviews conducted for this study, is the Bottom of the Pyramid (BoP). This term is used alongside the term rural poor in the research, and addresses the same population group.

1.4 Scope

This research will only focus on household cooking. Restaurants, schools, offices and other public buildings where cooking is done will not be taken into account. Only fuels and devices that are already available in India will be looked at in the analysis.

1.5 Method

1.5.1 Literature review

To answer the sub-question 1, a literature study of fuels and devices being used for cooking in India was carried out. A selection of technologies to be analyzed was made based on this literature review. Technologies selected are implementable in India, reduce of carbon emissions and look promising from literature. Traditional biomass cookstoves and the issues they cause in India were included as well, as they are the most widely used device-fuel combination in rural areas and results for this combination are needed to make a comparison with the other technologies. NSSO data was used to depict and analyze fuel use patterns in India.

1.5.2 Quantitative analysis

To be able to answer part of sub-question 2, calculations were done to analyze the environmental aspects of the different cooking technologies in terms of CO_2-emissions and indoor air pollution, and the economic aspects in terms of unit cost of cooking, net present value and the cost of CO_2 abated.

Input data from literature, seminars and meetings was used. The formulas used to calculate these aspects are for a device-fuel combination of fuel x and stove y stated in Table 1.1, where η is efficiency, i is interest rate and l is lifetime.

Table 1.1 Formulas used for calculation of environmental and economic aspects

Parameter	Formula used
Daily fuel use for cooking (kg/day)	$= \frac{\text{Daily energy requirement for cooking } (MJ)}{\text{Energy content fuel } x \left(\frac{MJ}{kg}\right) * \eta\ (\text{thermal, stove } y)}$
CO emissions from cooking (g/day)	$= \text{Daily fuel } x \text{ use for cooking } \left(\frac{kg}{day}\right) * \text{carbon fraction fuel } x \left(\frac{kg}{kg}\right) * \text{C to CO fraction fuel } x \left(\frac{g}{kg}\right)$
$PM_{2.5}$ emissions from cooking (g/day)	$= \text{Daily fuel use for cooking } \left(\frac{kg}{day}\right) * \text{PM2.5 ratio fuel } x \left(\frac{g}{kg}\right)$
CO_2 emissions from cooking (kg/day)	$= \text{Daily fuel } x \text{ use for cooking } \left(\frac{kg}{day}\right) * \text{carbon fraction fuel } x \left(\frac{kg}{kg}\right) * \text{C to CO2 fraction fuel } x \left(\frac{kg}{kg}\right)$
Potential power generation from biomass savings (GW)	$= \text{Firewood use (stove } y) \left(\frac{kg}{day}\right) - \text{Firewood use (traditional)} \left(\frac{kg}{day}\right) * \text{number of households} * \text{Energy content wood } \left(\frac{MJ}{kg}\right) * \eta\ (\text{thermal, biomass based power plant}) * \frac{\frac{1}{1000} GJ}{MJ} * \frac{\frac{1}{86400} day}{sec}$
CO_2 emission reduction from coal replacement (kg/stove/day)	$= \text{Firewood use (stove } y) \left(\frac{kg}{day}\right) - \text{Firewood use (traditional)} \left(\frac{kg}{day}\right) * \text{Energy content wood } \left(\frac{MJ}{kg}\right) * \frac{\eta\ (\text{thermal,biomass based power plant})}{\eta\ (\text{thermal,coal fired power plant})} * \text{emission factor coal } \left(\frac{kg\ CO2}{MJ}\right)$
Unit cost of cooking (Rs/day)	$= \text{Daily fuel } x \text{ use for cooking } \left(\frac{kg}{day}\right) * \text{price fuel } x \left(\frac{Rs}{kg}\right) + \left(\text{capital cost stove } y\ (Rs) * \frac{i\,(1+i)^{l(y)}}{(1+i)^{l(y)} - 1} + \text{O\&M factor } \left(\frac{Rs}{yr}\right)\right) / 365$
Net present value (NPV)	$= -\text{Cost stove } y + \left(\text{Daily firewood use for cooking (traditional)} \left(\frac{kg}{day}\right) * \text{price firewood} \left(\frac{Rs}{kg}\right) - \text{Daily fuel } x \text{ use for cooking } \left(\frac{kg}{day}\right) * \text{price fuel } x \left(\frac{Rs}{kg}\right)\right) * 365 - \frac{\text{O\&M factor } \left(\frac{Rs}{yr}\right)}{(1+i)^{l(y)}}$
Cost of CO_2 abated (Rs/kg)	$= \frac{\text{Unit cost of cooking (stove } y)\left(\frac{Rs}{day}\right) - \text{Unit cost of cooking (traditional)}\left(\frac{Rs}{day}\right)}{\text{CO2 emission from cooking (traditional)}\left(\frac{kg}{day}\right) - \text{CO2 emission from cooking (stove } y)\left(\frac{kg}{day}\right)}$

A discount rate of 10 percent was used for the financial calculations, based on several literature sources on the economics of cooking technologies in developing countries (Ravindranath et al., 2006; Smith et al., 2000; Purohit & Purohit, 2007; Afrane & Ntiomoah, 2012; García-Frapolli et al., 2010).

1.5.3 Qualitative analysis of programs and studies

To answer the other part of sub-question 2, an analysis of stove programs was carried out using general literature on stove programs, literature on specific past programs in India and worldwide, and stakeholder consultation by interviews on recently developed programs in India and Africa, and field visits at program sites in India. All the programs discussed are analyzed based on the following aspects:

- Technology appropriateness: what factors decide whether a technology is appropriate, and are the resources available that are needed for the production, repair and maintenance and distribution of a technology?

- Environmental aspects: what are a program's implications in terms of deforestation, climate change and indoor air pollution?

- Economic aspects: what prices and financial mechanisms are used and how does this affect affordability?

- Sociocultural aspects: how do cultural preferences and habits influence a program in terms of design, implementation and success?

1.5.4 Analysis of financial mechanisms

From the results of the economic analysis and the qualitative analysis of programs and studies, the need for an analysis of financial mechanisms was identified. This analysis was done using sources from literature, newspaper articles, stakeholder questionnaires and interviews.

1.5.5 Policy evaluation

Based on the lessons learned from the analysis of programs and studies and the analysis of financial mechanisms, a generic framework of success and failure factors for the evaluation of stove programs was developed. To answer the third sub-question, an evaluation of current stove policy in India was done based on this framework and strengths and weaknesses were identified. This leads to an advice on how to improve this policy to stimulate improved cooking methods in rural India.

2. Current status and transition

Currently, traditional cooking methods are still widely used by Indian families to prepare their daily meals. Whereas in urban areas, people are starting to use other devices and fuel options for cooking, rural households keep relying on biomass. In 2007-2008, 85% of rural households used biomass sources as their primary energy source for cooking, mainly firewood (77.6%) and dung cake (7.4%) (NSSO, 2010). Because firewood is freely available from their own fields or the forest, it is the most preferred fuel for rural Indian households (Pohekar et al., 2005). This leads to 144 million rural households relying on biomass sources for their daily cooking (Rehman et al, 2011).

The traditional stove that is used most widely in India is a mud stove, which can be produced by the households free of cost (Venkataraman et al., 2010). However, as mentioned before, cooking with this type of stoves has a lot of disadvantages. The problems caused by cooking with traditional stoves using biomass are not only environmental, but also include health and cultural issues. The main problems are discussed below.

Figure 2.1 Traditional mud stove

2.1 Global climate change

Traditional stoves have very low thermal efficiencies because of their simple design. This causes a large part of the heat produced by combusting biomass to flow into the surrounding air instead of reaching the pots on the stove (Venkataraman et al., 2010). Because of this, large amounts of biomass are needed to cook a meal. As most of the carbon content in the biomass is transformed into CO_2 when combusted, this low efficiency leads to large emissions of CO_2 from cooking every day (Venkataraman et al, 2010). The total amount of CO_2 produced worldwide by traditional cooking practices is therefore vast. CO_2-emissions from the increasing use of fossil fuels for energy purposes have led to a significant increase in the atmospheric concentration of CO_2 in the past century, which is one of the major causes of global warming (Bond et al., 2004). The large amounts of CO_2-emissions from traditional cooking contribute to this effect. However, in places where renewable biomass is used for cooking, there are no net CO_2 emissions, which is discussed later in this chapter.

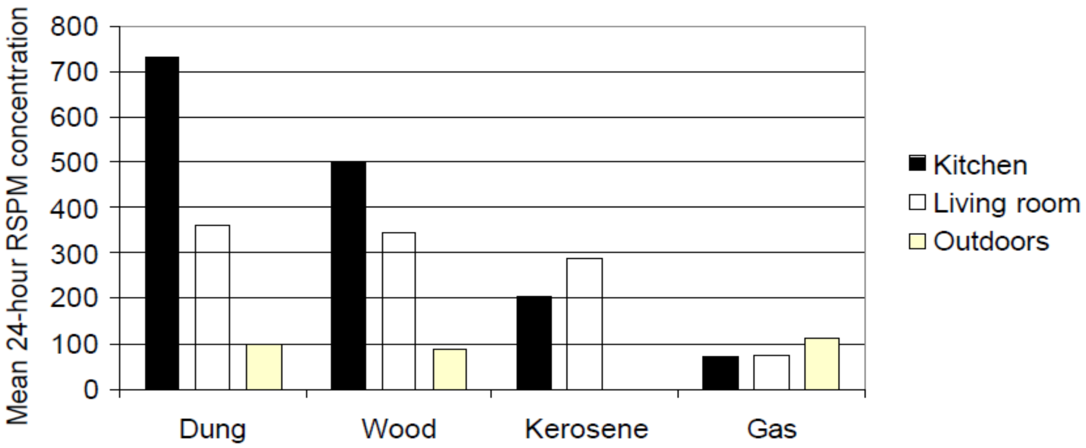
Combustion efficiencies of traditional stoves are in the range of 84-94% (Venkataraman et al., 2010). The remaining part of the fuel is not converted into heat, but into different products of incomplete combustion (PICs). One of these PICs that are emitted is black carbon (BC) in the form of aerosols. Worldwide, 18% of black carbon emissions are caused by residential biomass burning (Foell et al., 2011). Black carbon is a short-lived pollutant that only stays in the atmosphere up to a couple of weeks (Kar et al., 2011) and can influence the climate both on a local as on a global scale (Shrestha et al., 2010). Large particles remain in the region and can lead to health effects and reduced crop yield when entering the soil (Venkatamaran et al., 2010). However, it is the small particles that go into the atmosphere and make black carbon the second largest contributor to global warming (Kar et al, 2011). On the one hand, it absorbs solar radiation that is reflected from clouds and the Earth's surface. On the other hand, when deposited on ice and snow, it reduces the Earth's albedo, leading to a reduction of the sunlight reflected out of the atmosphere (Shrestha et al., 2010).

2.2 Indoor air pollution and health impacts

Next to black carbon, large amounts of other PICs are emitted by traditional cooking. These include particulate matter ($PM_{2.5}$/PM_{10}), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur oxides, formaldehyde, and polycyclic organic matter (Ezzati & Kammen, 2002). The emission of these (toxic) pollutants, in combination with limited ventilation in households in developing countries, lead to high levels of indoor air pollution (IAP). Exposure to these pollutants by members of the households is very high, often much higher than World Health Organization (WHO) guidelines (Smith et al., 2004). IAP caused by cooking with traditional fuels accounts for about 3% of the global burden of disease (Smith et al., 2004). In India, cooking is mainly done indoors, resulting in high levels of indoor air pollution. With a share of the national burden of disease from IAP of 4-6%, this is even one of the largest risk factors in the country (Smith, 2000).

Exposure to IAP can lead to a number of health impacts, including eye and lung irritation during cooking, acute respiratory infections, chronic obstructive pulmonary disease (COPD), lung cancer, asthma, middle ear infection, cancer of the nasopharynx and larynx, tuberculosis, perinatal conditions and low birth weight, and diseases of the eye such as cataract and blindness (Ezzati & Kammen, 2002).

To analyse indoor air pollution, UNDP-World Bank (2003) compared the average 24-hour concentrations of respirable suspended particulate matter (RSPM, PM_{10}) in different parts of a house when cooking with dung, wood, kerosene and gas. The results are shown in figure 2.2.



Note: Dung refers to households using dung and wood, or dung with small amounts of kerosene to start the fire.

Figure 2.2 RSPM concentrations of fuel types (μg/m³) (UNDP-World Bank, 2003)

The difference between the traditional fuels dung and wood and the more modern fuels of kerosene and LPG is large. It can be noted that the numbers for wood and dung far exceed the 24-hour health-based PM_{10} standard, which is 50 μg/m³ in the United Kingdom and 150 μg/m³ in the United States (UNDP-World Bank, 2003). Other literature states that values for the 24-hour average concentration from in-house biomass combustion can even become as high as 5000 μg/m³, which is far off this scale (Ezzati & Kammen, 2002). The RSPM concentrations are in line with the conversion efficiencies of the different fuel types (Reddy et al., 2009).

Smith et al. (2004) identified four categories of interventions to reduce health impacts of household cooking (and heating) with traditional fuels, being behavioral changes to reduce exposure, changes in household ventilation, stove improvements or shifts to higher-quality, low-emission liquid or gaseous fuels (Smith et al., 2004). In this research the focus will be on the last two categories.

2.3 Gender issues

Women, but also female children, are responsible for the collection and transport of fuelwood in India (Pohekar et al., 2005). In total, women provide 30% of the national energy in India in the form of traditional fuels, mainly wood (Planning Commission, 2006). On average, the time these women spend on fuel collection is in the range of 1 hour a day up to as much as 2.7 hours per day (Rao et al., 2009; Parikh, 2011). On top of this, women in India spend an average of 2.74 hours a day in the kitchen during cooking times, when indoor air pollution is at its highest (Parikh, 2011). Many health problems are caused by the gathering of fuelwood, like neck aches, headaches, backaches and bruises. Also, because of all the time spent in the kitchen, women are the ones experiencing most health problems from indoor air pollution.

Middle-aged women (16-50 years old), who are most often responsible for household cooking practices, are the demographic group with by far the largest exposure rates to IAP. But also children in the age of 0-16, especially girls that often help during cooking, have very high average exposure concentrations (Ezzati & Kammen, 2002). Research on the health impacts on women due to traditional cooking fuels in India showed that health symptoms from IAP are especially high for girls below the age of 5 and females in the age group 30-60 compared to males of the same age group (Parikh, 2011).

The large amount of time spent on cooking practices every day withholds women and children from spending time on other activities, such as education. Also, they do not have time for income-earning activities like selling homemade crafts or farm products (Pohekar et al., 2005). The social gap between men and women, which is still very large in India compared to Europe, therefore remains in place. A change of this situation is needed to stimulate the personal development of women in India, in line with the Millennium Development Goal of promoting gender equality and empowering women (Rehfuess et al., 2006).

Figure 2.3 Girl suffering from smoke while cooking on a mud stove

2.4 Deforestation

India is the largest consumer of fuelwood in the world, although it has a very low per-capita share of forests compared to other countries (FAO, 2012). Of India's surface, 19.5% consists of forest. Because this percentage was decaying in the past as a result of deforestation, the National Forest Policy was started by the Indian government in 1988 (FAO, 2010). By afforestation projects, the Indian forest cover has increased significantly. Between 1990 and 2005, the forest stock grew with 6% (FAO, 2010). Due to this fact, deforestation is not the main concern in India in terms of the issues caused by biomass-based cooking (FAO, 2012). Also, twigs or branches that grow back easily are mostly used for cooking instead of whole trees, so a situation of sustainable harvesting of biomass is in place (Turare, 1998). However, there are regions in India where the problem of deforestation does occur and leads to an increase in time consumption for fuel collection. In some cases, the distance that women have to walk to reach the nearest forest to collect firewood has increased to 4 hours (Pohekar et al., 2005).

2.5 Transition in fuel choices

To make a transition to low carbon cooking technologies one can either shift to other, cleaner energy sources or use traditional fuels in a more efficient way. The shift towards cleaner fuels for cooking is explained by the “energy ladder”.

Fuel choice is for a large part dependent on income levels. According to the energy ladder principle, people tend to move up the energy ladder towards more expensive, cleaner fuels when income rises. For cooking, firewood, dung and coal are at the bottom of this ladder, followed by kerosene and then by more modern fuels like LPG, biogas and electricity (Bhide, 2011).

In urban India, a shift from biomass to these modern fuels has taken place in the past decades. LPG and kerosene account for a large share of urban energy use for cooking (Bhattacharyya, 2006). But this is not the same for rural areas, where firewood is still the prevalent fuel, as figure 2.4 shows.

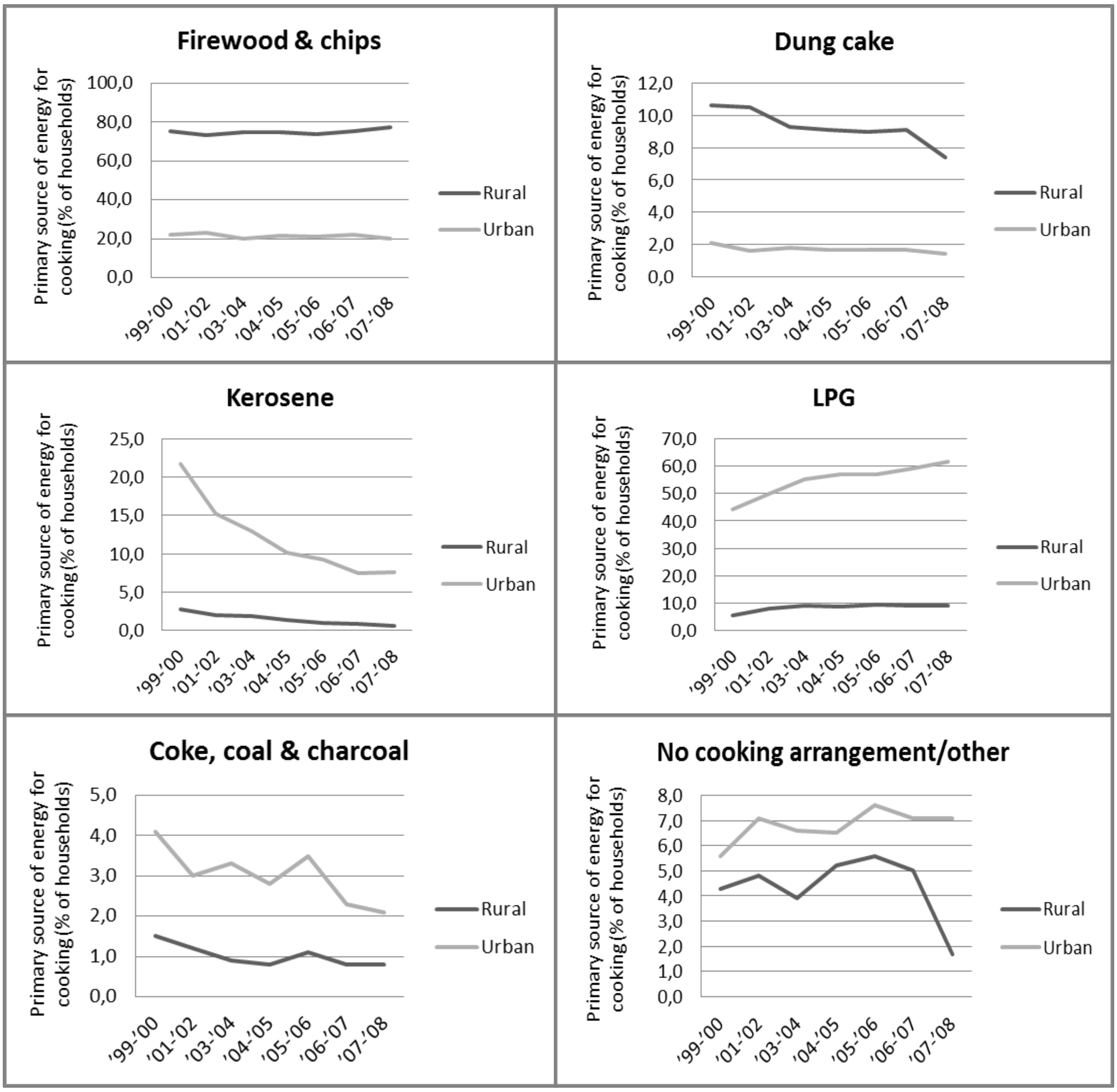


Figure 2.4 Rural vs.urban energy use in India (1999-2008)

Figure 2.4 shows that in rural areas, a shift towards modern fuels for cooking is still barely happening and large amounts of biomass in the form of firewood and dung cake are still being used. Masera et al. (2000) describe characteristics of rural areas that contribute to this lack of transition in rural areas:

- The prevalence of freely gathered traditional biofuels and their cost (in monetary term) is zero;
- Modern fuels are not available and in many cases their distribution is unreliable;
- The price of modern fuels as well as their transaction costs for production and transportation are usually high;
- A large portion of income in rural regions is non-cash and often the cash income of rural households is too low to offer upfront payments associated with modern energy systems;
- Income in rural regions is uncertain and variable (e.g. seasonal) and therefore regular payments that require commercial energy sources or pay-back of loans are difficult to manage;
- Local customs related to cooking practices and methods are stronger in rural regions than in urban centers (Masera et al., 2000).

Figure 2.5 shows an analysis of data from the National Sample Survey Organisation (NSSO, 2006) of the cooking fuels used by different Monthly Per Capita Expenditure (MPCE) classes in rural areas.

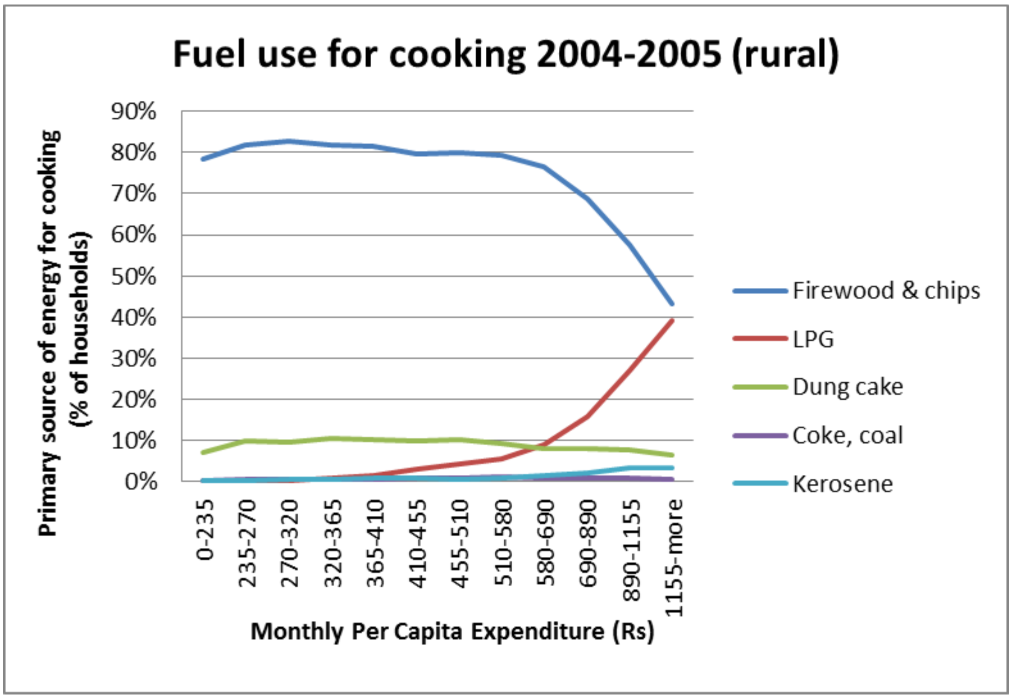


Figure 2.5 Cooking fuel use of different expenditure classes in rural India

It can be seen that a shift in the fuel used for cooking only happens in expenditure classes higher than 350 rupees per month. Even for the highest expenditure classes, firewood still provides over 40% of the total energy used for cooking. Also, there is only a slight decrease in the use of dung cake, which is a fuel that is available for free using animal waste. The main substitute for the traditional fuels is LPG, which is not in line with the concept of the energy ladder, where a transition to kerosene would occur before moving up to LPG. As shown in figure 2.3, kerosene only accounts for a very small part of energy used for cooking, even in the highest expenditure classes. The characteristics of LPG and kerosene as cooking fuels are described in Chapter 3.

Literature often criticizes the concept of the energy ladder, as households do not simply move from one fuel to the other. Instead, they tend to use a combination of them, a portfolio of energy systems, which depends on their budget, preferences and needs. This phenomenon is called "fuel stacking". Larger household more often tend to use a variety of fuels (Kowsari & Zerriffi, 2011). In rural India, this pattern of fuel stacking explains the fuel situation much better than the energy ladder. New fuels are used when income rises, but traditional fuels are still being used in significant amounts as well. This has to do with the free costs of firewood and dung cake on the one hand, but also with cultural preferences in terms of habits and taste and with the availability and access to modern fuels. These aspects will be elaborated on in later chapters.

Apart from moving to different or multiple fuels, a shift to renewable technologies is possible. Solar cookers that use solar heat and biogas made from animal dung are technologies which can (partly) replace traditional cooking devices and fuels (Puhorit, 2002).

But as mentioned before, a transition to other energy sources is not the only way to reduce the carbon emissions from cooking. Another option, one that will be focused on in this thesis, is a shift from traditional biomass cookstoves to improved biomass cookstoves (IC's), which use biomass in a more efficient way and therefore reduce biomass consumption (Shrimali et al., 2011). Because the characteristics of rural areas make an entire shift towards modern fuels very unlikely, IC's seem like a promising option, as they will reduce fuelwood consumption and the time of gathering it.

If less biomass is used for cooking, the possibility to use the biomass for renewable electricity generation could be advantageous. With a total generation of 200 GW, India has the fifth largest electricity demand in the world. Currently, coal is the fuel that is used for 71% of the electricity generation. After coal, large hydro energy accounts for 11% of the generation, followed by natural gas with 9% (Central Electricity Authority, 2012). Of these energy sources, coal is by far the most polluting, with the highest CO_2 emission factor per kWh of electricity produced (Central Electricity Authority, 2012). If the biomass that is saved by using more efficient biomass cookstoves can be used for renewable electricity production, this can cause even higher CO_2 savings on top of the direct savings from more efficient cooking.

Many programs to stimulate the use of improved cookstoves, biogas plants, solar cookers and modern non-renewable fuels have been implemented in India and in other developing countries in the past decades, which are described in Chapter 4. Still, these programs often did not have the result that was aimed for, as per capita fuelwood consumption in rural areas has barely declined (NSSO, 2006). However, new promising technologies of improved biomass cookstoves have become available recently, which have barely been described in literature yet. As a new program is being developed by the Indian government, it is necessary to look at the technological, environmental, financial and sociocultural aspects of these technologies, to see what approach this new program should take. The following sections describe the characteristics of the different devices and fuel options for India, which factors contribute to a change in device and fuel choices, and address the barriers and success factors of different cookstove programs in India and in other countries.

3. Quantitative analysis of cooking options

3.1 Devices and fuels

Figure 3.1 shows an overview of energy sources and devices that are used for cooking in India. This chapter describes the characteristics of the most prevalent device-fuel combinations followed by a quantitative analysis of the environmental and economic aspects of these technologies.

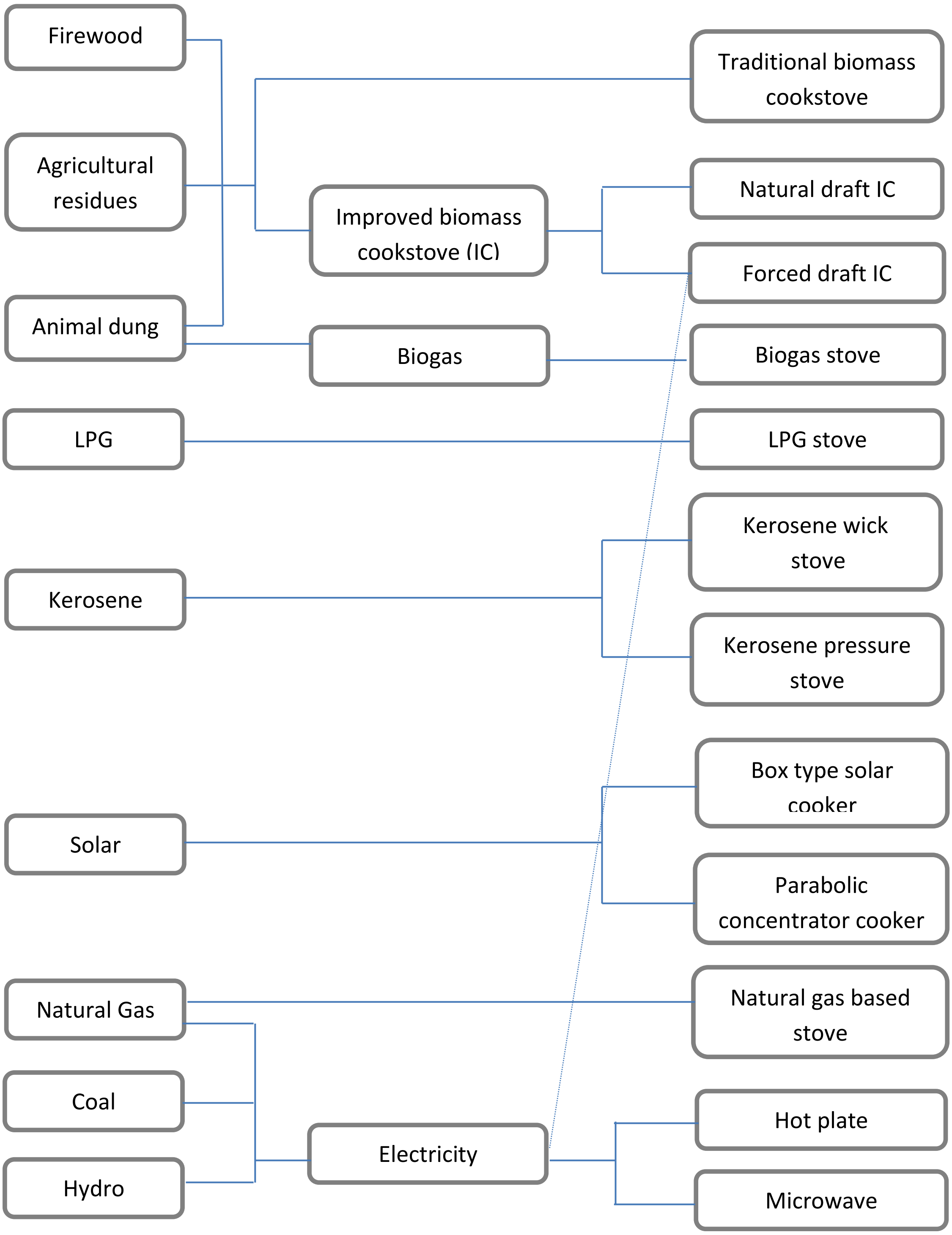


Figure 3.1 Energy sources and devices for cooking in India

3.1.1 Kerosene

Kerosene is a typical middle class cooking fuel (Pohekar, 2005) and is mainly used in urban areas. In 2007-2008, 0.6% of rural households used kerosene as the primary energy source for cooking, against 7.6% of urban households. In rural areas, the average MPCE of kerosene users was Rs. 945, which is above the average Indian monthly per capita expenditure of Rs. 772 (NSSO, 2010). Kerosene consumption grew steadily from the year 1950 to more than 8% of the total Indian household energy consumption in the year 2000. However, looking at the latest NSSO data, it can be seen that the use of kerosene as a primary cooking fuel, in rural as well as in urban areas, has been declining over the past decade to only a third of the amount that was used in 2000. The major state with the highest rural use of kerosene as primary cooking fuel is Gujarat, with 2.4% of households. This can be explained by the fact that household expenditure in Gujarat is about 10% higher than the Indian average, both in rural and in urban areas (NSSO, 2010).

Kerosene is used in much larger amounts for lighting purposes than for cooking. In 2007-2008, 38.9% of the rural households used kerosene as their primary energy source for lighting, against 5.1% of the urban households (NSSO, 2010). Kerosene is often described as a transition fuel, because the use of it increases when income increases but then decreases again when income rises above a certain level and it is substituted by more expensive fuels like LPG and electricity (Bhide, 2011). This is definitely true for urban areas, where kerosene for cooking has been substituted by LPG and kerosene for lighting by electricity (NSSO, 2010). But the unavailability of these resources in rural areas prevents this transition from happening.

Figure 3.2 Kerosene wick stove
Source: bombayharbor.com

A public distribution system (PDS) for subsidized kerosene is currently in place in India. This system stems from a pricing scheme that was set up in the time that the Indian energy sector was still largely state-owned, where some fuels were taxed and others were subsidized. Now, deregulation of a large part of the energy sector has taken place, but some fuels are still being subsidized, among which kerosene and LPG. These subsidies are of a fixed level and not targeted (Gangopadhyay et al., 2004). The government provides a subsidy of Rs. 0.82 per liter of kerosene, and an under-recovery (amount paid by the Indian government to the oil companies to erase the gap between local and international oil prices) of Rs. 27.20. This means that the (government owned) oil companies sell their product at a much lower retail price (Rs. 14.83) than the total desired price of Rs. 41.00 when all production, transport, marketing, taxes and other costs are taken into account (Ministry of Petroleum & Natural Gas, 2012). These under-recoveries account for large amounts of government money spent on kerosene but also diesel and LPG for which a similar system is in place.

The reliability of the PDS supply often proves to be a problem, and unavailability is a big issue (Pohekar et al., 2005). Another problem with the PDS is that is does not always reach the households and the purpose that it was aimed for. The National Sample Survey Organization (NSSO, 2008) concluded that where subsidies for kerosene were aimed to promote the penetration of kerosene for cooking in rural areas, it actually was bought for lighting purposes and did not make any difference in terms of cooking.

The main advantage of kerosene stoves is that the flame can be controlled well and they are easy in use. Disadvantages are their smell and safety issues such as the flammability (Pohekar et al., 2005).

Two types of kerosene stoves are available on the Indian market, the wicks stove and the pressure stove. The wick stove is lower in power, the pressure stove has a higher power output but is very noisy in use (Bhattacharya, 2011). Kerosene stoves can reach efficiencies in the range of 35-50% (Reddy & Balachandra, 2006).

3.1.2 LPG

In 2007-2008, 9.1% of rural households used LPG as a primary source for cooking, against 61.8% of urban households. In both rural and urban areas, LPG use has been growing in the past decade, although rural LPG use for cooking has only increased slightly in the past 10 years (NSSO, 2010). In 2007-2008, the average monthly expenditure of rural households that use LPG as their primary cooking fuel was Rs. 1389, which is almost double the average Indian MPCE of Rs. 772. The major state with by far the highest rural use of LPG for cooking is Punjab, with 29.5%. Punjab is the state with the second largest rural consumer expenditure (NSSO, 2010).

A PDS is also in place for the distribution of LPG. The LPG connection and cylinders are supplied by three companies in India, and every household is eligible for only one connection (India Development Gateway, 2012).The government provides a subsidy of Rs. 22.58 per cylinder for domestic use and an under-recovery of Rs. 319.20 to enable a retail price of Rs. 399.26 (Ministry of Petroleum & Natural Gas, 2012). For LPG, the unreliable supply is a disadvantage as well. This unreliability is due to uncertainties in the amount of LPG production and uncertainties in the delivery procedure that have to do with poor and irregular distribution and the lack of infrastructure. An additional problem in the supply of LPG is that it is very difficult to store, which makes it impossible to buy a large amount ahead of using it (D'sa & Murthy, 2004).

LPG stoves are the most popular cooking devices in urban areas, because they are clean, safe, efficient and cost-effective. Also, compared to traditional and kerosene stoves, they are easier to ignite and use (Pohekar et al., 2005). Because LPG has a high energy content, LPG stoves can reach efficiencies up to 60% (D'sa & Murthy, 2004). However, LPG is used much less in rural areas due to the lack of a distribution network and the high initial costs it requires (Pohekar et al., 2005). The model that is used most in India is a double burner LPG stove, which is widely available on the market.

Figure 3.3 Double burner LPG stove *Source: indiamart.com*

3.1.3 Biogas

Biogas produced from animal dung or organic waste can be used as a domestic cooking and lighting fuel (Kurchania et al., 2010). In rural India, where many people still rely on cattle to make a living, a very large potential of 12 million family size biogas plants is identified (Purohit et al., 2002). Biogas is a mixture of the combustible element methane (55-70%) and CO_2 (30-45%). It is produced in a process of microbial degradation, with biogas slurry as a by-product. This slurry can be used to substitute fertilizer, which could result in a climate benefit on top of the benefits from cooking with the biogas (Pathak et al., 2009).

One family-sized biogas plant which uses four cattle can substitute more than 5 tonnes of firewood every year. However, there is always 5-15% leakage of methane in the production process, which has a global warming potential around 4 times as large as CO_2 and partly offsets the climate benefits of using biogas (Pathak et al, 2009).

The thermal efficiency of a biogas stove is around 55%. It provides a clean and efficient way of cooking (Kurchania et al., 2010). Also, cooking with biogas instead of directly using the animal dung, mostly in the form of dung cake, leads to three times more useful energy, so the fuel is used in a more optimal way. The main disadvantage of biogas is the high investment needed to build a family-sized plant. Also, this technology can only be used by households that own cattle, so it is not a solution for the rural poor that often do not own cattle (Pohekar et al., 2005). On top of financial drawbacks, repair and maintenance proved to be problematic issues for biogas plants in India, which is described in Chapter 4.

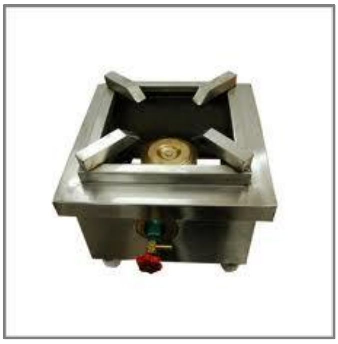


Figure 3.4 Biogas stove
Source: products.tradeindia.com

3.1.4 Solar cookers

With a high solar radiation and more than 275 sunny days per year, the availability of solar energy in India is large, and this energy can be used for cooking (Pohekar et al, 2005). Solar cookers absorb solar energy, convert it into heat and capture this heat in an (enclosed) space where the cooking happens (Saxena et al., 2011). There are two types of solar cookers that can be used: a box type solar cooker and a parabolic solar concentrator.

Figure 3.5 Box-type solar cooker
Source: indiamart.com

A box type solar cooker consists of an insulated box that receives solar heat through a glass cover. On the inside, the box is black to capture as much heat as possible. A mirror on the insight of the top lid can reflect the sunlight into the box when the lid is open (Saxena et al., 2011). Advantages of this type of solar cooker are that it is very easy to construct and needs few attendance while it is in use. However, because only low temperatures up to 100 degrees centigrade can be reached, the cooker is very slow and it takes a long time before a meal is cooked, up to three times as long as traditional cooking (Muthusivagami et al., 2010; Pohekar & Ramachandran, 2006).

In a parabolic solar concentrator, a mirror with a parabolic shape reflects the sunlight and concentrates it to one point, where a cooking pot is placed (Muthusivagami et al, 2010). With this type of solar cooker, much higher temperatures of 350-400 degrees centigrade can be reached, with a thermal efficiency up to 60%. It can be used for different cooking operations like boiling, baking, frying and roasting, whereas the box type solar cooker is only suitable for the first two (Pohekar & Ramachandran, 2006). Because of this, almost any type of food can be cooked with the solar concentrator, and heating times are shorter. However, this type is more expensive because of a larger size and more complex design. Also, it needs to be adjusted to the direction of the sun during cooking, and there is a risk of fires because of the high temperatures (Muthusivagami et al, 2010).

Figure 3.6 Parabolic solar cooker
Source: solarcooking.org

In general, the fact that there are no recurring costs is a main benefit of using a solar cooker. However, it is less useful in urban areas, where less space with enough direct sunlight is available.

Also, the high upfront costs in combination with the novelty of the technology and the big change in cooking habits it requires can be a barrier for the dissemination of the technology in India (Pohekar et al., 2005).

3.1.5 Improved biomass cookstoves

There has been a lot of progress in the area of improved biomass cookstoves in the years after the National Programme on Improved *Chulhas*[I] (NPIC), the stove program of the Indian government, was stopped in 2002. A new line of stoves, based on a fan which caused a forced draft, has come up. Because there is not much literature available on this new stove type and it's suitability for the Indian market, an interview with TERI experts provided most of the information for this chapter, which gives a description of the different models of improved biomass cookstoves.

There are basically two types of improved biomass stoves that are available in India, the natural draft (ND) and the forced draft (FD) stove.

3.1.5.1 Natural draft stoves

The natural draft model, which has been on the market for a long time, is based on a chimney that creates a draft needed to keep the fire burning. The chimney height, fire power and temperature difference are factors that all influence the efficiency of the stove. Also, the size of the combustion chamber matters, every centimeter difference in design can have an impact on stove performance. Efficiencies of ND stoves are in the range of 10-20% based on water boiling tests.

Figure 3.7 Front-loading natural draft stove
Source: envirofit.org

In ND stoves, it is not possible to control the burning rate, because the air flow is natural and cannot be influenced. Also, there is no control on the distribution of air in the combustion chamber.

Natural draft stoves can be front- or top-loading, meaning that the biomass sometimes has to enter from the front in a horizontal way, and sometimes from the top (Raman & Ram, 2012).

3.1.5.2 Forced draft stoves

Forced draft stoves have a fan included in the bottom which causes a "forced" air flow through the combustion chamber. They work on a gasifier principle, meaning that the fuel is first heated and gasified before it is combusted.

In FD stoves, air input and burning rate can be controlled by the power of the fan, and so can the air distribution. Therefore, there is a much better control on the power level of the stove. Efficiencies of FD stoves are much higher, in the range of 35-40% based on water boiling tests. In regions where charcoal is used, efficiencies beyond 50% can even be achieved (Raman & Ram, 2012).

Forced Draft stoves are always top-loading. Because of the small size of the combustion chamber, small wood twigs, chips or pallets are needed in this type of stove. The size of these fuels can be maximum 4 inch wide and 1 by 1 inch in diameter.

[I] *Chulha* is the traditional Hindi word for cookstove

Because the fan runs on a battery and the lifetime of the battery is usually shorter than the lifetime of the stove, the battery should be available in the market for replacement. A battery that is widely available is also preferred for manufacturing of the stove. To charge the battery, solar panels can be used. The battery can charge during the day and be used for cooking, but also as a power source for lighting at night, which is a technology that is already available in India and Africa. Instead of an external battery, a thermoelectric generator can be placed inside of the stove which produces energy from the temperature difference within the stove.

Figure 3.8 Woman cooking on forced draft stove

Instead of using firewood, biomass fuel pellets made from pressurized agricultural residues have become available on the market as a fuel for cooking. These pellets can be used in both natural draft as forced draft top-loaded improved cookstoves. Some stove manufacturers even claim to produce stoves that run on pellets only. However, according to Raman and Ram, these stoves are all suitable to run on firewood as well (Raman & Ram, 2012).

3.2 Environmental analysis

The next two paragraphs will describe the results of a quantitative excel analysis of the device-fuel combinations mentioned in section 3.1. Solar cookers and biogas stoves are not taken into account in this analysis. This is because the compatibility of solar cookers in the Indian culture is too problematic in terms of food taste, cooking habits and cooking time, as was described in section 3.1.4. Biogas, next to the issues with plant repair and maintenance that were identified in India, is only an appropriate technology for households that have enough resources in terms of cattle and the very large prior investments compared to other cooking technologies, which makes it an unsuitable technology for the rural poor that are targeted in this thesis.

For all values, a minimum and maximum scenario is calculated, based on ranges (low vs. high value) in efficiency, daily energy use for cooking and other factors. It has to be noted that these minimum and maximum values calculated are indicative numbers that show the highest efficiency improved technology replacing the lowest efficiency traditional stove, and the other way around. These are therefore extremes that show the possible range of outcomes for the aspect that is analyzed.

Because the environmental and health aspects are the biggest incentives for improved cooking methods, it is important to discuss the device-fuel combinations in terms of their emissions. In this paragraph, the firewood consumption, CO, $PM_{2,5}$ and CO_2 emissions are shown. The amount of firewood used for cooking was calculated using the values given in Table 3.1.

Table 3.1 Input values - daily firewood use for cooking

Parameter	Low value	High value
Daily cooking energy requirement	11 MJ[a]	20 MJ[a]
Efficiency (thermal) traditional	5%[b]	10%[b]
Efficiency (thermal) ND	10%[c]	25%[c]
Efficiency (thermal) FD	25%[c]	40%[c]
Energy content wood	15 MJ/kg[d]	

Sources: [a] Venkataraman et al., 2010; [b] Kandpal & Maheshwari, 1995; [c] Rehman, 2012; [d] Grieshop et al., 2011

Using these values, the results for the daily amount of firewood for cooking was calculated for the three devices that use firewood as a fuel (i.e. traditional, ND IC and FD IC). Here, the minimum scenario represents the high efficiency stoves combined with the low daily cooking energy requirement, and the maximum scenario shows values for low efficiency stoves and a high daily cooking energy requirement.

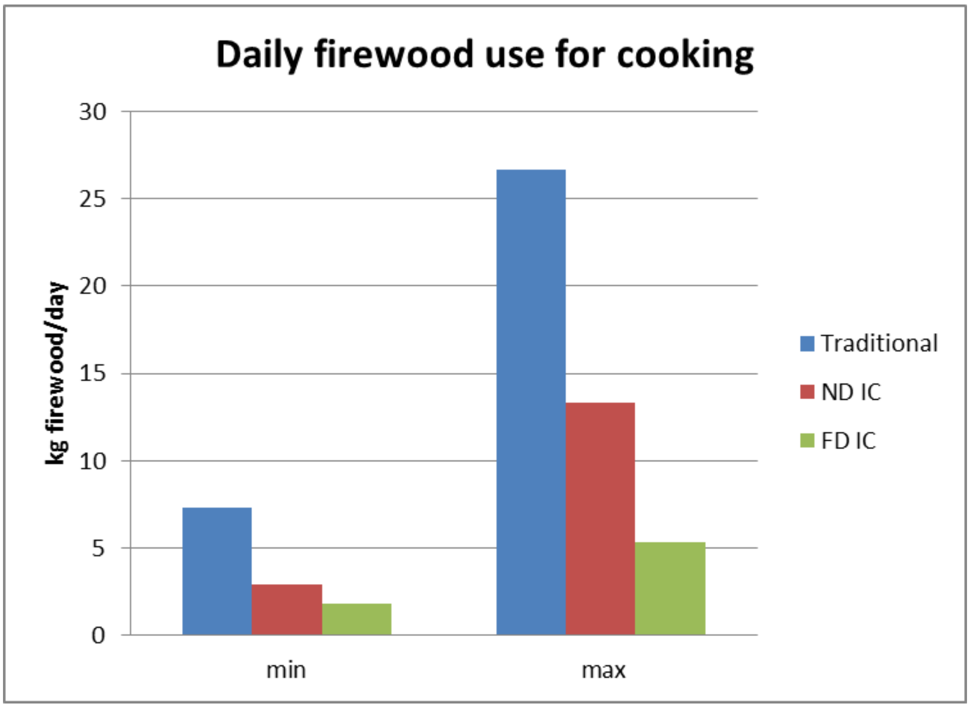


Figure 3.9 Daily firewood use for cooking (kg/day)

Figure 3.9 shows that daily firewood use can be reduced significantly by substituting a traditional stove with a natural draft stove, with around 50% reduction in both scenarios. Even more firewood is saved with a forced draft stove because of its higher thermal efficiency, leading to a reduction in the range of 80% of the amount used by traditional stoves in both scenarios.

3.2.1 Local environment

In the local environment, the two products that cause most harm in show terms of health issues are carbon monoxide (CO) and suspended particle matter ($PM_{2,5}$). Figures 3.10 and 3.11 show the CO and $PM_{2,5}$ emissions, which are a result of incomplete fuel combustion, based on the values in Table 3.2. The forced draft stove using pellets was not included in this analysis, because no numbers on CO and $PM_{2,5}$ emissions are available for this fuel, but these values are assumed to be similar to the values for a forced draft stove using firewood.

Table 3.2 Input values – CO, $PM_{2.5}$ and CO_2 emissions from cooking

Parameter	Value
Carbon fraction firewood	0.50 kgC/kg firewood[a]
C to CO_2 fraction firewood	0.485 kgC/kg firewood[a,b]
C to CO fraction firewood	3.5 gC/kg firewood[b]
$PM_{2,5}$ ratio firewood	8.5 $gPM_{2,5}$/kg firewood[b]
Carbon content kerosene	19.5 kgC/GJ[c]
C to CO fraction kerosene	7.6 gC/kg kerosene[b]
$PM_{2,5}$ ratio kerosene	0.5 $gPM_{2,5}$/kg kerosene[b]
Carbon content LPG	17.2 kgC/GJ LPG[c]

C to CO fraction LPG	6.4 gC/kg LPG[b]
$PM_{2,5}$ ratio LPG	0.5 $gPM_{2,5}$/kg LPG[b]
CO_2/C ratio	44/12[c]
CO/C ratio	28/12[d]

Sources: [a] Roden et al., 2006; [b] Grieshop et al., 2011; [c] IPCC, 2006; [d] Harley et al., 2001

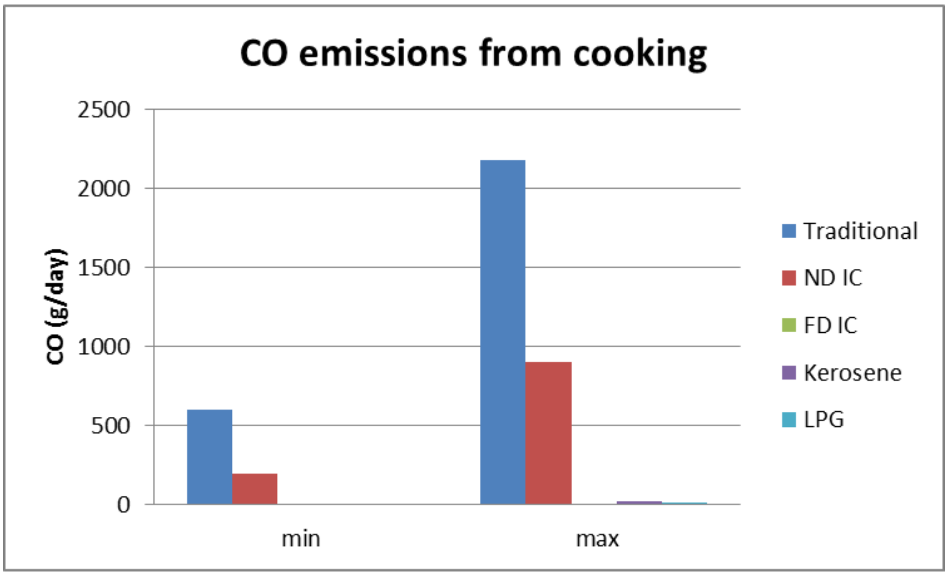


Figure 3.10 CO emissions from cooking (g/day)

Figure 3.10 shows that the natural draft stove reduces CO emissions by more than 50%, and CO emissions from all other options are even negligible, almost 100% of CO emissions from traditional cooking is avoided by these options. This can be explained by the higher combustion efficiencies of these devices compared to natural draft stoves, and especially to traditional stoves. The Ministry of New and Renewable Energy (MNRE) recently renewed the standards of the Bureau of Indian Standards (BIS) for improved cookstoves. One element in the standard is the CO/CO_2-ratio, which shows the amount of incomplete combustion. The standards are <0.04 for natural draft stoves and <0.02 for forced draft stoves. With the CO_2 emissions (which are shown in section 3.2.2) this ratio was calculated for the devices in the analysis.

Table 3.3 CO/CO_2-ratios

Device	CO/CO_2-ratio
Traditional stove	0.04790
ND IC	0.03759
FD IC	0.00356
Kerosene stove	0.00228
LPG stove	0.00069

This shows that the natural draft stove just performs according to BIS standards, but the emissions of the forced draft, kerosene and LPG stove are significantly below the standards.

The $PM_{2.5}$ emissions of the different stoves are shown in figure 3.11.

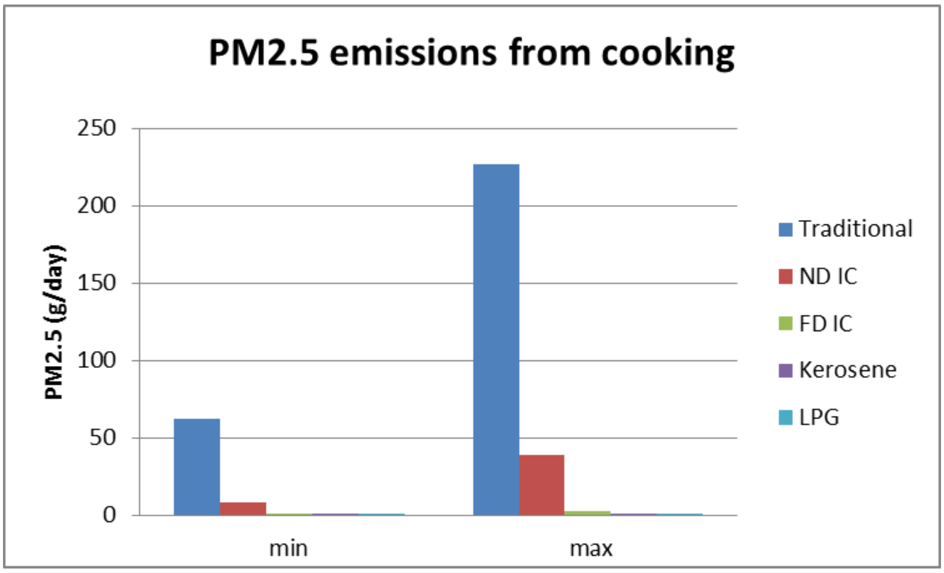


Figure 3.11 $PM_{2.5}$ emissions from cooking (g/day)

In Figure 3.11, a reduction of over 80% for the natural draft stove and again a reduction of almost 100% for the other stoves compared to the traditional situation is shown. Comparing this to Figure 2.2, assuming an 80% reduction in suspended particles would give 24-hour concentrations in the kitchen of around 100 $\mu g/m^3$, which is below the United States standard but above the United Kingdom standard. So it could be argued whether the reduction in suspended particles (assuming these are proportional to the reduction in $PM_{2.5}$) by natural draft IC's is sufficient to lift all health issues from cooking. The fact that products of incomplete combustion are still emitted by the natural draft stove means that a certain amount of smoke is still produced. Therefore, problems of short term eye and lung irritation will probably remain, but to a lesser extent compared to traditional cooking.

3.2.2 Global environment

In terms of the global environment and climate, it is important to see the amount of CO_2 that is emitted by the different devices, to be sure that a new technology-fuel combination does not perform worse than the traditional way of cooking. In this analysis, it is assumed that biomass used for cooking is sustainably grown. This choice was made based on the fact that India's forest cover is increasing, and because mainly wood twigs and agro residues are used for cooking instead of whole trees, as was mentioned in section 2.4. Therefore, according to IPCC standards, it is assumed that the CO_2 that is emitted by the traditional stove and the improved biomass cookstoves is compensated by a renewed stock of carbon. This is a major advantage of the IC's over the fossil fuels of kerosene and LPG, which always have positive net carbon emissions, and moreover are depleting resources. The CO_2 emissions from cooking with kerosene and LPG stoves are shown in Figure 3.12. Upstream emissions from fuel production and transport were not taken into account in this figure.

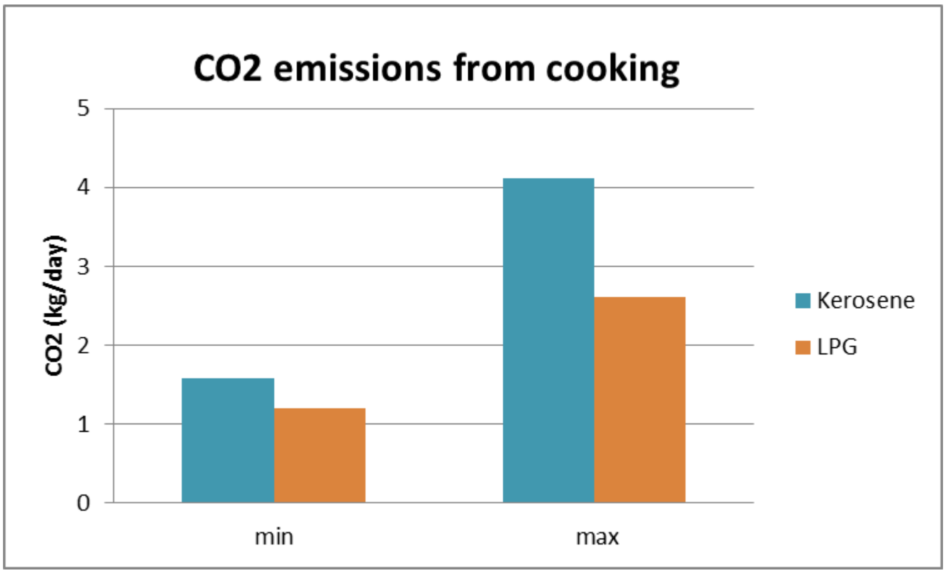


Figure 3.12 CO_2 emissions from cooking (kg/day) assuming renewable biomass

Figure 3.12 shows that CO_2-emissions from cooking with kerosene are higher than for LPG, due to the higher emission factor per MJ.

Although no CO_2-emissions for the traditional stove, natural draft and forced draft IC's are depicted, it is important to realize that there can be specific situations in India where deforestation is a problem and where wood is harvested in an unsustainable way. In these situations, CO_2-emissions from cooking with this non-renewable biomass will be in place. Also, in the case of cooking with fuel pellets, there will be some CO_2-emissions from the pressurization process in the production phase, which have not been taken into account in this analysis.

The reduction in (renewable) firewood by the improved biomass stoves compared to the traditional stove brings along opportunities of saving more carbon emissions than by the replacement of the stove alone. Theoretically, the amount of firewood that is saved could be used for electricity production as a substitute of coal. Some biomass-based power plants are already in place in India, so the technology to do this is available and could be upscaled. Also, co-firing of biomass in coal power plants is possible. The Ministry of New and Renewable Energy states that the potential for biomass-based electricity production is 17 GW (MNRE, 2012a), but this number could be highly increased if surplus firewood is taken into account. The potential electricity production from biomass savings was calculated for a scenario where all the 144 million households in India currently using traditional cooking methods would switch to natural draft or forced draft improved cookstoves, and the firewood saved is used in biomass-based power plants. Also, the potential CO_2-savings per device were calculated. Values used are given in Table 3.4.

Table 3.4 Input values – Biomass based power generation and CO_2 reduction from coal replacement

Parameter	Value
Efficiency Indian coal-fired power plant (average)	29%[a]
Fuel emission factor coal	90.6 gCO_2/MJ[b]
Efficiency Indian biomass-based power plant (average)	24%[c]

Sources: [a] Chikkatur et al., 2007; [b] Central Electricity Authority, 2011; [c] MNRE, 2012b

The potential power generation for the different devices is shown in figure 3.13. The forced draft IC using pellets was not taken into account in the calculation, as there is a lot of variety in the composition of pellets. Kerosene and LPG stoves were not taken into account in this analysis because the renewable biomass-based power generation would be generated by substituting the biomass for cooking with fossil fuels.

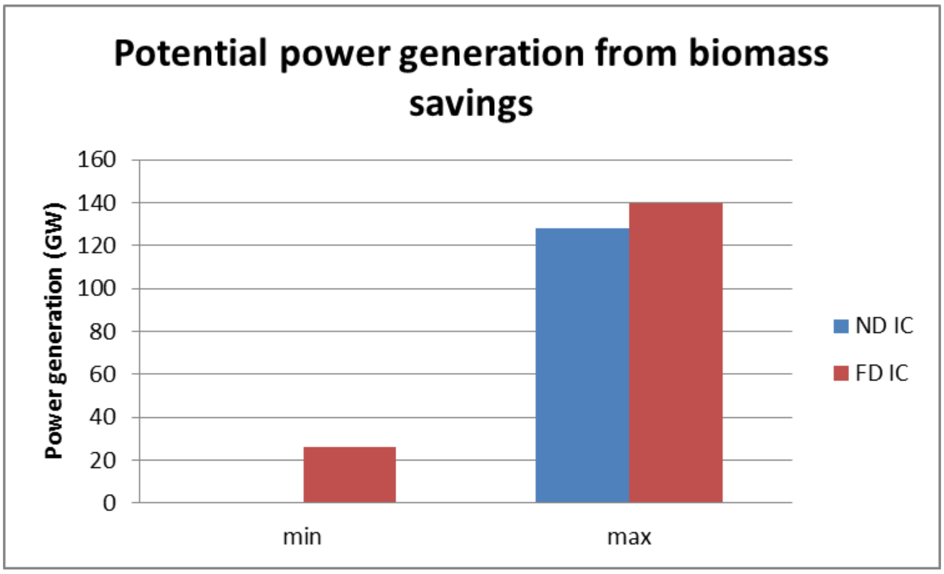


Figure 3.13 Potential power generation from biomass savings

This figure shows that the potential for biomass-based electricity production of 17 GW can be highly increased if a transition in cooking methods takes place. If IC's with high efficiencies are implemented, which is shown in the maximum scenario, the potential is over 8 times as much as the current potential. In the minimum scenario, it can be seen that there is no power generation potential for a situation where a high efficiency traditional cookstoves is replaced by a low efficiency natural draft IC. Looking at figure 3.9, the daily firewood use for traditional stoves in the minimum scenario is indeed lower than the daily firewood use for natural draft IC's in the maximum scenario, so replacement of the traditional stove with a natural draft IC would even lead to an increase firewood use in this situation.

If this substitution of coal by renewable biomass in electricity production occurs, extra CO_2 savings are realized. These savings per stove were calculated for the IC's, as shown in figure 3.14.

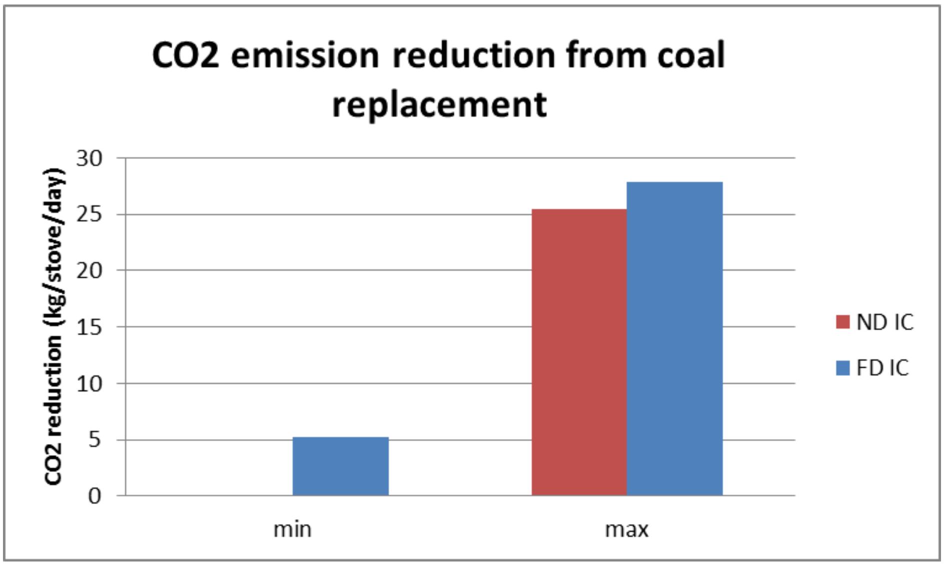


Figure 3.14 CO_2 emission reduction from coal replacement

The ratio of these results is the same as in the previous figure, but it is interesting to compare this graph with figure 3.12. It can be seen that the CO_2 savings per cookstove are even higher than the daily CO_2-emissions from cooking with fossil fuels, meaning that significant CO_2 reductions per stove implemented could be achieved by the substitution of coal with the biomass saved.

In India's National Plan on Climate Change from 2008, the need to reduce the country's greenhouse gas emissions was recognized, and this has been a national mission since. If, like in the scenario described above, all the rural households using traditional stoves would switch to improved stoves, and the maximum CO_2 reduction scenario from figure 3.14 could be reached, annual savings would be around 1200 (ND) – 1300 (FD) million tonnes CO_2, which is more than twice as large as the total annual CO_2-emissions from the Indian power sector of 579.8 million tonnes CO_2 (CEA, 2011). Although issues of biomass collection and dispersed availability would have to be considered, this would be a good opportunity for the Indian government to explore.

3.3 Financial analysis

In this paragraph, the financial aspects of these different device-fuel combinations are discussed to see which of these firewood-saving options are most viable financially. A factor that influences the outcome of these analyses significantly is the price that is accounted to firewood. Of course, in most rural areas, wood is freely gathered and the actual financial price is zero. However, there are hidden costs which can be included in a shadow price for firewood. On the one hand, this shadow price represents the burden of firewood use in terms of drudgery and collection time. On the other hand, it is the opportunity costs of the potential to sell the firewood saved on the market. For this analysis, two scenarios are used: one that is based on the zero-private-cost situation of freely gathered firewood (scenario I), and one that takes into account a shadow price of wood of 4 Rs/kg, which is the current market price of wood (scenario II)(Prasad, 2012).

To see how much a household would have to pay on a daily basis for cooking with a fuel, the unit cost of cooking was calculated, which represents the costs of cooking including the fuel, but also the device costs. This was calculated for all six device-fuel combinations using the values in Table 3.5.

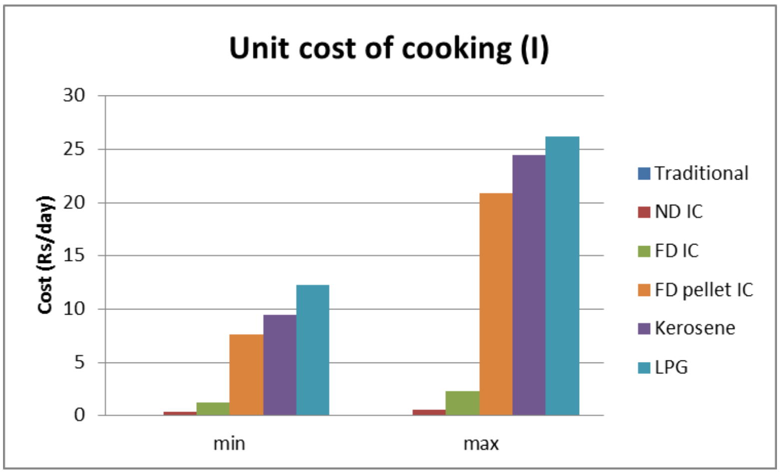
Table 3.5 Input values – Unit cost of cooking and Net Present Value

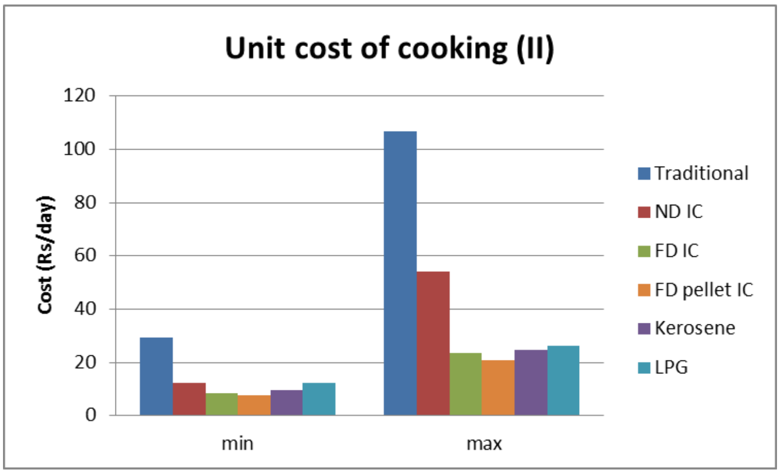
Parameter	Low value	High value
Efficiency (thermal) FD pellet	25%[a]	40%[a]
Efficiency (thermal) kerosene	35%[b]	50%[b]
Efficiency (thermal) LPG	50%[c]	60%[d]
Energy content pellets	17.28 MJ/kg[e]	
Energy content kerosene	43 MJ/kg[f]	
Energy content LPG	46 MJ/kg[f]	
Cost traditional stove	0 Rs[g]	
Cost ND stove	500 Rs[a]	800 Rs[a]
Cost FD (pellet) stove	1500 Rs[a]	3000 Rs[a]
Cost kerosene stove	200 Rs[h]	600 Rs[i]
Cost LPG stove	2400 Rs[i, j]	4400 Rs[i, j]
Price of wood	0 Rs/kg[k]	4 Rs/kg[k]
Price of pellets	4 Rs/kg[l]	
PDS Price of kerosene	30.67 Rs/liter[m]	
PDS Price of LPG	399 Rs/cylinder[m]	

Lifetime IC's	5 years[n]
Lifetime kerosene stove	10 years[o]
Lifetime LPG stove	15 years[p]
Discount rate	10%[q]
O&M costs ND IC	10 Rs/yr[r]
O&M costs FD IC	60 Rs/yr[s]
O&M costs kerosene stove	25 Rs/yr[t]
O&M costs LPG stove	75 Rs/yr[t]

Sources: [a] Rehman, 2012; [b] Reddy & Balachandra, 2006; [c] UNDP/World Bank, 2003; [d] D'Sa & Murthy, 2004; [e] biomassenergycentre, 2012; [f] Grieshop et al, 2011; [g] Venkataraman et al, 2010; [h] Rajvanshi et al., 2007; [i] cheapestindia.com, 2012; [j] Indg, 2012; [k] Prasad, TERI field manager, 2012; [l] Singh, TERI stove lab, 2012; [m] Ministry of Petroleum & Natural Gas, 2012; [n] Panwar et al, 2009; [o] Reddy & Balachandra, 2009; [p] Reddy, 2003; [q] Ravindranath et al., 2006; [r] Subramaniam, 2000; [s] Singh, TERI stove lab, 2012; [t] D'Sa & Murthy, 2004.

The results for the unit costs of cooking are shown below.





Figures 3.15 Unit cost of cooking (Rs/day) for scenario I (no firewood cost), scenario II (shadow price of firewood)

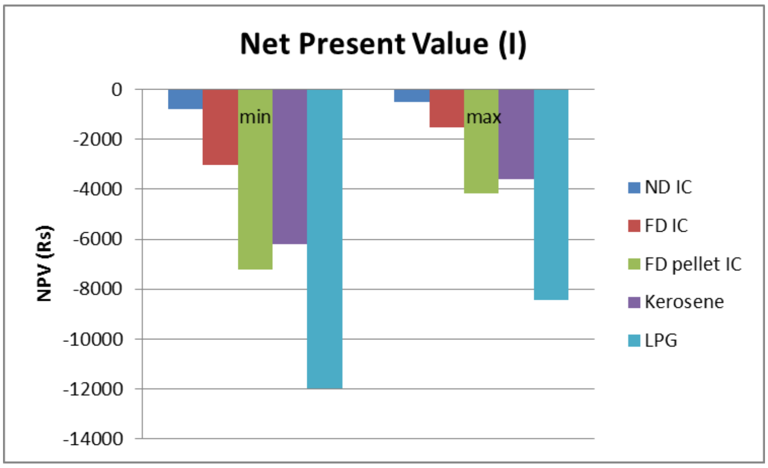
In these figures, it can be seen that if a shadow price of wood is taken into account, all the improved stove options have lower unit costs of cooking than the traditional stove, due to the large reduction in firewood use. An interesting result is that where the IC's have higher or similar units costs of cooking as the fossil fuel devices in this scenario, in scenario I they have by far the lowest costs, because no fuel costs are taken into account. That is why the pellet IC is the only device that comes close to the kerosene and LPG stove in scenario I. But even with the pellet price that has to be paid, this IC still has lower costs of cooking than the fossil fuel devices in both scenarios.

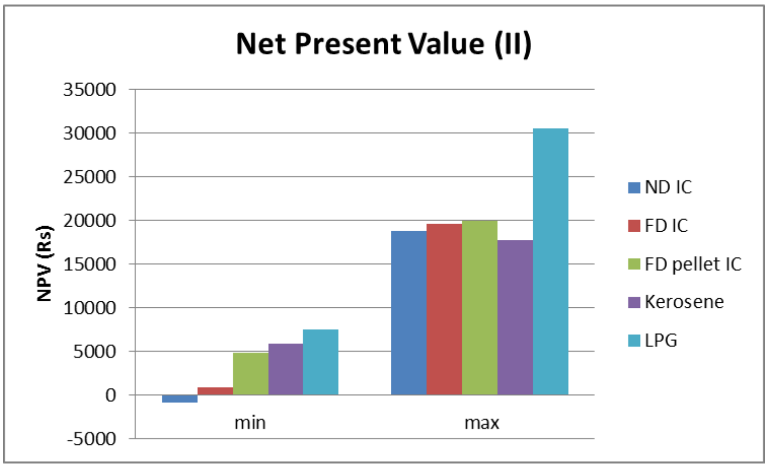
Another interesting result from this figure is that cooking with LPG is only a little more costly than using kerosene, even if the device costs for LPG are much higher. This is because of the lower fuel costs and the higher efficiency. The unit cost of cooking for the stove using pellets is in between the low costs for the other IC's and the high costs for the fossil fuels kerosene and LPG. It has to be kept in mind that the prices taken for LPG and kerosene are PDS prices, which are subsidized. So the government actually pays money for every liter of kerosene and cylinder of LPG that is used. Without these subsidies, the unit cost of cooking would be in the range of Rs. 26–67 for kerosene and Rs. 21–46 for LPG, which is around double the numbers given in figures 3.15. Because these extra costs are paid with public money, they provide an extra incentive for the government to stimulate the use of IC's instead of these fossil fuels next to the lower unit cost of cooking for end-users.

If the unit costs of cooking from figures 3.15 are compared to the average daily rural consumer expenditure of Rs. 34.50 (NSSO, 2011), it can be seen that in the maximum scenario, most options would not be realistic for rural households, as they would have to spend a very large share of their income on cooking. Kerosene and LPG costs require around 80% of this amount. Even in the minimum cost situation, households would still have to spend one third of their expenditures on these fuels, which makes kerosene and LPG less viable options for rural areas. The IC's seem to be more affordable options in scenario I, but if you compare their costs to the average daily consumer rural expenditure of the target group, the 30% poorest households, of Rs. 22.20 (NSSO, 2011), the pellet IC would still be a very expensive option for this target group, and in the maximum scenario the cost are almost equal to this number. In scenario II, none of the options seem viable for the poorest 30% because of the high cost of firewood, and they would have to spend at least half of their daily budget on cooking. To address the rural poor, it is therefore very important to produce low cost devices that use the fuels efficiently, so that the minimum cost situation can be realized. Also, the device costs, especially for the forced draft stove, are too high for the rural poor to afford at once, so initiatives that reduce this initial expenditure are needed.

As soon as a price is attributed to firewood, the costs of the traditional, but also the natural draft stove, go up significantly. However, the forced draft IC's still have unit costs a little below the kerosene and LPG stoves in scenario II, because of the large firewood savings.

The Net Present Value (NPV) of the device-fuel combinations when replacing the traditional situation was calculated using the values given in Table 3.5.



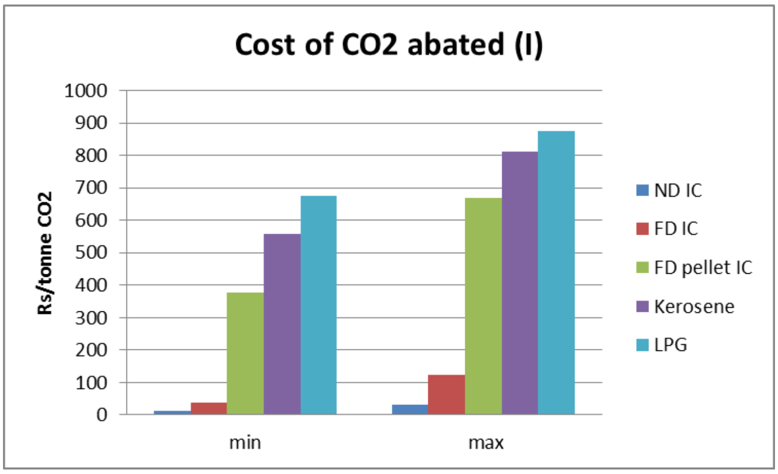


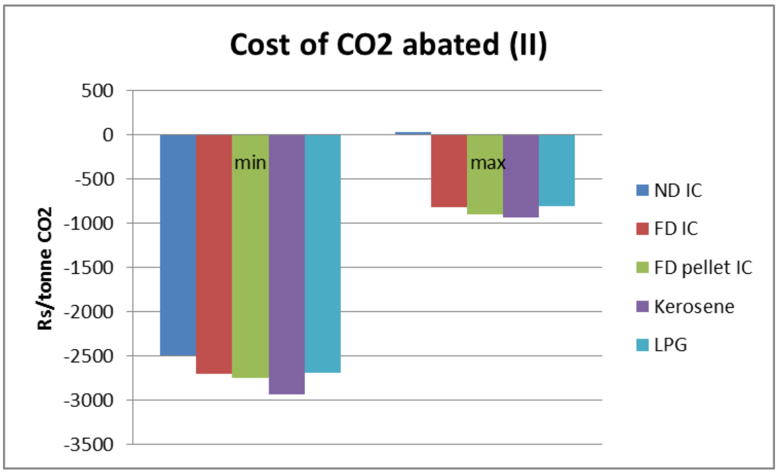
Figures 3.16 Net Present Value (Rs) for scenario I (no firewood cost), scenario II (shadow price of firewood)

In scenario I all NPVs are negative, because the traditional stove has zero private costs. Scenario II shows that when a shadow price of wood is applied, NPVs of all options except for the natural draft IC are positive in both the minimum and the maximum scenario. The LPG stove has the highest potential NPV in the maximum scenario, which is due to the highest efficiency and the very high lifetime of the device compared to the IC's and the kerosene stove. The natural draft shows a negative NPV in the minimum case, where a lot of firewood is still needed.

However, this scenario II is not the most realistic scenario, as end-users will not value the shadow price of firewood. When looking at scenario I where firewood is seen as a free commodity, the natural draft stove definitely performs best in terms of NPV because of its low device and O&M costs. Here, the kerosene, LPG and FD pellet stove have large negative NPVs, because they require both expensive devices and additional fuel payments. The forced draft IC using firewood is in between, because only the device costs are high but the fuel is free of costs.

In a climate change perspective, a factor that is often used to analyze the viability of climate measures is the cost of CO_2 abated, which is the cost of mitigating one unit of CO_2-emissions. The calculation results for the cost of CO_2 abated of the device-fuel combinations are shown below.





Figures 3.17 Cost of CO_2 abated for scenario I (no firewood cost), scenario II (shadow price of firewood)

These figures show large differences in the costs of CO_2 abated for the different options. The ND and FD definitely seem promising options in scenario I, with costs in the range of 10–120 Rs/tonne. Compared to the current market price of CO_2, which is around 4€/tonne (CO2 prices.eu, 2012) or 280 Rs/tonne for Clean Development Mechanism (CDM) credits and can be up to three times as much on the commercial market, these costs are low. On the other hand, the abatement costs of the other devices are relatively high compared to this market price of CO_2.

In scenario II, negative costs of CO_2 emissions abated can be seen, so if the shadow price of firewood is taken into account actual earnings are generated by substituting traditional devices by improved methods. Only the natural draft stove shows very small positive abatement costs in the maximum scenario due to the high firewood consumption compared to the other devices.

For the IC's, the cost of CO_2 abatement could be even lower if the potential CO_2 emission reductions from replacing coal in power generation from figure 3.14 were taken into account. This was not done for the calculation of figure 3.17, because it represents a possible future scenario which is not a realistic option yet.

3.4 Concluding remarks

From this analysis, conclusions can be drawn in terms of which device-fuel combinations are most suitable to substitute traditional cooking in rural areas of India from an environmental and financial point of view. First of all, it is obvious that kerosene and LPG stoves are the least preferred options. Not only do they cause CO_2-emissions, they also lead to large government expenses because of the subsidies and under-recoveries on these fossil fuels. On top of that, they are very expensive for the rural poor. For middle-class households in urban and peri-urban areas, LPG will probably be the prevalent option, because people are willing to pay for the comfort of cooking that LPG offers. Lowering or quitting the large under-recoveries on LPG and kerosene paid by the Indian government would increase the financial benefit of getting an improved biomass cookstove instead of an LPG or kerosene stove.

Of all the improved biomass stoves, the forced draft IC seems to be the best option. Its device costs are higher than the natural draft stove, but the savings in firewood consumption are much bigger and the higher combustion efficiency leads to very low emissions of products of incomplete combustion. The costs of CO_2-abated are low for both natural draft as forced draft IC's. Using pellets as a fuel is even more efficient, but is also more costly because of the high fuel price. If cheaper pellets could be produced because of upscaling and technology innovations, this could become a viable future option.

Even in the situation of minimum unit cost of cooking, the share of the total expenditures that is needed for cooking with any of the improved options is quite large and the high upfront costs are a problem. For the rural poor, these technologies are not affordable without a financial mechanism that reduces the initial expenditure to buy the device. This could happen through subsidies, but also using more recently developed mechanisms. Microfinance is one possibility, where small loans are provided to rural households that do not have the resources to get access to bank loans. Another option is the use of carbon finance, where the carbon savings from stove projects in developing countries raise money through carbon credits sold on the market in developed countries and these earnings are used to support rural families. These two mechanisms are discussed more elaborately in Chapter 5.

4. Qualitative analysis of programs and studies

In this chapter, a qualitative analysis is done to identify factors that lead to success or failure in the implementation of low carbon cooking technologies. First, a description of factors mentioned in literature is given. Then, stove initiatives in India and other developing countries and the factors that contributed to the success or failure of these programs are discussed. This analysis is divided into findings from literature study of past and running programs, findings from interviews with developers of (recent) programs and findings from field work at program sites. The barriers and drivers in terms of technology appropriateness, environmental, economic, sociocultural and other aspects of these different stove initiatives are addressed.

4.1 Literature

Adoption of new energy systems by households can be divided in demographic, geographic and cultural conditions on the demand side and technology on the supply side. Household income or expenditure level is a factor that influences energy consumption. However, as shown in previous chapters, when household income rises the variety of fuels used increases (fuel stacking), but households still keep relying on biomass sources for part of their energy services. Other household characteristics like age, household size, gender, education, literacy and occupation also impact the choice of fuel type (Pachauri et al., 2004; Howells et al., 2010). On top of these factors, demand can depend on climate and weather conditions, but more importantly the cultural preferences like food type, lifestyle and cooking habits (Kowsari & Zerriffi, 2011).

Transition to other technologies on the supply side is determined by their availability, affordability and fit to cultural preferences (Bhide, 2011). It is important to understand what benefits are valued most by local communities and to take this into account in the stove design (Shrimali et al., 2011). A critique on previous research done on the adoption of cooking energy systems in developing countries is that they either address the technical and economic issues, or the cultural issues, but not both. There is a lack of studies integrating these different approaches, which are needed to get a complete view of the problem (Kowsari & Zerriffi, 2011).

A division of stove initiatives can be made into government based policy initiatives on the one hand, and commercial efforts on the other hand. Literature on both types is discussed here.

4.1.1 Government based policy initiatives

Policy aimed at implementing new cooking systems should hold in mind the characteristics on the demand side in the process of designing and implementing these systems. Kees & Feldmann (2011) identify the following reasons for success of policy measures:

- Technology is convenient, modern and affordable
- Training local artisans, using local material, employing local service providers and NGOs for training and promotion
- Intensive monitoring from the start for product quality
- Political system supports massive scaling-up by setting clear targets

On top of this, there should be an effective business implementation model which is mainly based on private investments and requires only low governmental support, and the technology should have real benefits to users (Kees & Feldmann, 2011).

A joint project of TERI and the University of Waterloo (UW) in 1994 studied different government based stove programs implemented in India to see what could have been improved in the implementation process and to find the reason for low dissemination rates of some of the projects (Neudoerffer et al., 2001). According to the study, poor quality control, lack of repair and maintenance and limited local capabilities led to the poor performance of the programs. Also, the high government subsidies on commercial fuels in made renewable options less popular. Local communities were seen as targeted beneficiaries, but there was no interaction with the different stakeholder in the process, while they should have been seen as partners in the development process. An important conclusion of the joint project was the lack of R&D and knowledge on the transition towards cleaner energy systems, especially for rural areas (Neudoerffer et al., 2001).

4.1.2 Commercial efforts

Next to government-based initiatives, commercial efforts have come up in India in the last decade. India is seen as an area suited well for commercial cookstove companies. Its large population centers, relatively supportive and stable policy environment, comparatively well-developed infrastructure and rapid economic growth contribute to that fact. But most of all, with the number of households still relying on traditional cooking methods, the Indian market for IC's is very large.

Shrimali et al. (2011) give some insights in the way commercially oriented distribution efforts need similar, but also different approaches from government-based distribution programs.

- Stove technology and design choices are very important. Because of the incentive to make money, commercially based efforts are likely to focus more on matching product attributes to the target's needs and desires. Decision making should be an iterative process using customer feedback. Design should be driven by an understanding of the value of different benefits for the targeted population. Manufacturing and dissemination does not have to be limited to India only.
- The population that is targeted is an important factor. Different segments require different strategies. For commercial companies, solely addressing BoP without subsidies is almost impossible, but targeting commercial buyers as well could lead to cross-subsidies for the poorer ones.
- Financing strategy, which means making the product accessible to the consumer, is an important issue. Financing through commercial banks, the company itself or retailers, for example in the form of microfinance, carbon finance or by stimulating local entrepreneurs, are things to be considered.
- Marketing strategies should focus on "social marketing", creating awareness of the product and the benefits it has. How benefits are valued by the targeted population needs to be taken into account in marketing efforts. Rural marketing strategies, such as converting opinion leaders, should be looked at for reaching rural areas.
- A robust supply chain of stoves and an after-market support channel are very important. These are essential factors to enable scalability and financial sustainability. Especially in rural, remote areas, setting up these channels can be very challenging.

- The inherent nature of commercial cookstove sellers, including experiences and business models, can influence the sales results (Shrimali et al., 2011).

In the next section, findings from literature on past and long-running government-based and commercial cookstove distribution programs will be discussed, and the drivers and barriers that led to the success or failure of these programs are described in terms of technology appropriateness, environmental, economic, sociocultural and other aspects.

4.2 Past and running programs

4.2.1. Programs in India

4.2.1.1 National Program on Improved Chulhas (NPIC)

The National Program on Improved *Chulhas* was set up in 1985 to reduce fuelwood consumption and indoor air pollution in kitchens. A large number of 33.8 million improved cookstoves were installed by the program (Ranganathan et al., 2010). However, a study carried out by the National Council of Applied Economic Research in 1993 to evaluate the program found that only 55.6 percent of the cookstoves were actually in use at that time. Fuelwood savings were calculated to be only 3.7 percent, instead of the 9 percent that was aimed for by the program (Kishore & Ramana, 2002). Because of its disappointing contribution to fuelwood reduction, the NPIC is often seen as the main example of how government initiatives on cookstoves can go wrong (Shrimali et al., 2011). The failure of the NPIC was due to many different factors.

Technology appropriateness

The first stove designs under the program were complex and not user-friendly. Designs that were easier to use were introduced later in the project, but the fact that the design had to be simple put restrictions on the stove performance, which led to lower-efficiency stoves (Hanbar & Karve, 2002). Also, because a lot of the stoves implemented were mud stoves, which have an average lifetime of less than two years, many stoves broke down soon after installation (Kishore & Ramana, 2002). No utilities or plans for repair and maintenance were incorporated in the program, so most of these stoves were not repaired (Venkataraman et al, 2010).

The fact that multiple biomass fuels were used for cooking was not incorporated in the first stove designs, which had been tested only for firewood as a fuel. This led to very low efficiencies of the stoves when used in combination with other fuels, and had to be changed in during the project (Hanbar & Karve, 2002).

Environmental aspects

One of the main goals of the program was to reduce deforestation, which was still a problem in India when the NPIC started. However, as mentioned before, domestic fuel use is not a main source of deforestation, because usually only twigs and branches are used and no trees are cut down. So the target of reducing deforestation by the distribution of improved cookstoves turned out to be wrong (Hanbar & Karve, 2002).

Another goal of the program was to reduce women and children’s exposure to indoor air pollution. When it was found out that stoves with a higher thermal efficiency did not directly lead to lower PIC emissions, and sometimes even increased PIC emissions because of reduced combustion efficiency, it was decided to implement stoves with chimneys. But according to research, the use of chimneys does not always lower indoor air pollution (Hanbar & Karve, 2002).

Economic aspects
A subsidy on an IC was provided only once, with the goal of households buying a new IC on the market when the first one broke down. Since there was no formal monitoring of this, it is unknown whether and how many of the initial consumers continued to use improved stoves (Hanbar & Karve, 2002).

Sociocultural aspects
Rural youth were trained to install the improved *chulhas* in the households in their village. It was expected that they would keep doing this throughout the program and make a living with it. However, many of them dropped out because it was impossible for them to make enough money in the rural poor areas (Hanbar & Karve, 2002).

Other
Because there was little or no monitoring after stove dissemination, there was a lack of information on needed improvements in design and dissemination methods during the project (Venkataraman et al, 2010).

The improved stoves were often used only as extra cooking devices on top of the traditional *chulhas*, and were not used as the primary cooking device (Hanbar & Karve, 2002). This "stacking" of cooking technologies had not been anticipated on at the start of the program.

A new program, the National Biomass Cookstove Initiative (NCI), was started in 2009 with the aim to implement "the next-generation of household cookstoves, biomass-processing technologies, and deployment models" (Venkataraman et al., 2010). With these cookstoves, the government of India wants to reach energy services and emission levels comparable to those of cleaner fuels like LPG. Implementation has not started but pilots are on the way. This program is described in more detail in Chapter 6.

4.2.1.2 National Program for Biogas Development (NPBD)
In the 1980s, India's Ministry of Non-conventional Energy Sources (MNES) initiated a major program for the promotion of biogas plants in rural areas as an answer to the growing fuel crisis (Neudoerffer et al., 2001). So far, 3.3 million biogas plants have been installed under the National Program for Biogas Development (Ranganathan et al., 2010). With a national potential of 12 million biogas plants, this achievement only represents 24% of the total potential (Neudoerffer et al., 2001).

The NPBD is seen as an unsuccessful program, mainly because of the technological problems and high mortality rates of the biogas plants that were installed, and because of unnecessary high central subsidy that was given to already well-to-do farmers. Even though MNES has changed its strategy over time using the findings from research and monitoring studies, there is no sign that the performance of the NPBD has improved over the years. Reasons for this are found in different areas (Planning Commission, 2002).

Technology appropriateness
A large share of the biogas plants became non-functional due to technical or operational problems. Because plant owners did not get trainings on repairing the often simple defects, and the repair and maintenance program set up by MNES often did not work properly, plants became unused. In 2002, only 45% of the installed plants were fully working (Planning Commission, 2002).

Economic aspects
The NPBD is the rural energy program with the largest investment ever launched by the government of India. Subsidies accounted for around 75% of the total cost, which proved too high and in many cases unnecessary. In a review in 2002, 60% of the households stated that the subsidy was unimportant for them, as family-sized biogas plant adoption generally took place amongst the well-to-do farmers. This is supported by the fact that a reduction in the amount of subsidy in 1998 did not lead to a significant change in adoption pattern. The rural poor, which were the ones the government wanted to target with the subsidy, hardly benefited from the program. This was due to the fact that no strategy to identify and reach this target group was developed (Neudoerffer et al., 2001).

Other
The MNES used a top-down approach, with implementation happening through a lot of different agencies. These agencies were each other's competitor, which led to a bad quality of construction and materials because of cost competition, no focus on sustainability criteria, and low credibility of the reporting system because of over-reporting of achievements and under-reporting of failure.

There was a lack of quality checks during plant construction and of monitoring and supervision after plant implementation. Progress reports were prepared without field visits, which make them very unreliable (Planning Commission, 2002).

4.2.1.3 Solar cooker program
In 1982, the Indian government started the National Programme for the Development and Use of Renewable Energy Sources, which included a solar cooking dissemination project. Mainly box type solar cookers were disseminated through this project in six states of India (Solar Cookers World Network, 2012). Under this national project, Gujarat State introduced a program to promote the production and sales of solar cookers in the state. This resulted in a total distribution of 45,000 box type solar cookers in 1999. However, a later study found that most of these devices were stored under beds instead of being used (Ahmad, 1999). A case study was done in Gujarat, India to get insight in the problem of under-used and disused solar cookers. It was found that box-type solar cookers were viewed on as cheap, easy to operate and low-maintenance, so the problem had to be found in other factors.

Technology appropriateness
Because of the low temperatures in box-type solar cookers, cooking times were as high as 2-3 hours. Also, frying temperatures could not be reached (Ahmad, 1999). These two features of the solar cooker implied that big changes in cooking habits were required, which are described below.

Sociocultural aspects
The longer time needed for cooking caused a shift in daily family routines, because cooking had to start much earlier than usual. On top of that, the low cooking temperature made it impossible to

cook *chapattis*[ll] and fried food, which are essential items of the typical Indian meal. Because of this, conventional cooking methods were still used next to the solar cooker to make *chapattis*.

In urban areas, the only sunny area to cook was the roof. This brought along two problems. Firstly, it was not preferred to cook on the roof, because of its distance from the kitchen and the need to walk up and down the stairs. Also, because Indian families are used to keep their belongings indoors overnight, they had to carry the cooker in- and outside every day, which proved very heavy.

Taste, texture and color of the food varied from food cooked in a conventional way, and sometimes food could turn out under- or overcooked. Families found it hard to adapt to these changes (Ahmad, 19999.

Other

The case study concluded that there was a “missing link” between the project developers and the potential users. The project actors should incorporate the potential users in the process of project and technology development in a trial-and-error way, so that (some of) the problems mentioned could be overcome. Although this is a time-consuming process, constant interaction between the actors is the best solution for under-use and disuse of the devices (Ahmad, 1999).

4.2.1.4 LPG program

The “Deepam LPG scheme” was introduced by the government of India in 1999. The goal of this scheme was the distribution of domestic LPG connections to women of families living below the poverty line in rural areas. The barrier of fuel switching was overcome by providing a one-time subsidy at the amount of the initial cost. The program objectives were to reduce dependence on firewood, reduce drudgery, reduce pollution and improve women’s health. About 90% of the target of 1.1 million households was met, but the program was not as successful as it looked, as only 20% of the beneficiaries were households with incomes below Rs. 11,000/year/family, which was the targeted population (D'sa & Murthy, 2004). Problems encountered include:

Technology appropriateness

Refill rate of the cylinders was down to 85% in three years, the rest remained unused. This was due to the large distance to distribution points, or because LPG was only found useful during the monsoon when firewood was hard to collect (D'sa & Murthy, 2004).

Economic aspects

Although the targeted low-income population benefited from the program, 80% of the households in the region with higher incomes also took advantage of the subsidy, leading to large unnecessary government expenses.

High refill costs were seen as a main disadvantage by the households. Sometimes, illegal commissions were put on top of the price and unannounced charges for supply or collection of the LPG cylinders were asked for. This affected the target group of low-income households most. Reduction in cylinder size was suggested by the households, so lower costs would have to be paid per refill (D'sa & Murthy, 2004).

[ll] The chapatti is a traditional flatbread that is consumed with every meal North-India. This bread is baked at very high temperatures by sticking it on the inside of a stove or an oven.

Sociocultural aspects

Targeted households were often found to give away LPG cylinders to relatives instead of using them themselves, because of implementation bottlenecks like limited stove choice or the suppliers' inability to supply stoves at all. In households that did keep the cylinders, the fuel use pattern did not change as much as was intended. Freely gathered firewood remained the number one cooking fuel. LPG was mostly used to make tea or to cook for guests but did not affect the daily cooking pattern much (D'sa & Murthy, 2004).

4.2.2. Commercial efforts in India

4.2.2.1 First Energy

First Energy started in 2006 as a part of British Petroleum (BP), but was sold in 2009 and is now a privately owned Indian company. The company has over 35 distributors and more than 2500 dealers in India (First Energy, 2012). The First Energy stove is a forced draft stove that needs processed biomass fuel in the form of pellets. Both the stove and the pellets are produced and sold by First Energy. Extensive market research and stove design and development happened when they were still part of BP. First Energy disseminated as much as 450,000 stoves up to 2010 (Shrimali et al., 2011).

Economic aspects

As the funding from BP has been dropped in 2009, First Energy had to increase the price of biomass pellets by 60% since, which caused a large reduction in device use. This led to a shift to commercial users in 2010, because LPG is not subsidized for these users and the biomass pellet price is still competitive (Shrimali et al., 2011).

4.2.2.2 Envirofit

Envirofit started cookstove operations in 2007 with charity-based resources from Shell Foundation. Start-up funding, preliminary market research and field testing were covered by these resources. The University of Colorado is a partner of Envirofit and has provided research, but also a big part of the staff. The stove sold by Envirofit is a natural draft stove that can combust any type of biomass. By staying close to the simple design of a traditional cookstove, Envirofit has the advantage that it has less quality issues and less issues regarding consumer acceptance (Shrimali et al., 2011). Stove sales have gone up rapidly in the past years, up to over 300,000 stoves so far. At the moment, Envirofit has 40 manufactorers and 400 distributors and operates in Kamataka and Tamil Nadu (Envirofit, 2012).

Economic aspects

Evidently, both Envirofit and First Energy, the biggest players on the Indian market for improved biomass cookstoves, have generated a significant amount of IC sales in the last few years. However, the prices of their stoves are too high for most rural households to afford, so they have mostly reached (peri-)urban households or affluent rural households, not the BoP. Without some sort of financial mechanism, a transition to IC's for the rural poor is hard to reach with commercial stove models.

4.2.3 Programs outside India

4.2.3.1 China's National Improved Stove Program (NISP)

The largest and most successful cookstove program worldwide is the Chinese National Improved Stove Program (NISP) (Ruiz-Mercado et al., 2011). NISP was started in 1983 with the main goal to take on the energy shortage perceived in rural areas. A variety of improved cookstoves using different fuel types were sold under the NISP. However, the program was not directly aimed at reducing poverty, so the program mostly targeted better-off regions of China (Sinton et al, 2004). Still, 166 million households adopted improved stoves under this program (Foell et al., 2011). But the main success was that, according to a survey done in 2002, most families that got a stove under NISP also replaced it with a new version of an improved cookstove, which is different from most other stove programs (Sinton et al., 2004). Reasons for this great success were:

Technology appropriateness

Stove designs were adapted to local conditions and the opinions of local stove designers. Local availability of the materials and fuels was taken into account, as well as the suitability of the stove for local cooking practices (Sinton et al., 2004).

Because of well-trained stove builders, the quality of the stoves was said to be consistent and living up to efficiency standards in a range of 20-32% (Sinton et al., 2004). However, a survey of stove efficiencies in 2002 found an average efficiency of the improved stoves of only 14%. Although this is still higher than the 9% average efficiency of traditional stoves, this was much lower than the standards set for the program. This could be due to a degradation of stove performance over time, which is a factor that had not been anticipated on by the NISP (Sinton et al., 2004). So even though the program was very successful in many aspects, the fuel savings are not as big as stated by the Chinese government.

Economic aspects

The program was very cost-effective, as 94% of the total costs of stoves and their installation were covered by the households themselves (Sinton et al., 2004). This is a difference compared to most other stove programs, where government or state subsidies covered a significant share of the total costs

Other

A very intensive training program for different stakeholders was in place. Staff of government agencies received rural energy-trainings, local professional house-builders were trained to become stove builders because of the resemblance in tasks, and end users got in-home demonstrations on operation and maintenance of the stoves (Sinton et al., 2004). This created a good combination of a central push on a national level with locally coordinated efforts to create functioning markets for stoves (Shrimali et al., 2011).

4.2.3.2 Brazil LPG program

In 1975, the Government of Brazil started an LPG program with funding from the national oil company. The aim was not only to reduce fuelwood for cooking, but also to reduce gasoline and diesel use. They stimulated this by cross-subsidizing gasoline and diesel prices for all Brazilian households. The increase in these fuel prices led to an increase in LPG consumption. The program was very successful, as LPG is now provided to about 90% of the households. The success of the program was due to a couple of factors:

Technology appropriateness
There was a very reliable supply of LPG cylinders, which was possible because 81% of Brazilian households live in urban areas (D'sa & Murthy, 2004). Local demand numbers were collected and concentrated in a primary supply basis. A distribution model based on an automatic delivery system delivered cylinders at different intervals up to one month, with also an emergency delivery system in place (Lucon et al., 2004).

Economic aspects
Until deregulation of the program, a controlled price was in place, which made LPG affordable compared to other fossil fuels (D'sa & Murthy, 2004). However, deregulation in 1998 caused poorer families to switch back to fuelwood. This was countered by implementing an LPG-subsidy for low-income households in 2002 (D'sa & Murthy, 2004). Also, the introduction of smaller cylinders which required smaller payments at once made LPG more accessible to poorer families who had difficulties paying the increased price after the deregulation of the government program (D'sa & Murthy, 2004).

4.2.3.3 Sri Lanka
A clean biomass cookstove study in Sri Lanka was performed to find the socio-economic issues and context that influence the transition towards clean cooking technologies. This study reported some interesting findings.

Economic aspects
The study showed that labor opportunities for women were the main driver to change to clean energy options. This had two reasons. First of all, because they had less time to spend on gathering fuelwood and cooking. Secondly, because labor gave them the financial capacity to pay for cleaner energy options (Wickramasinghe, 2011).

Sociocultural aspects
Even though a shift towards clean cooking methods was found to be stimulated by economic development, fuelwood was still partly used in households with high incomes, because of the preferred taste of the food cooked, or because it could be freely gathered or was available from agricultural waste. Entrepreneurial opportunities from turning biomass into a market commodity could catalyze the adoption process of clean cookstoves (Wickramasinghe, 2011).

4.2.3.4 Mexico
A study on the adoption and sustained use of the improved cookstoves program in Mexico had the following findings.

Sociocultural aspects
It was shown that households value the benefits of fuel savings, speed of cooking, convenience, compatibility with local cooking practices and status of modernity more than pollution-related benefits (Ruiz-Mercado et al., 2011). Also, the community was a very important factor in the adoption process. Meetings with women in every community were held to make them understand the health problems and the benefits of IC's. Also, local builders received trainings from NGOs.

However, local people first had to see the health problems caused by traditional stoves before they were interested in building improved cookstoves (Troncoso et al., 2011).

Other
The study emphasized the importance to include the possibility of fuel stacking into the analysis of cookstove programs, as it is not likely that fuelwood is completely substituted. The whole cooking system should therefore be looked at, including the users, stoves and fuels. The importance of monitoring sustained use was also emphasized in the study (Ruiz-Mercado et al., 2011).

A summary of the findings from past and current programs is included in a table in Appendix I.

4.3 Recent programs

4.3.1 Fair Climate Fund improved cookstove project (Koppal, India)
The Fair Climate Fund (FCF), an organization founded by development agency ICCO in The Netherlands, just started a carbon financed stove program in Koppal, South India. They did this in cooperation with a local NGO named JSMBT. Distribution started in June 2012, and about 5000 stoves are planned to be distributed every month. FCF ordered 43,000 stoves, which will be distributed in 134 villages. Every household will receive 2 stoves.

Technology appropriateness
The stove that will be distributed is the Chulika, a front-loading natural draft stove that is produced by a local company. The stoves were adjusted to the villager's comments during pilots. The producer gives a warrantee of 5 years for the stoves, although the lifetime is said to be longer than that. If repair and maintenance is needed, every village will have men available that provide these facilities. Also, 4 or 5 stoves will always be available for replacement. According to FCF, the main advantage of the stove is that the women have to spend less time and energy gathering firewood.

Environmental aspects
The efficiency of the Chulika was measured at 30.8%. CO_2-savings are estimated at 1 tonne CO_2 per year per stove. To improve indoor air pollution, the place where cooking happens in the households will be monitored. FCF hopes to improve ventilation during cooking by encouraging the villagers to cook in open air spaces, so that the exposure to smoke is reduced even more than by the stove alone.

Economic aspects
The Chulika stove will cost Rs. 1500-2000 in retail. However, families will only have to pay Rs. 150 as a registration fee to join the project, so the stoves are paid by the FCF. The fact that almost 100% is subsidized is what makes this project different from other stove programs. FCF acknowledges that this brings along some extra risk, as low prices can make people value their stoves less, leading to lower usage numbers.

The project duration is 10 years. FCF receives the program's carbon credits and sells them to companies and other buyers in the Netherlands. FCF only has a 5-year contract to receive the carbon credits from the stoves, after this the credits can be sold by the local NGO and the families that join the program will receive an agreed percentage of the carbon income from these sales. This should happen through signed end user agreements between the NGO and the households.

Sociocultural aspects

The local NGO in Koppal, that already has a lot of contacts in the communities, will implement the monitoring of the project. Several groups will be created and paid within the villages to monitor the usage of the stove by the households. Representatives per street will gather information on monitor factors like stove usage, and to identify stoves that need repair. This information will be entered into a database which will be updated frequently, every 2-4 weeks. According to FCF, this integrated monitoring will increase the program's viability and usage rates, but the fact that monitoring is done by local people with little experience does increase the risk at human errors in the system.

To increase awareness, NGO teams are educating the villagers about the program, where they identify and approach families interested in the project. Before the stove is delivered to the families the teams demonstrate how the stoves work and information about climate change is provided. The villagers who join the project will receive a video manual to explain how the stove works.

Other

According to the FCF, the price of CDM credits is very low at the moment, but may go up in the future because both Australia and South Korea will start a trading scheme in 2015 and the demand for CDM credits will rise again. In the voluntary market, a lot of projects are in the pipeline. FCF states that there are enough project developers, but it is hard to find buyers. However, they see that there is still a very big market, considering all the companies that do not do any corporate social responsibility activities at the moment.

4.3.2 Do-inc cookstove program (Tanzania)

Do-inc, a company in Amsterdam with expertise in carbon project development, helped develop a cookstove project in Tanzania. This project is being set up in cooperation with a US NGO and a one-man company that designs the stove and the pellets needed for it. Do-inc develops the Project Design Document (PDD), calculates emission reductions and makes sure the project is validated.

The project is program of activities (PoA) based, meaning that many small activities are incorporated into one carbon financed project. This way, stoves can be distributed in different regions under the same program. The advantage of this structure is that it does not have to be decided beforehand in how many regions the program will be implemented. The duration of the project is 28 years, but only 10 years per PoA. 15,000 stoves are planned to be distributed per activity. So far, 3 districts have been chosen where distribution will take place. The stove is still in the testing phase, and will first be distributed in pilot projects.

Technology appropriateness

The stove that is used is a natural draft top-loading stove which runs on renewable biomass fuel pellets produced from agricultural residues. The design is very simple, which is an advantage since it does not require a big shift in cooking habits. A disadvantage of the stove that was discovered in field tests is that it is difficult to move it after cooking, because the handles get very hot. A new design is now made with wooden handles to prevent this problem. The lifetime of the stove is only around 3 years, so a strategy solution has to be found to replace the stove after its lifetime. Do-inc is still thinking about the best method to do this.

Environmental aspects
In Tanzania, wood and charcoal are the two fuels widely used at the moment. However, deforestation is a huge problem, and many households therefore have to buy wood from the market, as it is not possible to gather it for free in the neighborhood of the villages. The need for renewable biomass is therefore large. Emission savings from the improved stove are estimated to be 4 tonnes of CO_2 per stove per year. No tests for efficiency, CO or PM levels were done, as there are no regulations for this in Africa, which is a big difference with India in terms of government intervention.

Economic aspects
The upfront funding for the project is raised partly by the US NGO, and partly comes from a fund of the Tanzanian government.

The retail price for the stove, including subsidy, will be around €16. Local production has to be enabled for the costs to go down, because transportation over long distances would be too expensive. Some local villagers mentioned in pilots that they think the stove price is too high. However, there were also villagers that said they would buy the stove for the retail price, so Do-inc is confident that enough stoves will be sold. They are still thinking about a solution to reach the people that cannot afford this price. Payment in installments would be an option for this. Table 4.1 shows the monthly household cost of pellets compared to the cost of fuels currently used in the area.

Fuel	Costs per unit	Units per month	Monthly fuel costs
Firewood	€0.50/bundle	10	€5
Charcoal	€2/bucket	3	€6
Pellets	€0.18/kg	45-50	€8.10-€9

Table 4.1 Monthly household fuel costs of firewood, charcoal and pellets

Table 4.1 shows that pellets are the most expensive fuel option compared to prices of other fuels. However, Do-inc states that when pellet production increases the prices are likely to drop, and prices in the range of the other fuels can be reached. Also, the fact that villagers have to pay for fuels anyway because of the scarcity of wood makes the price barrier lower.

Sociocultural aspects
The NGO already has contacts in many of the local villages, which makes the project easier to implement. The stoves will be locally produced. For monitoring, agents are needed in every distribution area. However, Do-inc is not sure whether local agents have the right knowledge and resources to do this, so outsourcing the monitoring tasks is an option, but they have not found a suitable party yet.

The stoves were tested in the field in two villages, which provided some interesting insights. One of the villages had received development aid before, the other village was much more remote and had no experience with development aid. It was found that the first village had much more criticism on the stove program, because they were afraid the project developers would leave after a couple of years, like many others did in previous projects. The other village, where such bad experiences did not exist, was much more positive about the upcoming project.

Other
According to Do-inc, there is a lot of potential for cookstoves on the voluntary carbon market because of all the extra benefits they incur, but for CDM projects it will be difficult after 2012, as credit prices are expected to go down. This makes it difficult to find investors, because of the

uncertainty in projects' earnings from credits sold. Do-inc mentions that, for carbon financed projects, the time lag in designing a project and actual implementation is currently too long. There is often a deadlock situation because you cannot earn money if you don't implement the stoves, but you can also not go on with a project and implement more stoves if you don't have money. The validation process is also long and expensive. According to Do-inc, a solution to make the period before implementation shorter and less costly would be to have a fixed baseline. This is already in place for some countries, but there is no value for Tanzania yet.

4.3.3 Abt Associates advanced stove project (Uttar Pradesh, India)

Abt Associates is a company founded in the US working on research and program implementation in the fields of health, social and environmental policy. Abt's office in New Delhi is currently doing a stove project in the state Uttar Pradesh (UP), for which they are involved with three other parties: the stove manufacturer, the distributor and the microfinance institution (MFI). As there was no manufacturer located in UP when the project started, Envirofit was chosen as the manufacturer for the project. Project implementation started around April 2011, and advanced cookstoves will be implemented in 100 villages. Members of the MFI that they are partnered with are targeted for this, which are about 15 per village (so 1500 in total).

Technology appropriateness

The Envirofit stove that is implemented is the G-3300, which is a front-loading ND stove. Front-loading was chosen because it requires less behavioral change from the user, because traditional mud-stoves are front-loading as well.

Environmental aspects

According to user feedback, reduced fuel use is the main benefit. Users stated that they used around 50% less fuel. The stove was tested according to BIS standards.

Economic aspects

Villagers can purchase the stove based on a zero-interest loan. The distributor absorbs the interest part of the loan. The price of the stove is Rs. 1599, which is paid in 16 weekly terms of Rs. 100. Users do think this is expensive, because at first they had zero cost for cooking. However, Abt states that all users that adopted the stove do see the benefits, and they all use it as their primary stove now.

According to Abt, the main problem with the current program in UP is how to reach non-MFI clients. They think the availability of a low-cost stove that still complies with BIS standards could be an option to make stoves more accessible for these people. The focus now is to start working with local manufacturers to decrease the costs, for example by avoiding taxes that now occur as different parts of the stove come from different states.

For a commercially viable model, Abt thinks that cross-subsidizing is a mechanism that is probably needed, so that the interest part of the zero-interest loan is generated by the distributor by selling at higher prices to the more affluent sector of the population. They acknowledge that it is very difficult to reach the BoP with any commercial model, and that this requires subsidies, government support.

Sociocultural aspects

Demonstrations to women in the villages are done by entrepreneurs on the village level that were recruited by the distributer. Abt states that this is the most cost-effective way of creating awareness in rural areas where communication media like TV's and radios are not widely available. They see supply and promotion as crucial aspects. The technology had to be at the end-users doorstep, because they will not go to a shop that is hard to reach for them.

The conversion rate of MFI clients that want to have a stove after demonstration is about 13-14%. But according to Abt, the potential is much larger. While households in India have changed and many have a TV (of around 5000 Rs.) and a mobile phone, the kitchen has not changed. This is because the cookstove is used by women, while men make the financial decisions. Marketing tactics have to be applied to reach the male of the household as well, to make sure conversion rates are as high as possible. Research has shown that conversion rates are double if the male is involved in demonstrations. That is why, based on the clients that are interested in the stove after a demonstration, a second demonstration in the households is given, where the husband is also attending.

Other

In Abt's view, the BIS standards are suited for the Indian market, but require modifications. A short study of the BIS standards and the changes made recently was done as a small part of the project. They found that, because different materials and devices have become available in the past decade, different standards are required. Also, they state that, for carbon finance purposes, additional standards to the efficiency, CO/CO_2- ratio and PM level would be needed.

Abt is certain that microfinance lowers entry barriers as it is easier to identify target groups through MFI's. Although they are not targeting the majority of the market, the model is scalable and commercially viable. They suggest that other MFI's could implement similar projects to increase the scale. Also, they are interested in looking at other manufacturers, so that more devices in different price classes can become available, which gives consumers a choice.

4.3.4 Philips woodstove project

Philips was one of the first companies to develop and market a forced draft stove. The stove had the cleanest stove results of all stoves tested at Aprovecho, an independent testing facility (Hegarty, 2006). Field trials in India took place from 2005-2007, but Philips has decided to focus its cookstove operations on the African continent.

The Philips stove will be distributed in Lesotho, Africa through Africa Clean Energy (ACE). The first 5000 stoves will be produced in the summer of 2012. These stoves will be sold as a pilot project before large scale production will start. They will first be sold through department stores in cities, townships and peri-urban areas. The stove is meant to address many different market segments. Some sales of the stoves will happen through partner organizations that buy the stoves and sell it through their own network. The choice to start implementation in Lesotho was made because ACE was already there. Manufacturing was shipped from India to Lesotho.

Technology appropriateness

The Philips stove is a forced draft gasifier stove with a battery included in the bottom part. The stove runs on firewood or charcoal. An earlier model included a thermo-electric generator instead of the battery in the bottom part of the stove that is used in the newer model. Although the performance of the initial model was better, there were technical problems with the generator that forced the use of a rechargeable battery. This problem can be solved now because of better technology, but still the current model is the preferred option as it is cheaper. The battery of this model has a lifetime of 2 years, but the batteries are widely available on the local market for replacement.

Thermal efficiency of the current Philips stove is around 50%. Philips mentions that a skirt (a cover around the pan and vessel to reduce heat flowing outside) could increase the thermal efficiency up to even 90%. However, they state that a skirt is not desired by users, because it makes it more difficult to put wood into the stove and one skirt only fits one cooking vessel and one pan, so either multiple skirts would be needed or the choice in pan size would be very limited.

Environmental aspects

In Africa, deforestation is a major issue, which is why improved cookstoves are needed badly. In Lesotho, an area where barely any trees are left, kerosene stoves are the primary cooking devices used now, but only by people who can afford these.

Indoor air pollution is minimized by the Philips stove, as its combustion efficiency is higher than 99.9% according to Philips. The high combustion efficiency is partly due to the holes in the top part of the inner stove that point downwards at an angle to have an optimal airflow in the stove. This is different from other forced draft stoves, and a patent of Philips. If the stove it lit well, this means there is no smoke at all.

Economic aspects

The stove will be sold in Lesotho for US$ 65-70. These costs are expected to come down when scale increases, but will not be less than around US$ 50. Kerosene, the fuel that is replaced by the woodstove, is expensive, so Philips expects the improved biomass cookstove to pay back in a few months.

People in cities or townships can afford the stove price straight up. Philips wants to address the BoP as well, they are still looking into business models to find the best way to achieve this. Carbon finance is a mechanism they are looking at, but the huge amount of work, insecure income and extensive monitoring needed make that it is not the most preferred option. However, the Philips stove does record usage numbers, which would make monitoring easier.

Other

The Philips stove is also used for a project in Rwanda, where households in the future can lease the stove for a low price which is embedded in the price of pellets that will be used as the fuel for the stoves. People can hand in biomass themselves, which will be made into pellets. According to Philips, this is only possible when a large market and a good distribution system are in place. Pelletization is a process that needs very high pressures, so a pelletization machine is always quite big and has a large capacity, which makes it difficult to decentralize.

Box 4.2 The Philips stove in India – lessons learned

Philips started distribution of their woodstove in India in 2005. India was chosen because of its huge market size, because Philips had already been in operation in India for 80 years, and because of the English language. Also, India was seen as a single market, whereas Africa was perceived as much more problematic because of all the different countries. However, Philips decided to quit operations in India soon after the first cookstoves were distributed. Only 2000 stoves were produced for the Indian market. Reasons for them to pull out were:

- Because of the financial crisis, every division had to cut costs. Because the woodstove business was just starting it was not as profitable and easy as other segments, and risky as well, they decided to cut the woodstove segment.
- Distribution, service, getting sales channels were all things that appeared more difficult than anticipated in India. Philips in India tends to sell through shops in urban areas, but a whole other market had to be addressed for the woodstove, which was difficult.
- The cultural differences between Europe and India were more difficult than they had expected. They found it very hard to get things done, and too much paperwork was required all the time because of the bureaucratic business culture.
- The financial ownership of the woodstove project was put too low in the organization, so there was too much focus on profit and loss. This should have been done from a corporate perspective, where the costs and benefits (financial as well as non-financial) of such a project can be judged differently.
- Deforestation is not such a big issue in India as it is in Africa.
- Indian people may have felt like the stove was a Western product pushed into India.

After the financial crisis had stabilized a little, Philips was contacted by ACE in Lesotho, and they decided to try the woodstove business again. This time, the project is supported directly by the CEO of Philips Africa, which will give it a better chance in terms of financial ownership. Africa is seen as a test bed for reaching the BoP market, the bigger picture is to expand to other countries in the long term. India would be one of those other countries where opportunities could be explored again. For example, Philips finds that Indian slums would be an interesting market to look at. However, shipping from Africa is expensive, and that is where the only manufacturing is happening at the moment. Also, Philips first wants to see if the program in Africa turns out successful, because the woodstove business will always be “high risk, unknown reward”.

4.4 TERI programs

The Energy and Resources Institute (TERI) is an Indian NGO and research institute in the fields of energy, environment and sustainable development, based in New Delhi. TERI has developed different cookstove projects in the past, and is currently involved in two of them, one in Jagdishpur, Uttar Pradesh and one in Mewat, Haryana. Different stakeholders in these programs were visited and based on interviews and field work, experiences and views of these stakeholders are presented here.

4.4.1 TERI manufacturer – New Delhi

The manufacturer in Delhi produces the stove models that are designed by TERI. These are the findings from an interview with the owner.

Technology appropriateness

Three types of forced draft stoves are produced with a fan running on an electric battery that can be charged in a socket or by solar panels. Two of the models are side-loading and square in shape, one single and one multi-pot, the third stove is top-loading and cylindrical.

According to the manufacturer, the main advantage of the stoves compared to a traditional stove is the utilization of 100% of the wood because there is no incomplete combustion, and the possibility to make food at night because a lantern can be attached to the device. Also, the stove heats food very fast, tests have shown that it only takes 3 minutes to boil 20 liters of water.

The weak part of the stove is the connection of the battery. However, the manufacturer states that this can be repaired by any local electrician. Apart from the battery, he claims that there will be no defects in the stove, and it can last some decades because the stainless steel will not age.

Economic aspects

The manufacturer receives a fixed amount per stove, which differs per model. They calculate exactly how much the materials and manufactory costs and charge TERI these fixed prices. TERI decides the selling price of the stoves in the market.

Sociocultural aspects

Although the improved stoves are much easier to use than the traditional *chulha*, the manufacturer admits that they are not as convenient as an LPG. End-users will need to learn new skills to use it. In urban areas, a brochure is sufficient to provide instructions on how to use the stove. In rural, illiterate areas, training is needed.

The manufacturer claims that it is possible to cook all North-Indian dishes with the stoves, including *chapattis*. However, the traditional way of cooking *chapattis* inside the stove is only possible with the front-loading model. He thinks that a reason for households not to use the stove can be the fact that it takes some time to start the stove. Also, the fan can be difficult to understand, so proper instructions are needed. Sometimes the wood fails to start burning. End-users have to understand that they have to put the wood in first, and sometimes they have to sprinkle it with kerosene to get it burning. Another reason mentioned is that the solar panels and battery have to be connected, which takes some effort, especially in rural areas where people are not used to these technologies.

4.4.2 Stove test lab – Jagdishpur

An interview was held with Lokendra Singh, the TERI employee who runs the stove test lab on the field site in Jagdishpur. The TERI stove is costly (Rs. 2500) because of the outer material, so new solutions are being tried out in the lab.

Technology appropriateness

In Jagdishpur, the Philips stove is mostly used as the improved cookstove, but there are a lot of problems with this stove. First of all, the spare parts are very expensive and hard to get. Also, there is a problem with the battery: Singh gets complaints from end-users saying that water flows over the stove while cooking, gets into the circuit which is place underneath the stove, and the circuit quits working and has to be replaced. That is why the TERI stove uses a separate battery. Philips, when asked about this problem, claims that this cannot happen if people use the stove correctly. They expect that the problem is caused by other factors, such as cleaning the stove with too much water. According to Philips, this should be prevented by properly informing end-users on how to use the stove.

The single pot top loading TERI stove reduces emission by 60-80% and doubles efficiency from 10-12% of the traditional stove to 25-35%. The front loading TERI stove has an efficiency of 20-25%. According to Singh, the combustion chamber cylinder is the main thing that matters for the performance of the stove, what is put around it does not matter so much. The outer body can be made of different materials, differing in costs.

A crucial component in the stove is the fan. If it does not operate properly, the improved stove performs less than a traditional stove because of the smaller combustion chamber and less natural oxygen supply. The Philips stove uses a 12 volt computer fan, whereas the new TERI stove uses a 5.9 volt fan that is used in kids toys. Because the Philips stove requires more power, the battery will run for only 3-4 hours. According to Singh, a minimum of 20 hours is required because many days without power can occur in the field, and charging takes 8-10 hours. In one day, a stove is operational for 3-4 hours depending on family size. In some villages, there is no electricity, so solar energy or a thermoelectric generator are the only options to charge the battery.

Chopped wood is needed in the top-loading stove, which is a time-consuming process for the women. A manual wood chopping machine was developed, but this can only be used for green biomass so turned out to be not very successful.

Environmental aspects

Singh states that from an environmental perspective, top-loading stoves are the preferable option, as they have the highest efficiencies and lead to the highest fuel savings. This is especially suitable in situations where wood is very scarce, which gives an incentive to spend money on a stove that uses the least amount of fuel.

Economic aspects

The challenge of cookstove programs, according to Singh, is the fact that the utility of cooking is already there free of cost with traditional a mud stove. So the costs have to drastically come down to make programs viable, especially in the long term since subsidies cannot be going on forever. TERI wants to achieve a price of around Rs. 1500, which should include the total package of stove production, entrepreneur/manufacturer margin, shipment to site, retailer's margin, marketing expenditure, O&M service charges and tax. To include all this, the stove itself can only cost around 800-1000 Rs.

Of the Rs. 2500 of the TERI stove, half is the cost of the power pack and half is the stove itself. A solar panel as charging station increases the costs by Rs. 400-500. The combustion chamber costs Rs. 200, the battery Rs. 400. The price of insulation material can vary from expensive insulation material of Rs. 200 per stove to flowerpots of Rs. 35 per stove.

Sociocultural aspects

According to Singh, although top-loading stoves have the highest fuel savings, front loading stoves are better from a user perspective, as the wood does not have to be chopped and *chapattis* can be baked inside. This perspective matters most for adoption, especially in North India where *chapattis* are an essential part of every meal. In South India there is no need for this as they have other food preferences.

Dung cake is used as a fuel to simmer milk very slowly, it turns the milk a little reddish and people like the taste of this. Singh states that it should not be tried to change that, as these cultural changes can only happen very slowly. On top of that, people don't want to waste things and if dung is readily available they will use it anyway.

Other

Singh mentions that an extra incentive for households to get an IC is the fact that the LPG distribution in Uttar Pradesh is a big problem. Even if people have the right to get subsidized cylinders, they have to go to the cylinder distribution office and often wait for a whole day to get the cylinder, with the risk of not receiving one because the office ran out of cylinders for the day or week. This makes supply very unreliable and a time-consuming process for the customer. Black market cylinders are available for around Rs. 600 (subsidized ones cost Rs. 400). The scope of this black market is very large, as many people, especially restaurants and other commercial cooking institutions, are happy to spend the Rs. 150 extra to get their cylinder without travelling to the distribution office and waiting (restaurants do not have the right to get PDS cylinders as they are available for households only). For households, however, this Rs. 150 extra can be a large chunk of their monthly income, and they are dependent on the supply of subsidized cylinders.

4.4.3 Operation and maintenance shop – Jagdishpur

The O&M shop in Jagdishpur was initiated by TERI a little after the start of the program in 2009. Repair and maintenance services on solar panels, solar lanterns and cookstoves are performed in the shop. The entrepreneur who runs this one-man shop was interviewed.

Technological appropriateness

The amount of repairs needed is very much dependent on the use, because some people use their stove more careless than others. After 2 or 3 of the same repairs, people understand the way the problem is caused and prevent it from happening again. The battery, adapter and fan need most repairs.

A disadvantage of the Philips stove mentioned by the entrepreneur is the fact that spare parts are very hard to get and the supply is very unreliable, especially for batteries. The battery has a lifetime of 1.5 to 3 years, so on average it has to be replaced every 2 years. Batteries and small parts have to come from Lucknow, the nearest city 1.5 hours away. Other parts have to be bought in Delhi, about 8 hours away. Households can have to wait up to two weeks for battery replacements, depending on the availability and delivery time. The shopkeeper is working on developing some networks in the area to make proper arrangements with suppliers for more reliable and faster supply.

Economic aspects

Prices for O&M services are Rs. 30 service charge, and separate prices for different spare parts. Villagers find these prices high, though the entrepreneur thinks these prices are fair. He can just live off the profit he makes with the shop, but he would like to earn more. He usually gets 5-10 customers per day, but he would like to get 15-25 customers to increase his profit. Of the 8-10 hours the shop is open every day, he only spends 2-3 hours on repair and maintenance services, so there is room for more customers.

The low availability of the batteries on the market makes replacements more expensive for customers. The price already had to be increased from Rs. 200 to Rs. 350 in 1.5 month. It is very difficult to convince customers to pay for these expensive batteries.

The entrepreneur would like to stock more materials and parts to provide faster service. But this is very costly and earnings are not high enough now to acquire this stock. However, he expects more customers in the future, because of the aging devices. Some people come to the shop and want to buy a stove, but there is no availability of stoves now, this could be improved so that he can also sell stoves.

Sociocultural aspects

According to the entrepreneur, all the households with a broken stove eventually get it fixed, because he goes to the village every two weeks. So even if households cannot reach the shop because the male works elsewhere or they don't have time to go, the repair will come to them. The only problem is soldering, which needs electricity and that is not available always and everywhere in the city. So he needs a PV-charged soldering device. During repair or while their stove is broken, households use their mud stove, or an LPG stove if they have one.

According to the entrepreneur, the main benefit for households to get an improved stove is the wood saving, because the wood price in urban areas is high, so households either want to buy less wood or they want to sell the wood they save. The second benefit is that there is no smoke. In the entrepreneur's view, the problem with the adoption stoves is that rich people have and LPG stove so they don't need an IC, and poor people want a costless device so they go for a mud stove.

4.4.4 End user – Jagdishpur

Several households in the village of Jagdishpur were visited to observe the cooking practices, and 6 women of different households were interviewed. These households all received a Philips stove in 2009, which was provided by TERI free of cost.

Technology appropriateness

Of the six households interviewed, all women state that they have at least 50% fuel savings, and that the stove is convenient to use. The main technological disadvantage of the Philips IC as stated by the villagers is the fact that the biomass used must be chopped into small pieces before it can be put into the stove. The second drawback of the stove is the fact that it uses electricity, as this utility is very unreliable in rural areas. According to the villagers, electricity will sometimes not be available for over a week, which makes it impossible to charge the IC.

Another problem that was clearly seen from the visits was the fact that the battery is the weak part of the stove and gets broken often. End-users state that the availability of these batteries on the market is too low so repairs both take a very long time and are very expensive, often too expensive in their eyes. This leads to many broken stoves not getting fixed and being substituted by a traditional mud stove.

Economic aspects

When asked what price the local women would be willing to pay for the stove if they had not gotten it for free, all answers lay in the range of Rs. 500 to Rs. 1000, which is much lower than the current market price of the stove.

Sociocultural aspects

While at least half of the households say in the interviews that they use the improved stove for every meal, observing the cooking in the village showed otherwise. Only mud stoves were used at the time of visit. People explained this with the weather conditions, because there was a lot of wind and according to them it is hard to cook with the improved stove in these conditions. However, the improved stove is portable and can be put in a place where there's no wind, while the mud stoves they were using were fixed outside, so the excuse of wind does not seem valid.

Also, half of the families interviewed had a broken stove and did not take any effort to get it fixed at the repair and maintenance shop yet, but all were saying they were planning to go soon. It seems like the villagers are actually waiting for a TERI worker to come around, or for the repair and maintenance shop to visit the village, which makes the time it takes for a broken stove to get fixed much longer than necessary.

Reduced smoke emissions are definitely identified as the highest valued benefit of using an improved cookstove, all 6 women mention this. Faster cooking and better control of cooking are also seen as great benefits of the IC compared to the traditional *chulha*. Benefits like reduced time spending on collection biomass and less blackening of the walls and vessel are valued less important by the households.

The *chapattis* definitely are an important issue: 4 out of 6 women say that the taste of *chapattis* is different when they are cooked on the improved cookstove. That is why the mud stove is often used supplementary to the improved stove to make the "real *chapattis*", which have to be stuck inside of a stove to bake at high temperatures, something that is not possible with the Philips stove.

Villagers' perceptions about the improved cookstove are observed to be very strong and can influence the adoption pattern to a large extent. For example, a woman mentioned that she does not like to cook on the IC because she can only use one pot at a time, while she can use two at the mud stove. So even though she knows that cooking time and fuel use reduce significantly by using the IC, still she prefers the "mental satisfaction" of having two pots on the fire at the same time. Another woman did prefer to cook with the IC and did not mind the fact that she could only use one pot, although she acknowledged that the time savings are minimal because she has to cook the dishes one at a time, compromising the shorter fuel collection and faster cooking time. However, when asked if she would prefer an improved cookstove with a double pot to reduce her cooking time, she said she would not, because a double pot would emit more smoke, which is not true.

These examples show that false perceptions sometimes have to be lifted to make household members see the full benefits of an innovation, in this case an improved cookstove. Promotion and trainings or workshops involving local people are very important for this purpose and have to address all potential village perceptions to make sure no unclarity exists at the start of operations.

When asked what the women use the spare time for that is created by the faster cooking and reduced wood collection, they all say they use it for some kind of livelihood-related activities, like household chores or handwork.

4.4.5 End user – Mewat

The improved TERI top-loading stove has now been implemented in 90 of the 200 households in the village for the cost of Rs. 500 per household. The first stoves were distributed at the end of 2011. This is a pilot project, TERI hopes to implement the stove in more surrounding villages. IRRAD, a local NGO, does the monitoring part of this pilot. A group interview with 8 women in the village was done, of which 5 women already had the TERI stove and 3 were still using the traditional stove.

Technological appropriateness

Because the stoves have only been distributed a couple of months ago, not many technological flaws have occurred yet. Women do not see the chopping of biomass for the top-loading improved cookstove as a problem, because no large wood logs are used, only thinner twigs. They can easily break these twigs with their hands.

Economic aspects

Other villages in the Mewat area have seen the implementation of the stoves and are asking for them too. Therefore, IRRAD has ordered 22,000 cookstoves from TERI. Manufacturing this amount of stoves is not a problem, but there are some issues to be solved before TERI will meet the demand of IRRAD. They want to receive a minimum of Rs. 2000 per stove, which can be quite a high price for the villagers. IRRAD has already motivated households in the area and discussed the price with them, but households are right now willing to pay 1000-1200 Rs. This is not enough, as the aim of the program for TERI is to make it into a commercially viable model, which cannot happen if villagers only pay half of the price of the stove (Rs. 2500 at the moment). Some research efforts to decrease the price of the stove are going on, but TERI field manager Rakesh Prasad is not sure about the quality of these low-cost stoves and thinks the households can be persuaded to pay more because they see the large benefits from the pilot village.

Sociocultural aspects

Traditionally, the mud stove is used in Mewat, with a combination of firewood, dung cake and crop residues as fuels. When asked what aspects of traditional cooking the local women suffer from most, the main aspect that is mentioned by 6 out of 8 women is the physical burden from collecting firewood. Secondly, all 8 women mention the time consumption of firewood collection and cooking as a significant issue. These answers are explained by the fact that the local women spend 7-8 hours a day, every day for the duration of four months per year, collecting firewood in the hillside. They do this in the winter months because it is cooler then, and prefer to collect firewood for the whole year during these months. Every day, they carry over 40 kg of firewood on their heads back to the village. Other problem that some of the women pointed out as a burden are breathing difficulty and lung irritation from the smoke that the traditional *chulha* emits. Especially when starting the stove, a lot of smoke is released, that goes very deep into the lungs and hurts.

Out of the 5 women who got the improved stove, 4 of them see the fact that it cooks much faster than a traditional *chulha* as the main benefit. They explain this by saying that before they had this stove, they always had to plan ahead when visitors were expected, because they had to start cooking the tea long before. Now they can just start the tea when the visitors are there and prepare it in a few minutes. The fact that they have to collect less firewood is seen as a main benefit by 3 women, because of the long time spent every year and the physical burden this takes. The fact that the IC emits less smoke is also mentioned by 3 women as an important benefit, which is explained by the lung irritation they used to have from traditional cooking. But in spite of these benefits, and the fact that the households use the TERI stove for every meal, all of them say that they still also use the mud stove to make *chapattis*.

When asked how the women spend the time saved by the IC, all of them answer that they use it for social activities, which include some household practices but also simply chatting with the other women in the village. Spending time with their children is also mentioned.

A very interesting phenomenon took place in the village when the TERI stoves were just introduced there. Because the villagers had not received training yet on how to use the stove at that time, and the device runs on electricity, the men in the village found that it was their job to run the device, because women should not be involved in things that have to do with electricity. So the men started doing the cooking in the village. At the time of the interview, a couple of months further, there had been in-house trainings and all the women knew perfectly well how to use the stove. However, the men had not stepped away from their new job and still did the cooking whenever they were at home. The women appreciate this very much.

5. Recent financial mechanisms

From the financial analysis and the program evaluation, it follows that stove and fuel prices are very high for the rural poor to afford them, especially if the device costs have to be paid at once. Therefore, some sort of financial mechanism is needed to enable the purchase of improved cooking methods by this demographic group. The mechanism that has often been used in the past, as was seen in the program analysis, is subsidizing (part of) the stove price. Based on experiences in the programs and literature analyzed, this mechanism can be successful under certain circumstances, but also failures have been observed. In this chapter, the opportunities of microfinance, other credit models and carbon finance, which are recently developed alternative financial mechanisms, are discussed.

5.1 Microfinance and other credit models

5.1.1 Microfinance in India

Many people in India have no access to financing from private banks. After China, India is the country with the most unbanked people in the world (Sinha, 2009). These unbanked people mostly reside in the rural areas, where as much as 87% of the people have no access to any kind of formal banking credit (Rao et al., 2009). Microfinance, which was introduced in India in the mid 1990's, provides a way for these people to get access to banking services and credit to improve their living standards (Sinha, 2009). Microfinance is based on a system where the poor can borrow a small amount of credit from a microfinance institution (MFI), which can be paid back in recurrent terms at a low interest rate. This way the poor, who do not fulfill the requirements to receive actual private bank loans, get access to money to make small investments (Morgan & Olsen, 2011).

In India, there are two types of microfinance models. The one that is most widely used is a self-help group (SHG) based model, which contributes to around 60% of currently outstanding microfinance loans. In this model, a bank lends credit to a self-help group, which in turn lends the money to its members (Bi & Pandey, 2011). SHG's consist of 10-20 people, mostly women, and determine the size of the loan based on a member's needs, the interest rate and all other rules and norms in their area (Rao et al, 2009). This group is generally promoted by an agency, which can be an NGO or a government agency (Bi & Pandey, 2011). The banks that lend money to the SHG's are mostly commercial banks, but can also be regional rural banks on non-banking financial institutions (Parida & Sinha, 2010; Bi & Pandey, 2011). In 1992, the National Bank for Agriculture and Rural Development (NABARD) started the SHG Bank linkage program to stimulate microfinance institutions to become linked with SHG's and increase the availability of bank loans (Rao et al, 2009). This program led to the coverage of over 70 million households by SHG's in 2008 (Parida & Sinha, 2010).

The other model that is used is the Grameen model, which was invented in Bangladesh. In this model, local banks are set up which give out loans to members in the surrounding villages. Only when repayments in a pilot phase are done successfully, a village gets entry to bank loans. The Grameen model is based on fixed value weekly repayments and rules are the same for all local banks, so bank workers do not have the freedom in deciding norms and rules like SHG's do (Rao et al, 2009).

The main advantage of microfinance for the rural poor is that it removes the barrier of high initial investment and divides these costs in affordable chunks. Also, the self-help group based model is very effective in increasing the social empowerment of women, as they are the dominant members of the SHGs. A study found that 92% of the women who took part in SHG's felt more socially empowered and experienced improved self-confidence, decision making and communication skills (Parida & Sinha, 2010).

5.1.2 Microfinance for cookstoves

Microfinance can improve the affordability of improved cooking devices, which require an initial investment that many rural households cannot pay at once (Shrimali et al, 2011). But despite of this, it is often said that cookstoves are not suitable for microfinance, because of the relatively low device cost which makes the transaction costs very high compared to the size of the loan (IEA, 2011). Also, microfinance is usually granted for income-related activities, mostly small farmers and food processors in rural areas (Rao et al, 2009). This is not the case for cookstoves, which are purchased for in-house use but do not generate earnings. Microfinance is always a risky mechanism because of the chance exists that members do not repay their debts (IEA, 2011). For the rural poor, who are the main target group for improved cookstoves, this might be a problem because of their very low incomes. At the moment, although the availability of microfinance in India has grown significantly in the past decade, most initiatives are concentrated in the South of the country, where poverty rates are much lower than in other areas. A better spread is needed to ensure access to microfinance throughout India and to reach high-poverty areas as well (Sinha, 2009).

5.1.3 Suggested model

A disadvantage of the microfinance model on the national level is the high interest rate that banks ask for providing microfinance. Interest rates including processing fees are around 30% on average, but can be as high as 50% in specific cases, making it very difficult for rural people without regular incomes to repay their loans (SIDBI, 2011). In some cases, high interest rates are needed because of the high transaction costs that local banks incur to provide the microfinance loans, and to account for the high risk they take by lending money to less affluent people. Because there are no regulations on who can provide microfinance in India, for-profit lenders have entered the market next to the NGOs and government agencies, asking for higher margins to make money out of it (The Economist, 2010).

To reduce the high interest rates asked by NGOs and government agencies, a solution is needed to decrease the risk that providing microfinance entails. This could be done by linking these institutions to development schemes like the National Rural Employment Guarantee Scheme (NREGS). This scheme was implemented in 2005 to increase the livelihood of rural people by guaranteeing them to 100 days of paid labor per year. Because minimum wage is provided, it is ensured that only persons who cannot earn more elsewhere participate in the program, so only the rural poor are targeted (Shankar et al., 2011).

Although this sounds like a promising initiative, the scheme received a lot of criticism. One thing that is often mentioned is the large gap between the demand for jobs and the amount of jobs offered, so by far not all the rural people who want to participate can actually do this (Gaiha et al., 2010). An audit in 2007 revealed that only 3.2% of the registered households in poor areas of India actually received 100 days of work (Shankar et al., 2011). Also, the work that is provided is sometimes of a questionable nature in terms of usefulness. For example, many mysterious ditches and dykes were built in the most drought-affected regions of the country (The Economist, 2008). So ensuring that the work done is actually functional is a task for the government to work on. One way to do this is by making SHG's part of the program. Self-help groups can be a source of high value jobs under the program, which also helps to achieve the 33% participation of women that is mandatory by the NRGES (Shankar et al., 2011).

A possible model to make microfinance for cookstoves more available would be a situation where the government creates a fund in state banks and this way provides a guarantee for the bank, which can then provide loans with lower interest rates. The bank could then provide credits to SHG's appointed under the NRGES or other development schemes that stimulate SHG's. If this credit is provided in bundles, the high transaction costs for separate credit for one cookstove are avoided. Cookstoves can then be one of the many technologies or income-related activities that are stimulated by this bundle of microfinance. Finance can be given directly to the local households, but can also be used in the form of a public private partnership by providing it to local entrepreneurs who can in turn sell their stoves to the villagers and receive the money in installments.

5.2 Other credit models

Financial institutions that provide microfinance are not always available in rural areas (Koirala & Ortiz, 2011). Therefore, it is interesting to look at other potential mechanisms that can be used to spread out the initial investment for cookstoves over time, where no microfinance institution is involved. These mechanisms, which are already used for solar energy systems in India, are discussed briefly in this section.

5.2.1 Dealer credit model

In the dealer credit model, the stove manufacturer or dealer gives out credit directly to the end-user, by dividing the total payment in smaller terms and raising interest on this (Zerriffi, 2011). This model is based on mutual trust and suitable for places where localized sales people are in place and where customers are well known to the dealer. The advantage of this model is that it lowers the investment barrier without involving a third party. However, because there is a risk for the dealer, high down payments of up to 50% can be required, as well as high interest rates of around 25%, and the total amount has to be paid in a rather short time of a year maximum. Also, the fact that stove dealers have no or little experience with crediting systems and administration may make it a costly and time-consuming procedure (IEA, 2003).

5.2.2 Lease or rental model

Another model based on credits is a lease or rent model, where households pay installments over time to use the stove, but the ownership of the stove stays with the dealer, with the options of owning the stove after a certain amount of installments. This model has the big advantage that it requires very low down payments of the end-user, because the stove ownership stays with the supplier and the device can be retrieved if the end-user does not pay the installments. Thus, the barrier of initial cost is lowered significantly with this model. Also, the payment period is often longer and can fit the income level of the customer. The drawback of this model is that the fact that the end-user does not own the stove can lead to careless behavior with the device, leading to more repairs that the dealer has to take care of. Again, the dealer's lack of experience with crediting may also be an issue (IEA, 2003).

5.2.3 Fee-for-service model

In the fee-for-service model, the customer pays regular service fees for electric services to an energy service company, often through a central charging station. The service provider is the owner of the system. The end-user sometimes owns the device that has to be charged, but sometimes only pays a connection charge to use the system without owning the device (IEA, 2003). The advantage of this model is that it provides electricity to people with no access to this resource for a long period of time, which would enable people in remote rural areas with no or unreliable electricity connection to use forced draft cookstoves on a daily basis. Also, the charging station could act as central facility for repair and maintenance of the stoves. However, once a charging station is in place, it is hard to adapt to technological developments. Another drawback is that care of the system is lacking when people do not own the device, so ownership of at least part of the system by the end-user, for example the battery, should be stimulated. Also, the collection of fees on a regular basis is a time-consuming and expensive process (Reinmüller & Adib, 2002).

An example of a project that uses the fee-for-service model is TERI's Lighting a Billion Lives (LaBL) project, which is aimed at stimulating the use of solar lighting by the rural poor. In this project, solar lamps are rented to the rural community at an affordable fee every evening by a local entrepreneur, who delivers the energy service through a small solar enterprise. Loans are provided to facilitate the entrepreneurs in setting up these solar enterprises, and part of the enterprises is subsidized by TERI and by government agencies (TERI, 2012).

5.3.4 Concluding remarks

To make the use of forced draft cookstoves more affordable, a combination of a dealer credit model and a fee for service model could be made, where the end-user owns the stove and can pay in installments, but uses a central charging system for daily charging of the battery. Forced draft biomass stoves are portable and lightweight so there is a possibility to take the devices to a central place and recharge them. Because ownership is with the end-user in this model, they will treat their stoves with care, which decreases the risk at high repair rates. The fee-for-service model provides a reliable source of electricity for an affordable fee. Especially in remote areas with no or unreliable electricity connection and no availability of financial institutes, this would be a good solution to provide excess to clean cooking technologies. The applicability of such a model for the distribution of cookstoves needs to be studied in more detail.

5.3 Carbon finance

5.3.1 Introduction to carbon finance

Although the benefits from cookstoves in terms of both emission reduction and the improvement of livelihood are well known, the opportunities for cookstove projects in the carbon market have only just been discovered. For a long time, cookstove programs were not seen as viable to create carbon credits because of their small, decentralized nature and high transaction costs (GIZ, 2010). Only in recent years, cookstoves became recognized for their ability to create carbon credits, and the first programs have registered on the carbon market.

This was enabled by new methodologies introduced by the Clean Development Mechanism (CDM) and the Gold Standard (GS), the largest entities in the carbon market. CDM was established in the year 2000 as a result of the Kyoto protocol. It allows Annex-I countries to buy certified emission reductions (CERs) through carbon saving projects in developing countries, providing them with a "flexible" way to fulfill their Kyoto and ETS (European Trading System) emission commitments (Brechet & Lussis, 2006). The Gold Standard was introduced in 2003 as a certification standard for both the compliance and the voluntary emission reductions (VER) market. Most voluntary carbon financed projects choose to register using the Gold Standard methodology, though more standards exist.

In 2008, CDM introduced the first methodology that allowed small scale cookstove programs to register on the carbon market (Ministry of the Environment & IGES, 2009). Together with the introduction of a large scale methodology by the Gold Standard in 2008, this increased the opportunities for carbon financed cookstove programs and led to the registering of the first projects (GIZ, 2010). On top of these developments, two more methodologies have become available recently that are attractive for cookstove projects. The first is the Program of Activities (PoA), under which multiple small project activities can be bundled into one large scale CDM methodology. The second is a methodology for micro-scale project activities, allowing programs creating very small CO_2-equivalent savings to enter the carbon market.

Although these methodologies provided great possibilities for cookstove programs to receive financing from carbon credits, the number of programs that have registered is still small. The Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ (2010) estimated that 624,800 CER's and 1,136,763 VERs per year will be commissioned based on existing and upcoming stove projects. However, this is only a very small part of the potential of over 500 million credits for cookstove programs (Haigler et al, 2010).

5.3.2 Carbon finance for cookstoves

Carbon credits for cookstoves can stimulate the large scale dissemination of improved cookstoves. They can encourage the purchase of stoves by providing financial benefits, leading to lower prices for the customer (Simon et al, 2010). Also, the local manufactory of the stoves can spur economic development and provide a way for entrepreneurs lacking start-up capital to enter the stove market (GIZ, 2011; Simon et al., 2010).

The fact that there are so many co-benefits from cookstove programs next to the environmental benefits of reduced carbon emissions and deforestation can be an incentive for companies to include the buying of carbon credits in their CSR activities (Simon et al, 2010). In addition, the low costs of carbon savings compared to more complex technologies make them an attractive investment (Johnson et al, 2009). Besides, the monitoring requirements during the crediting period help to keep a program successful in the long term, as the lack of monitoring is one of the major failure factors of cookstove programs (GIZ, 2011).

Still, investors in the carbon market see cookstove programs as a high-risk area because of their challenging characteristics. Because cooking habits differ a lot between countries and regions, there is not one cookstove and dissemination method to fit all programs, and a lot of prior research is needed to decide the best approach. Often this starts with a pilot project to gather feedback before large scale dissemination can be achieved. Also, many tests have to be done to decide the baseline and project scenario, and elaborate trainings have to be given to operation and maintenance personnel on the project site. These are costly and time-consuming procedures that have to take place before a program is initialized, which makes the period between the start of a program and the first issue of credits at least two years (GIZ, 2011). After dissemination, projects have to be monitored regularly because previous experiences with cookstove programs show that the chance of non-usage of stoves because of broken parts or preferences for other devices is large, and because stove efficiencies can decrease over time. Advanced monitoring methods are needed for this, which entail high transaction costs (Simon et al, 2010).

A "stove use monitoring system" (SUMS) was recently developed by the research team of Kirk R. Smith of the UC Berkeley School of Public Health to monitor indoor air pollution in households of developing countries worldwide. This SUMS consist of a wireless device that is powered with the excess heat of the stove. This device can collect household usage data that is much more accurate than information collected by household visits (UC Berkeley School of Public Health, 2010). The use of such a device in carbon financed projects can decrease the time-consumption and number of people needed for monitoring, and provide more reliable monitoring results.

Because there is a lack of prior experiences with carbon financed cookstoves programs, it is not yet proven that they can be viable. Conservative methods for calculation program offsets therefore have to be applied, which reduces the amount of credits to be issued significantly. As there are already the standard uncertainties of price fluctuations and future demand of carbon credits, especially after 2012 when the Kyoto compliance scheme ends, a lot of risk is entailed in financing such programs (Simon et al, 2010).

The things mentioned above are barriers for potential investors, as they increase the risk of financing a cookstove project. However, experiences from the growing amount of programs that have started in the past few years can help overcome these barriers. These experiences can be used to highlight the flaws in current projects and methodologies. This is needed to reduce the risk entailed in carbon financed cookstove programs and to promote them as a viable option to carbon investors. Because carbon finance for cookstoves is such a recent development, hardly any literature is available that includes these experiences, so a stakeholder review was done to collect information and opinions on this topic.

5.3.3 Stakeholder review

Opinions on methodologies from 7 experts of 5 main funding organizations of carbon financed stove programs (co2balance, myclimate Foundation, J.P. Morgan Climate Care, Atmosfair and E+Carbon) are collected to see if their views are in line with (the few) literature sources and to get new insight in problems identified and possible improvements of the methodologies. Also, information on the current status of their projects was collected to see whether this is in line with the projections made in the Project Design Documents (PDDs).

Comparison of PDD predictions and actual project achievements

Although many of the CDM and GS stove projects have only started recently, three of the experts were able to provide numbers on the current status of their projects.

- E+Carbon has distributed 173,160 stoves in Ghana and 86,497 in Mali up to December 2011 under the *"Improved Household Charcoal Stoves"* programs. Respectively, 130,242 and 112,352 credits have been received for these programs up to August 2010. Stove usage rates in Ghana have gone from 97.5% in the first project year to 85% in the third year. In Mali, 100% usage was found in the first year, which has gone down do 89.4 % in the third year. Due to higher sales numbers than predicted in the PDD, emission reduction projections have been adjusted for both projects, showing almost doubled values.

- The *"Improved cooking stoves for Nigeria"* project developed by Atmosfair has led to the distribution of around 10,000 stoves so far and the issuance of 1867 credits. According to the sales scheme in the PDD, more than 20,000 stoves should by now have been implemented. Atmosfair admits that sales numbers are behind schedule, and ascribes this to the fact that they have been waiting for the first verification of credits before they wanted to commit larger funds into the project. This makes that the credits issued in the first year are only 20% of the yearly amount that was predicted in the PDD. Also, Atmosfair states that the emission reductions will be somewhat lower than anticipated, because usage of the improved cookstove is only 93% after the first year and not 100% as was predicted in the PDD, where drop-out rates were not taken into account.

- Two *"Efficient Cooking"* Climate Care projects in Uganda and Ghana have together produced about 1.25 million credits up to the end of 2011. In total, 430,000 stoves have been distributed. This is almost 100,000 more than the total amount stated in the PDDs. Climate Care confirms that sales numbers have been higher than expected. However, only 600,000 credits have actually been issued, as there has been a significant lag between production and verification of the credits. Still, if 1.25 million credits have actually been produced, this is much higher than the amount of around 700,000 that was predicted in the PDD's. From the monitoring report in the Uganda program, it seems that no drop-out took place. It was found that 92% of the stove buyers were satisfied with their stove, and 69% reported reduced fuel consumption and costs, but also 69% of the users kept using an unimproved charcoal stove next to their improved one. The monitoring report of the Ghana program stated 5% drop-off in the first year, and 10% in the second and third year, which seems more plausible than the 100% usage of the Uganda project.

- For the *"Qori Q'oncha – Improved Cookstoves Diffusion Programme"* in Peru developed by myclimate Foundation, 82099 stoves have been distributed and 52908 credits have been issued so far, which is only a little under the predicted value up to 2011. Monitoring has shown fuel saving values that are very close to the values stated in the PDD. Usage of the improved cookstoves is measured to be 84 % or higher.

- The *"Msambweni Improved Cook Stoves"* program in Kenya has only just started, but according to project developer co2balance the usage rate is 100% for the pilot phase of the project.

Main problems identified

When asked what the main problems are in setting up carbon financed stove projects, the issues mentioned by the project developers are almost all economic. These problems are described below.

- Co2balance, E+Carbon, myclimate and Climate Care see the large up-front costs of the programs as the main drawback of carbon financed stove projects. Co2balance and Climate Care point out that this makes seed capital hard to find, especially for smaller organizations. Myclimate thinks that especially the Department of Energy (DOE) charges for project validation are much too high and unaffordable for local NGOs.

- Atmosfair and co2balance identify the long time it takes before verification and issuance of credits take place as a problem. Because of this, it takes a long time to earn back the large up-front costs, which makes it impossible for small NGOs that lack capital to start projects like this, states co2balance. Atmosfair has experienced project delays because of the long time it takes for credits to be verified, as the first verification of credits was needed to show the viability of a project before continuing it.

- The fact that a lot of field work is needed for monitoring purposes makes a project very costly. Many dispersed units have to be monitored for a long time to assure the emission reductions of a project, which is seen as a drawback by Atmosfair. According to co2balance, this field work is not only very time consuming but also very hard work, putting a pressure on local NGOs that carry it out. This is in line with the argument of Climate Care and E+Carbon that institutional capacity for monitoring and auditing in the host country can be insufficient.

- Market uncertainty is also mentioned by co2balance and Atmosfair as a constraining factor. They both think CER prices are too low and have to rise to make carbon financed stove projects more profitable. Atmosfair expects VER prices to go down soon, because of the growing amount of voluntary projects, which will make voluntary initiatives less attractive.

Future opportunities

Most experts are hopeful about future possibilities for carbon finance to become one of the main mechanisms to fund stove programs. Co2balance expects an increase of CDM stove projects after 2012, because the EU ETS has decided to only buy credits from Least Developed Countries (LDCs), where traditional cooking is still happening on a large scale. However, they emphasize the fact that it has to be ensured that programs keep running after the issuance period is over, and the developer should not just “take the money and run”. To decrease the focus on making profit, a “fair trade” ranking scheme is suggested, so that developers are inclined to create social development as well. However, co2balance argues that even if developers are mostly in it to make a profit and emission reduction calculations may never be reliable, the fact that stove programs are created is always a good thing. DOE’s are seen as the biggest obstacle for grass roots cook stove development, and its influence and charges for validation and verification should be diminished. E+Carbon expects an increase of CDM stove projects in Africa, where most LDCs are located. Even when the Kyoto protocol is not revived, the voluntary market will still be there as long as climate change issues are there, and these buyers will not be restricted to LDCs. Myclimate and Climate Care also think that carbon credits will provide one method among others that will be used to finance stove programs. According to Climate Care, there will be and increasing amount of both compliance and voluntary stove projects in the market. The fact that these projects are output based and long term makes them more viable compared to input-based traditional finance methods that are often limited in scope. Atmosfair has doubts about future stove efforts in the carbon credit market, because there is currently too much uncertainty in the market price of these credits.

5.4 Concluding remarks

Both (micro)credit models and carbon finance are upcoming mechanisms for the financing of stove programs and have potential to become more widely used in the future. Microfinance and other credit models have the advantage that less paperwork and monitoring is required, and that they can be organized on the national level without involvement from Europe or other Western continents. Carbon finance on the other hand can provide the improved cookstoves that are so highly needed in developing countries at a lower cost for the end-user, in contrast to microfinance or credit-based initiatives where the full amount still has to be paid in the end. Also, the output-driven character of carbon finance is an incentive for project developers to make sure the stoves are properly and widely used.

For microfinance, linking development schemes that stimulate self-help groups with the provision of government funds to local banks could increase the opportunities for microfinance-based stove initiatives. The combination of a microfinance or dealer credit with a fee-for service model to provide reliable and affordable electricity is another possibility that could stimulate (forced draft) stove uptake. For carbon finance, even though the market developments are uncertain after the Kyoto protocol ends in 2012, there is confidence among project developers that a market for carbon credits will still be there. Least Developed Countries can still host stove activities through EU-ETS, and voluntary initiatives are expected to keep growing, which provides an opportunity for India which is not an LDC. Even when emission reduction prices will not stay as high as they are now because of this growing voluntary market, an economic equilibrium will eventually be reached. If the amount of credits to be issued increases because of improved methodologies, carbon finance can become a viable mechanism to catalyze the use of improved cookstoves worldwide.

The models have their downsides as well. For microfinance and dealer credit models these are mainly the high interest rates, down payments and transaction costs that make it hard for small devices like cookstoves to be worth getting a loan. For carbon finance, the high upfront investment required and the fact that it takes at least two years before the first credits can be issued are problematic and obstruct opportunities for small programs run by local NGOs. Costs of validation and verification processes have to be lowered and verification procedures have to become faster for these small players to enter the market.

6. Lessons learned

In this chapter, the important lessons learned from literature, past and recent programs in Chapter 4 and financial mechanisms in Chapter 5 are discussed.

6.1 Technology appropriateness

Fit with local circumstances

A fact that comes forward in almost all programs analyzed is the importance of a technology that fits local circumstances. Also, the user friendliness of the stove was shown to be a very important aspect. This involves the ease of operation, but also the changes in cooking habits that are required. Besides this, the taste of the food and the possibility to cook a full family meal meeting local standards is seen as very important by the end-user. The solar cooker program, where big changes in both cooking habits and food taste and choice were required, failed mainly because of these reasons.

Including the end-user in the development process of the stoves is necessary to make sure the stove is suitable for local cooking habits and preferences, which cannot be identified from a top-down level. This is emphasized in general literature by both Shrimali et al. (2011) and Neudoerffer et al. (2001) and is mentioned as a reason why the solar cooker program and the NPIC failed. A promising fact is that all the current programs did take into account user feedback in the stove design. Apparently the importance of this has been recognized from past experiences.

In North India, a problematic issue is the very specific cooking method of the traditional *chapatti*, which is not possible with a top-loading improved cookstove. A solution to this problem has to be found to prevent households from using a traditional stove to bake *chapattis* next to their improved stove, as this highly reduces the benefits of having an improved stove. The International Energy Agency (IEA) even wrote that because of the traditional bread, a complete transition to other fuels than wood in India is highly unlikely (IEA, 2006). The problem of fuel stacking was seen in all the past Indian programs analyzed and also in Sri Lanka, where similar cultural preferences are in place. Stimulating the development of front-loading improved biomass cookstoves, which is already done by TERI, could be a possibility to lift this issue, as *chapattis* can be baked inside of these devices.

Quality

Quality of the stoves is another important issue, which proved to be a problem in the NPIC and the NPBD. The distribution of low-quality deviced leads to high drop-out rates and has a negative effect on end-user's perceptions of improved cooking technologies. Not only should the stove be efficient and have low PIC emissions, it also has to include parts that are easily available for repairs. The battery, which is the part that is found to break down much faster than other parts in forced draft stoves, is a key component that should be available at all times. Monitoring to improve quality in the duration of the program is both recommended from literature (Kees & Felmann, 2011) as from the analysis of the successful Chinese program. The lack of this is one of the reasons why the NPIC and the biogas program in India failed. Moreover, lifetimes should be as long as possible, and preferably the stove efficiency should be tested for the whole lifetime to prevent overestimation of emission savings, like was the case in the Chinese NPIS.

Quality is always a compromise with the stove price. The example of the Philips stove, where a better model is available but is not produced because of the higher price, shows this. The different materials that are tested in the TERI lab in Jagdishpur provide different options for different prices, where the cheaper models are a little less efficient and will more easily break down.

Resource availability

Both the resources to manufacture and repair the stove and the fuel(s) needed for cooking with it should preferably be locally available. This is mentioned in literature by Kees and Feldmann (2011) and is seen implemented in all the recent programs. Pellets from agricultural residues are used in the Do-inc program, and also in Rwanda combined with the Philips stove, because these are the only biomass sources available. Whether these pellets will also become popular in India, where firewood is widely available, can be questioned. Already it is seen that few people are willing to pay the expensive pellets sold by First Energy. Even the use of chopped wood pieces in top-loading stoves was seen as a problem by end-users in Jagdishpur, where biomass was mostly available in the form of big chunks of wood. In Mewat, where mostly smaller twigs were available, this was considered no problem at all.

Supply channels and repair and maintenance facilities are very important to enable the distribution and continuous use of improved cooking technologies. In the LPG program, the large distance to supply points was one of the reasons for the dropping usage rates. The lack of retail channels to supply stoves also prevents commercial players to start in rural areas, where improved cookstoves are most needed. This has been one of the reasons why Philips left the Indian stove market. In Mewat, a distribution network with a local shop and O&M facility has to be set up to make scaling up and meeting the large demand possible.

For repair and maintenance facilities, both skilled labor to guarantee that repairs are carried out properly and the availability of spare parts are important. In the village of Jagdishpur, no improved cookstoves are available on the market and supply of spare parts is problematic, so even if people would want to replace or repair their IC this is often not possible.

One more resource that is needed specifically for forced draft stoves is electricity. In rural India where electricity is unreliable, this means that an improved cookstove often could not be used for over a week, as mentioned by the end/users in Jagdishpur. To prevent this, solar panels to charge the battery can be included in the stove package, though these are costly components. A central charging station based on solar energy is another possibility to create a reliable supply of electricity, which is already used for lighting purposes in India, as was described in Chapter 5.

6.2 Environmental aspects

Deforestation

The environmental aspect that stands out is the effect of deforestation on stove uptake. The differences between Africa and India are large. In Africa, where deforestation is a much bigger issue than in India, the need for improved biomass stoves is much more urgent, because they simply do not have enough biomass to cook in a traditional way. This is why both Philips and Do-Inc can sell their stoves in Africa at prices that will never be paid by end-users in India, where free biomass is available almost everywhere. As long as deforestation is not a main problem in India and firewood can be gathered free of cost, one might question whether a complete substitution of traditional cooking methods can be realized. Programs in India should therefore not focus on reducing deforestation, like in the failed NPIC, but should emphasize health issues and the reduction of drudgery instead.

Emissions

Comparing past and recent programs, stoves have become much better in terms of emissions. The higher thermal efficiencies and experiences of smoke reductions in the field and from tests done at the TERI and Philips lab show this. PIC reduction in the form of smoke is valued by end-users as a main benefit of the stove in both field sites. CO_2-reduction however is something end-users do not seem to care about at all. So even though CO_2-reduction and climate change mitigation should be incorporated as a goal of stove programs, this is not a benefit that should be used in the promotion of improved cookstoves for end-users. By distributing stoves that comply with BIS standards, low levels of emissions can be ensured, both for health and for climate reasons.

6.3 Economic aspects

Financial mechanisms

From the financial analysis, it already became clear that without any financial mechanism, most of the rural poor do not have enough resources to afford an improved cookstove, or at least not to pay the full price at the moment of purchase. That is the reason why in most of the programs described, subsidies were in place. However, an interesting conclusion that can be drawn from the program analysis is that in the two programs that are viewed upon as the most successful, in China and Brazil, only low subsidies or cross-subsidies were used. Other programs, where high subsidies were given, were not as successful. The NPIC in India is an example of this, and also the TERI program in Jagdishpur where stoves were handed out for free and seemed to be barely used after two years. This is also a risk for carbon financed programs if credits are used to sell stoves at very low prices, which was recognized by the Fair Climate Fund. The consequences of drawing back subsidies or of increased prices when a carbon financed program ends have to be taken into account, which was observed one of the reasons for failure in Brazil.

Thus, although the use of subsidies can stimulate stove sales by reducing the upfront costs, the level of subsidy does not seem to influence a program’s success all that much. This is supported by different sources from literature, where it was found that commercially sustainable solutions are much higher valued than government programs that provide indefinite support (Shrimali et al., 2011; Kees & Feldmann, 2011).The imperative to make money can lead to better matching of consumer needs and product development, and provides an incentive for technology adoption on top of the less valued health benefits (Shrimali et al., 2011).

Fuel price

Affordability does not only have to do with the price of the stove, but also with the price of the fuel which has to be bought or gathered in a certain frequency. Literature states that many households are not able to make monthly payments, as they have to come up with a large amount of money at once, while daily or weekly payments would be much more desired (Kowsari & Zerriffi, 2011). This can be seen in both LPG programs, where the need for smaller cylinders to reduce the payment per refill was found as an important aspect to make sure the less affluent households can afford the refills easier.

In India, the fact that kerosene and LPG are highly subsidized by the government provides a barrier for the transition to improved biomass cookstoves, as it makes cooking with kerosene and LPG much more affordable than it would be without these subsidies. However, for the rural poor, kerosene and LPG are expensive and hard to afford even with the subsidies, so they are not affected by these subsidies that much.

Targeting

Reaching the actual rural poor, the bottom of the pyramid, proves to be very difficult. Even if they were the targeted population of a program, it seems that they usually share the benefits with the better-off. This was the case in the Deepam LPG program, but also happens throughout India with the national LPG and kerosene subsidies. However, the successful programs in China and Brazil and all commercial efforts chose not to target the poorest market segments because of the lack of infrastructure and financial resources. From the Indian programs like the NPIC where the rural poor were targeted, it seems that subsidies may not be the most appropriate mechanism to reach the target group. Cross-subsidizing is mentioned multiple times as a potential solution, where the margin on products sold to the better-off can be used to decrease prices for the poor. Microfinance spreads out the payment over a period of time, but still requires the full price to be paid, often with high interest rates on top of it. This makes it still questionable whether the rural poor are actually targeted by this mechanism. Also, only members of microfinance institutes can profit from it, which limits the amount of households targeted, as was found in the program of Abt Associates. The possibilities for other, direct credit models should be explored to overcome this barrier.

6.4 Sociocultural aspects

Benefits

Literature is trying to find *the* main benefit of improved biomass cookstoves, especially for marketing purposes. But the differences that were seen on the two field sites show that there is no single main benefit of IC's. Circumstances are too different per village, so the aspects valued most also vary. For example, the fact that Mewat women spend 7-8 hours a day for four months in a row collecting firewood, while in Jagdishpur they either buy a year's supply for a low price or collect it nearby, makes that Mewat women value the reduction in firewood use much more, while the women in Jagdishpur see the smoke reduction as the main benefit because they don't have to large burden of collecting the firewood. These findings are in line with findings from a study in Mexico (Ruiz-Mercado et al., 2011).

These and other differences show that the way to approach a program has to be evaluated based on local circumstances and can never be generalized for a whole country. Although the basic business model can be similar, local habits and preferences should be taken into account, especially for emphasizing the main benefits in the promotion of the stove, which is in line with findings in literature (Shrimali et al., 2011). Providing different models within one program, like was done in the Chinese NISP, is therefore highly recommended. From the field sites it was found that even within one village, some women preferred the top-loading stove and others would rather have a front-loading improved stove. If this choice can be given, more stove uptake can probably be realized.

Observability

In both field sites it was seen that observability, the fact that villagers without an IC see the benefits other villagers enjoy by having one, is a very important factor. Villagers and people in the area hear about the improved cookstove and can actually see them at their neighbor's house. This is what they often need to be persuaded about the advantages the stove has over their traditional stove, and what makes them willing to pay the price for the IC. The community is an important factor in this process, which was seen in Mexico (Troncoso et al., 2011).

Gender

Gender was identified to be an important factor that influences stove uptake. This was identified in the program by Abt associates, where male community members were involved in the promotion and training program. Making the male community see the benefits of improved cookstoves is important because they are in charge of financial decisions. The fact that more forced draft stoves are being introduced which run on electricity could spur male involvement, if similar effects happen like in the Mewat village where men did not only become enthusiastic about the stoves, but also took over the cooking practices.

6.5 Method of implementation

Apart from the four aspects described above, one thing that was found to be very important from the program analysis is the way a program is implemented. Even an appropriate technology that is environmentally friendly, affordable and in line with cultural characteristics, is not guaranteed to be successful if it is not implemented in a proper manner. That is why this aspect is discussed in a separate section here.

Local character

The most important lesson to learn from the different stove programs in terms of implementation is that most practices should happen as local as possible. This was emphasized in literature by Kees and Feldmann (2011) and was seen back in all the programs analyzed. Local manufacturing, using local people for installments and operation and maintenance, and local monitoring effort are mentioned as success factors. It is very important that local stove builders and end-users are trained well, which is one of the main factors that attributed to the success of the Chinese NPIS. The local availability of manufacturing is also important to guarantee that people can replace their improved cookstove after the lifetime which is usually no more than 5 years. Of all the past programs analyzed, the NIPS in China has been the only one with successful replacement rates.

Philips, Fair Climate Fund and Do-inc all work together with local NGOs to make sure the things mentioned above can be realized. Selecting locations where these NGOs are operating is very useful, especially in the pilot phase of a project, because existing connections between the NGOs and target communities can be used to reach end-users.

Testing and monitoring

Testing procedures and quality standards for stoves should be in place to make sure only stoves that actually improve the current situation are distributed, which was not always the case in the NPIC. In Africa, no testing procedures or standards are available, and they are lagging behind in this respect compared to India where BIS standards and testing facilities are in place. Also, monitoring after distribution of the stoves should be done to provide valuable information on uptake rates and future design improvements. A pilot project has to be carried out to gather end-users opinions and adapt the stove and the program according to their need. Especially for carbon financed programs, testing and monitoring are crucial for a reliable calculation of carbon offsets. Finding the right people to carry out the monitoring has been mentioned as a problem by both Do-inc and Fair Climate Fund. Because of the lack of experience of local villagers, the reliability of the monitoring results is questionable. This problem could be minimized by training the monitoring personnel well. The importance of good monitoring skills can be seen from the Jagdishpur field case, where almost all the women indicated that they used the IC every day, but observation proved differently.

Creating awareness

Raising awareness is often necessary because the targeted population often does not see (all) the disadvantages of traditional cooking, as the study in Mexico showed (Ruiz-Mercado et al., 2011). Also, they can have false perceptions about improved cookstoves, which was seen in the TERI field sites. Workshops and demonstrations for local families or women can be a way to achieve this. Also, it is very important to promote the benefit of improved cooking technologies that is seen as most important by the local community, which is often not the health aspect, but could be time saving, smoke reduction or less drudgery.

The lessons learned in this chapter are summarized in Table 6.1, which can be used as a generic framework to evaluate stove programs. Although this framework was designed for India, the key insights may apply to programs worldwide, and the framework can be adjusted to specific circumstances and device-fuel combinations in other continents and cultures. The success and failure factors in this framework will be used to discuss and evaluate the new Indian national stove program (the NCI) in Chapter 7.

Table 6.1 Framework of success and failure factors

	Success factors/strengths	Failure factors/weaknesses
Technology appropriateness	- Fit with local cooking circumstances - User friendliness - Include end-user in product development stage - Reduced carbon and PIC emissions - Spare parts are easily available - Continuous monitoring and quality improvement - Constant stove performance - Locally available resources (skills, materials, energy sources) - Functioning supply channels - Opportunity to charge battery locally (forced draft)	- Big changes in cooking habits and food taste (i.e. *chapatti*) - Top-down design and development approach - Low emission savings compared to traditional case - Unavailability of parts for repair - No monitoring - Degradation of stove performance during lifetime - Lack of supply channels - Unreliable/no supply of electricity (forced draft)
Environmental aspects	- Deforestation is a major issue - Significant reduction of smoke - Apparent emission reductions in CO_2, CO and $PM_{2.5}$	- No deforestation issue - Reduced motivation due to large availability of firewood - No apparent emission reductions in CO_2, CO and $PM_{2.5}$
Economic aspects	- Low subsidies - Cross-subsidizing - Self-sustaining in the long term - Ability to accommodate locally available and affordable fuel - High frequency low payments - Clear target population - Using financial mechanisms that actually reach the target population	- Providing stove (nearly) free of cost - Drawing back subsidies too soon - Low frequency large payments - Subsidizing fossil fuels (kerosene, LPG) - Benefits shared outside target population - Targeting rural poor but not using (suitable) financial mechanisms to reach them
Sociocultural aspects	- Emphasize location specific benefits - Offer choice of stove models - Stoves are observable in community - Involve men in promotion and trainings - Stimulation of women empowerment - Awareness of health and gender equity issues of traditional cooking	- Marketing of less valued benefits - "One stove fits all" - No community involvement - Only women are involved in promotion and trainings - No awareness of health and gender equity issues of traditional cooking
Method of implementation	- Local manufacturing, O&M and monitoring - Trainings for stove builders and end-users in place - Test stoves before dissemination - Gather end-users opinions through pilot - Monitoring by reliable, trained local people - Workshops for awareness creation of end-users - Promotion by local demonstration - Benefits most valued by end-user emphasized	- Centralized approach - No replacement stoves available after lifetime - Lack of testing procedures or protocols - Inexperienced monitoring personnel - No initiatives for awareness creation of end-users - Benefits most valued by program developer emphasized

7. Suggestions for implementation of the National biomass Cookstoves Initiative (NCI)

In this chapter, the aspects of the NCI that came forward in an interview with the Ministry of New and Renewable Energy (MNRE) are described and evaluated based on the framework of success and failure factors created in the previous chapter.

7.1 Program description based on interview

In 2009, consultations with many stakeholders started for the development of a new national Indian cookstove program. The goal was to see how technology had advanced in the past 10 years, to see if there was a potential for higher efficiency stoves that further reduce emissions and PM levels. The potential of these advanced improved biomass cookstoves and their use in the field was recognized. That is when the MNRE decided to start a new program from a new approach.

The 4 goals of the National biomass Cookstoves Initiative are:

1. To provide *cleaner* energy solutions to energy deficient people in the poorest areas (cleaner, as 100% clean is not a realistic goal)
2. To have the health issues concerned with cooking addressed
3. To save biomass fuel sources
4. To reduce climate change impact

The pilot scale project is ongoing, after which large-scale dissemination will take place. According to the 12th five year plan, 3.5 million stoves will be implemented. The aim is to disseminate 150,000 stoves in 2013.

7.1.1 Technology appropriateness

The MNRE admits that in the NPIC, every cookstove producer could "just go ahead", which resulted in a not-functioning program and gave the government a bad name. This time, field tests are done for all the stoves to ensure they are of the right quality. Also, test facilities have been strengthened to make sure the stoves that are disseminated fulfill the standards. For all the improved cookstoves, MNRE wanted to see how much fuel could be saved, how much emissions could be prevented and what the health benefits were. In the testing phase, 15,000 family-size stoves have been disseminated, which resulted in fuel savings of 40-50% and the same reduction in cooking time.

A main difference with the NPIC is that the NCI is industry-driven from the beginning with a large focus on product development. According to MNRE, the cookstove has to deliver, otherwise the program has no point. Many improved biomass cookstoves that are currently sold on the market are not of the right quality. Research on more efficient combustion chambers is currently being carried out to increase stove performance.

The MNRE has considered using the existing LPG network for the distribution of stoves, but there is a mind-setting barrier concerned with this. This is because LPG distribution is organized through another ministry and the MNRE does not like to be linked to fossil fuel programs. Also, different skills would be needed for the distribution of stoves or fuel pellets that for LPG cylinders. Still, using the LPG distribution network is seen as a possibility to look into later.

7.1.2 Environmental aspects

Although reducing climate change impact is one of the program's goals, the MNRE admits that this is not one of India's main concerns at the moment. Climate benefits of stoves are seen as an extra advantage, but this is not the reason why the program was started.

Health benefits, on the other hand, are viewed upon as a very important aspect of the program. The goal is to distribute improved biomass stoves with an LPG-like performance. The MNRE has set up test labs where all the factors icluded in the BIS (efficiency, CO/CO_2-ratio and total suspended particles (TSP)) plus surface temperature, are measured based on water boiling tests. Because MNRE found that there has been a lot of development in cookstoves in the past decade, the BIS were revised and different standards have been developed for ND and FD stoves. Table 7.1 shows the revised BIS values.

Table 7.1 Revised BIS standards

	ND	FD
Efficiency	>25%	>35%
CO/CO_2-ratio	<0.04	<0.02
TSP	<2mg/m3	<2mg/m3

Apart from this, research is being carried out to set a limit to suspended particles smaller than PM2.5, which are not included in the standard yet but have shown to have severe health impacts.

So far, only 5 cookstoves have been approved according to these standards, but this number is expected to be around 12 at the end of 2012. The 5 stoves that have been approved are the First Energy Oorja, Vikram, Harsha, Agni and Philips stove. The Oorja, with an efficiency of 38-40%, is the best stove currently available on the Indian market. However, the fact that this stove uses pellets only is seen as a disadvantage. The Philips stove is the best stove that was tested, but unfortunately they moved out of the Indian market. The MNRE admits that the efficiencies of the approved stoves are not LPG-like, but states that the quality of flame is, as well as the emission reductions.

7.1.3 Economic aspects

Different subsidies will be provided to different stoves. The amount of subsidy will be decided by a star rating system based on efficiencies. The development of this rating system is still in process. In the pilot project, a fixed amount of subsidy is given. For natural draft stoves, which cost around Rs. 600-650, the ministry can offer Rs. 300 per cookstove. For forced draft stoves, this amount is Rs. 700, but costs are in the range of Rs. 1500-2500. MNRE is confident that stoves can be produced for low enough prices to reach a situation where 60% of the stove price is subsidized, because it is a market driven process. As more stoves will become approved by the new BIS standards this year, this will get the market and the competition started.

Next to subsidies, MNRE started looking into the possibilities for carbon finance. Although they were skeptical at first, they see a large potential now and are looking for a buyer of the credits that will become available from the project. With the revenues generated, buyers can replace their cookstove free of costs after its lifetime that is estimated at 5 years. An estimated 2.5 CERs (tonnes of CO_2 savings) per cookstove can be issued. MNRE is in the process of developing the program of activities (PoA), consulted by South Pole in New Delhi. The plan is to develop a central company, the Bioenergy

Corporation of India, from where the credits can be sold. This way, the program can work as a real business model.

> *Box 7.1 South Pole about the CDM program*
>
> South Pole Carbon Asset management is the project developer of the CDM program of activities (PoA) for the new Indian cookstove program. An interview with South Pole provided some extra insights on the program's carbon finance potential.
>
> According to South Pole, India's huge geographical size and its developing country status present many potential advantages for scaling up any program, and a great coverage area can be reached. Furthermore, the fact that the rural population represents the majority of the overall population creates an opportunity for covering a major portion of the population.
>
> As this is a PoA, as many projects as possible can be included in the future once the program is registered. This means there is no upper limit on the size of the program. A CDM PoA can run for as long as 28 years.
>
> This suggests that a very positive environment is in place for a successful CDM program. However, South Pole admits that any project or program that involves such a wide-spread coverage area with such small independent components is bound to have many complications involved, which is in line with the findings on carbon financing of cookstoves in Chapter 5.
>
> The potential carbon revenues from the program can be used to reduce the upfront expenditure for the end user to make it more affordable for the rural household. This is an advantage over microfinance, where end-users still have to pay the entire amount. The challenge is how to deal with the fact that carbon revenues are not always available up front, but only after successful operation of the project and issuance of credits.

Research is done to produce cost-effective processed fuels, because many forced draft cookstoves need processed biomass in the form of briquettes or chips. The cost of wood pellets is now Rs. 16/kg, which is much too high, so cost of production has to be reduced drastically. MNRE provides about 50% R&D support to the industry to develop machines with a low energy intensity to produce pellets in a more cost-effective way. They already spent over 10 million US dollars of the program's budget on this.

Reaching people below poverty line will happen through state government support, which can be added to the support by the national program.

7.1.4 Sociocultural aspects

According to MNRE, the main benefit of the improved stoves for the households is to enjoy good health, which is the main reason they started this program. The main selling point in the promotion of the stove has to be decided by the market. The fact that natural draft stoves are much cheaper than forced draft stoves could make them more popular, so MNRE expects that it might be difficult for forced draft stoves to be sold on a large scale.

7.1.5 Implementation method

Manufacturing will happen in a centralized manner, by industry. Distribution of the stoves will happen through these manufacturers themselves and through energy service companies, NGOs, and self-help groups. It is up to the industry how to promote the stoves in the market. Manufacturers have to create outlets on the local level to carry out repair and maintenance services

Trainings and technical assistance will be provided for the local service personnel during capacity building. Also, training for end-users will be in place. Monitoring will be done by a third party to collect measurement results on indoor air pollution and user feedback.

7.2 Program strengths

7.2.1 Technology appropriateness

By providing a choice between different stove types, there is a larger possibility that one of the stoves fits with local circumstances. Both natural draft and forced draft stove models have been approved of by the MNRE so far. This is an advantage, because in places where no electricity is available, households can go for the natural draft stove and still profit from the program.

The quality of the stoves implemented in the program is ensured by both testing them according to the BIS standards in the field during the pilot. This is a major improvement from the NPIC, where standards were less strict and field tests were not done, resulting in all kinds of bad-quality models being distributed. The good quality control in the NCI reduces the risk of stoves breaking down early in the program and increases the reliability of the program's results in terms of fuel and emission savings.

7.2.2 Environmental aspects

Reducing deforestation is not mentioned as a main goal this time, in contrast to the NPIC, so no unrealistic goals have been set. However, saving biomass fuel is a goal of the NCI. It would be good for the MNRE to expand on this subject, to see what benefits of saving biomass fuel they want to address with this goal. This could be the reduction of time consumption and drudgery from fuel collection on the one hand, or the possibility of biomass based electricity on the other hand. Setting clear targets has proved important in past programs, and this could be improved in this program.

The revised BIS standards to ensure the distribution of high-performance stoves are a good development. These standards should be continuously adjusted in the future, to set sharper standards for new stoves that are implemented based on developments in stove design and performance.

7.2.3. Economic aspects

Subsidies seem to be of the right amount, because no full subsidies are provided but only up to 60% of the retail price will be subsidized. The star rating system is very promising as it will stimulate the sales of the most efficient stoves by putting higher subsidies on these models. This is a system that has not been seen in other countries so far, so the effects of using a rating system like this and the possibilities to apply it in other countries as well are very interesting to research once the system is in place.

Carbon finance to enable free replacement is a good initiative, because from Chapter 5 it turned out that the main disadvantage of carbon finance is the long time between the start of a program and the issuance of credits. That is not a problem when carbon financing is done in this way because 5 years (cookstove lifetime) are available to create the credits from the first round of distributed stoves and issue them before replacement is required. Finding a buyer for the CDM project is the only uncertainty and should preferably be done before the end of 2012, as post-2012 CDM is likely to focus on projects in Least Developed Countries, which India is not. If CDM is realized, subsidies can be lifted after the program is running.

7.2.4 Sociocultural aspects

Self-help groups are one of the entities through which the program is being implemented in the pilot phase. This is a good thing that should be encouraged also when large scale dissemination starts. MNRE should try to target self-help groups for this as much as possible. However, for monitoring purposes, they should take into account that these women often have little or no experience with gathering user information and setting up databases for this, so good training should be provided to prevent unreliable results.

7.2.5 Implementation method

Because pilot projects are carried out, user comments can be included in the program design. Hopefully, the MNRE will use the user feedback from the pilot phase to adjust the program strategy accordingly. The fact that technical support for both service personnel and end-users is provided is promising for high usage and repair rates.

Monitoring will be done from the start in the NCI, which is a large improvement from the NPIC, where no monitoring was done at all. It would be interesting to know the third party that is going to be do the monitoring, to see if this party has the right capacities and resources to provide reliable monitoring results. It is advised to not only monitor usage and emission numbers, but to also gather information from the local operation and maintenance shop to see if people with broken stoves actually get them fixed, if services could be improved and if the entrepreneurs that run the shop can make a living from it. This is needed to prevent underpaid service personnel to quit and find other business opportunities, like happened in the NPIC.

7.3 Program weaknesses

7.3.1 Technology appropriateness

Although different stove models are approved by the program and a choice can be provided, the government makes the final decision on which stoves to include in the program, so it is not sure if an appropriate stove is available for all the distribution sites. Also, not all the stove models that will be distributed offer the possibility to bake *chapattis* inside, which could cause a problem in North India of lower than expected usage rates because of fuel and device stacking. This should be looked at in more detail by the government, because if traditional stoves will still be used to make *chapattis* this limits the program's success. It is recommended to include a (forced draft) front-loading stove with the possibility to bake *chapattis* inside in the choice of approved stoves, as this will prevent fuel stacking from happening. Also, including a two-pot stove could lead to higher stove uptake, especially for very large households who find the single pot stove too small to cook a whole family meal.

Because the stoves are developed by different manufacturers in India that are located in different places, manufacturing will happen at centralized locations. This can make it hard to have stoves and spare parts available in the (repair) shops on the local level, as they may have to be transported over large distances. It has to be made sure that networks are developed to enable distribution of all the approved models throughout India. The government leaves this to the industry, which could be tricky, as this means that rural areas that are hard to reach can be left out of distribution channels. MNRE should think of a strategy to ensure that all rural areas have access to sales channels. First of all, it should be checked whether the industry is capable of doing this by regular monitoring of sales channels during the start of large scale dissemination. If necessary, research should be carried out to find methods to create channels to sell the stoves, for example by using distribution channels of other products. This do not have to be other cooking-related products like LPG and kerosene, which are sensitive products because they “belong to” another ministry and are focused largely on urban areas, but can also be other low-carbon products like solar lamps, or products which have become widely used in rural areas lately like mobile phones.

7.3.2 Environmental aspects

Water boiling tests are used to test stove performance according to the BIS standards. However, it has been questioned in literature if using water boiling tests is the best method to test performance, as it does not resemble in-field performance (Johnson et al, 2010). This is an aspect that should be considered, but other, in-field test methods are very time-consuming and expensive. Also, stoves should be tested at multiple stages of their lifetimes to see if performance stays constant over time. The models that have been approved so far have been on the market for several years, so stoves that have been used for some time are available. Testing the performance of these stoves will provide valuable information on the actual benefits of the program.

7.3.3 Economic aspects

MNRE expects that stove prices will go down once large-scale distribution starts, but especially for forced draft models it is questionable whether prices will become low enough to reach retail prices of around Rs. 500-1000, which is what rural people state as the amount they are willing to pay for a stove. Even with the government subsidy, prices will still have to go down by at least Rs. 500 per stove to make stoves in this price range available.

MNRE is confident that State Government support on top of the national subsidies will be provided to enable the distribution of improved cookstoves to poor households. First of all, it cannot be expected that all states will initiate such a policy, and this is quite a presumptuous thing for the MNRE to say. Secondly, support in the form of additional subsidies is not recommended, as it will lead to a situation where the stoves are distributed (nearly) free of cost. The potential for other methods of state support through microfinance or other credit models should be investigated on the state level, stimulated by the national government.

7.3.4 Sociocultural aspects

No specific information on how stove promotion and marketing will take place was given. The government should keep track of promotional efforts by the industry to check if they actually take place and whether benefits are being emphasized that are highly valued by communities and end-users. Also, involving the male community in this process has been identified as a valuable thing in the program analysis and is something MNRE should consider.

7.3.5 Implementation method

The centralized manner of manufacturing can make it difficult to develop and organize repair and maintenance shops at the local level. MNRE should regularly check the status of these facilities to see if the shop is accessible for surrounding households in rural areas, if personnel are well-trained and if all the necessary spare parts are easily available.

There is no specific strategy to create awareness of the problems with traditional cooking, which is a first step that is highly needed before large scale dissemination can take place. MNRE cannot expect from industry to include this in their promotional activities of the stoves, so they should think of ways to catalyze the process of awareness creation.

7.4 Concluding remarks

Table 7.2 shows how the strengths and weaknesses of the NCI fit into the framework of lessons learned from Chapter 6. It can be seen that a lot of the lessons learned have been implemented in the program, especially in terms of the high quality of the stoves due to good testing procedures and the inclusion of a pilot phase in the process. These are major improvements compared to the previous Indian stove program. However, there are some weaknesses and especially some important question marks, which for a large part have to do with the centralized approach of the program. The lack of clear guidelines for the creation of supply channels, the marketing and promotional efforts and the training of local operation and repair personnel could become weaknesses when these aspects are not taken up by the industry. Also, there is still a lot of uncertainty about the financial mechanism that will be used to reach the rural poor, which depends on decisions on the state level. The government should look at all the question marks in the framework and make sure they turn into strengths instead of weaknesses to make the NCI a successful program.

Table 7.2 Strengths and weaknesses of the NCI

	Success factors/strengths		Failure factors/weaknesses	
Technology appropriateness	- Fit with local cooking circumstances - User friendliness - Include end-user in product development stage - Reduced carbon and PIC emissions - Spare parts are easily available - Continuous monitoring and quality improvement - Constant stove performance - Locally available resources (skills, materials, energy sources) - Functioning supply channels - Opportunity to charge battery locally (forced draft)	? √ √ √ ? ? 	- Big changes in cooking habits and food taste (i.e. *chapatti*) - Top-down design and development approach - Low emission savings compared to traditional case - Unavailability of parts for repair - No monitoring - Degradation of stove performance during lifetime - Lack of supply channels - Unreliable/no supply of electricity (forced draft)	X X ? ?
Environmental aspects	- Deforestation is a major issue - Significant reduction of smoke - Apparent emission reductions in CO_2, CO and $PM_{2.5}$	 √	- No deforestation issue - Reduced motivation due to large availability of firewood - No apparent emission reductions in CO_2, CO and $PM_{2.5}$	X X
Economic aspects	- Low subsidies - Cross-subsidizing - Self-sustaining in the long term - Ability to accommodate locally available and affordable fuel - High frequency low payments - Clear target population - Using financial mechanisms that actually reach the target population	√ √ √ ?	- Providing stove (nearly) free of cost - Drawing back subsidies too soon - Low frequency large payments - Subsidizing fossil fuels (kerosene, LPG) - Benefits shared outside target population - Targeting rural poor but not using (suitable) financial mechanisms to reach them	 X ?
Sociocultural aspects	- Emphasize location specific benefits - Offer choice of stove models - Stoves are observable in community - Involve men in promotion and trainings - Stimulation of women empowerment - Awareness of health and gender equity issues of traditional cooking	? √ √ 	- Marketing of less valued benefits - "One stove fits all" - No community involvement - Only women are involved in promotion and trainings - No awareness of health and gender equity issues of traditional cooking	?
Method of implementation	- Local manufacturing, O&M and monitoring - Trainings for stove builders and end-users in place - Test stoves before dissemination - Gather end-users opinions through pilot - Monitoring by reliable, trained local people - Workshops for awareness creation of end-users - Promotion by local demonstration - Benefits most valued by end-user emphasized	 ? √ √ ? ? ? ?	- Centralized approach - No replacement stoves available after lifetime - Lack of testing procedures or protocols - Inexperienced monitoring personnel - No initiatives for awareness creation of end-users - Benefits most valued by program developer emphasized	X ? ? ?

Conclusion

Different device-fuel combinations are available in India to substitute traditional cooking methods. Kerosene, LPG and biogas stoves, solar cookers and improved biomass stoves (IC's) are the most prevalent options. Solar cookers require a significant shift in cooking habits and preferences and biogas stoves require high investments compared to all other technologies which makes them more suitable for the non-poor rural population. Therefore, on a large scale, these technologies are not the most appropriate options for the rural poor in the transition towards clean cooking methods.

In terms of carbon emissions, IC's using renewable biomass are the cleanest, but kerosene and LPG stoves also cause enormous emission reductions compared to cooking with a traditional stove. Enormous reductions in the emission of health-hazardous products of incomplete combustion can be realized by all these technologies. If the biomass saved by IC's is used for electricity production, large savings in coal use and CO_2-emissions can be realized. In terms of costs, IC's seem like the most affordable option, especially when no cost for wood is assumed. In case a market price of wood is taken, the forced draft IC still competes with the fossil options of LPG and kerosene. But regardless of what price of wood is chosen, all options are expensive compared to traditional cooking in terms of upfront investment because traditional stoves are made free of cost. For the rural poor, these high upfront costs make cleaner cooking methods very hard to afford, therefore financial mechanisms are needed.

Subsidies can work as long as they do not cover the full device costs, which leads to low valuation of the stove by the end-user. Next to subsidies, other recently developed financial mechanisms can be used to stimulate the uptake of improved cooking methods by the rural poor. Microfinance provides the opportunity to pay off the high upfront costs in smaller terms. However, the full amount still has to be paid and high interest rates can be charged. Creating microfinance funds for self-help groups through government development initiatives could lead to lower interest rates and stimulate empowerment of women. This opportunity should be explored by the government. Carbon finance can reduce the total cost a household has to pay for a cooking technology by selling carbon credits, but has the disadvantage that the time lag between a project's start and the moment of credit issuance is at least two years and extensive monitoring is needed which is time-consuming and costly. However, the number of carbon financed stove programs is growing fast and the development of more flexible regulations could overcome the drawbacks.

Looking at past and recent programs, a generic framework of success and failure factors for the evaluation of stove programs was developed. This framework is based on findings in terms of technology appropriateness, environmental, economic, sociocultural aspects and implementation method. Evaluation of the National Biomass Cookstove Initiative (NCI) by this framework showed that the NCI has the potential to become a successful program with large scale coverage, but the Indian government has to realize that leaving promotion, targeting and distribution fully in the hands of industry may lead to less sales than expected, especially in remote rural areas. Also, relying on State Governments to provide extra subsidies for the poor seems very confident. The revised BIS and the choice of high-performance stoves that is provided look promising. It is recommended to include a front-loading stove with the possibility to bake *chapattis* inside, as this will prevent fuel stacking from happening in North-Indian regions. The use of carbon finance for free of cost replacement of stove after the lifetime seems like a good initiative, as the time-lag of credit issuance will not be an issue that way.

The framework developed in this thesis was designed for India, but can be adjusted for use on other device-fuel combinations and in other parts of the world. Research has to identify the specific factors and circumstances that apply in different continents and cultures. Furthermore, each of the factors in the framework can be researched individually to develop in-depth insights on these specific topics.

Promising financing mechanisms and their potential for cookstove projects need more research. As the first stove projects using these mechanisms have only been started in the last few years, hardly any literature is available on these subjects yet. Results of these projects should be used to develop new insights on the potential of financing stove programs using these mechanisms.

References

Afrane, G., & Ntiamoah, A. (2012). Analysis of the life-cycle costs and environmental impacts of cooking fuels used in Ghana. *Applied Energy,* 98, 301-306.

Ahmad, B. (1999). *Solar cooking technology - how far are technology promoters and users from each other?* Retrieved January 15, 2012, from http://solarcooking.org/gujarat.htm

Berkeley School of Public Health. (2010). *Stove sensor project takes top prize in vodafone competition for wireless innovation.* Retrieved January 29, 2012, from http://sph.berkeley.edu/news/2010/vodafone.php

Bhattacharya, U. F. (2011). *National innovation foundation - India: Pressure type kerosene stove.* Retrieved May 20, 2012, from http://www.nif.org.in/node/509

Bhattacharyya, S. C. (2006). Energy access problem of the poor in India: Is rural electrification a remedy? *Energy Policy, 34*(18), 3387-3397.

Bhide, A., & Monroy, C. R. (2011). Energy poverty: A special focus on energy poverty in India and renewable energy technologies. *Renewable and Sustainable Energy Reviews, 15*(2), 1057-1066.

Bond, T., Venkataraman, C., & Masera, O. (2004). Global atmospheric impacts of residential fuels. *Energy for Sustainable Development, 8*(3), 20-32.

Brechet, T., & Lussis, B. (2006). The contribution of the clean development mechanism to national climate policies. *Journal of Policy Modeling, 28*(9), 981-994.

Budya, H., & Yasir Arofat, M. (2011). Providing cleaner energy access in Indonesia through the megaproject of kerosene conversion to LPG. *Energy Policy, 39,* 7575-7586.

Central Electricity Authority (CEA), Ministry of Power. (2011). *CO2 baseline database for the Indian power sector.* New Delhi, India.

Central Electricity Authority (CEA), Ministry of Power. (2012). *Electricity generation during the month of April'12.* New Delhi, India.

Chikkatur, A. P., Sagar, A. D., Abhyankar, N., & Sreekumar, N. (2007). Tariff-based incentives for improving coal-power-plant efficiencies in India. *Energy Policy, 35*(7), 3744-3758.

CIA factbook. (2012). *Exchange rates.* Retrieved 07/06, 2012, from https://www.cia.gov/library/publications/the-world-factbook/fields/2076.html

CO2 prices.eu. (2012). *Analysis of the EU CO2 market.* Retrieved 07/16, 2012, from http://www.co2prices.eu/

Cynthia Neudoerffer, R., Malhotra, P., & Venkata Ramana, P. (2001). Participatory rural energy planning in India—a policy context. *Energy Policy, 29*(5), 371-381.

D'Sa, A., & Murthy, K. V. N. (2004). Report on the use of LPG as a domestic cooking fuel option in India. *International Energy Initiative, Bangalore, India.*

Envirofit. (2012). *About Envirofit.* Retrieved February 6, 2012, from http://www.envirofit.org/about/?sub=envirofit

Ezzati, M., & Kammen, D. M. (2002). The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs. *Environmental Health Perspectives, 110*(11), 1057.

First Energy. (2012). *Creating a sustainable business.* Retrieved Februari 6, 2012, from http://www.firstenergy.in/about-us/creating-a-sustainable-business-out-of-environmental-conservation.html

Foell, W., Pachauri, S., Spreng, D., & Zerriffi, H. (2011). Household cooking fuels and technologies in developing economies. *Energy Policy, 39,* 7487-7496.

Food and Agriculture Organization of the United Nations (FAO). (2010). *Forestry policies, institutions and programmes - India.* Retrieved May 18, 2012, from http://www.fao.org/forestry/country/57479/en/ind/

Food and Agriculture Organization of the United Nations (FAO). (2012). *Forests and the forestry sector.* Retrieved May 18, 2012, from http://www.fao.org/forestry/country/57478/en/ind/

Gaiha, R., Kulkarni, V. S., Pandey, M. K., & Imai, K. S. (2010). National rural employment guarantee scheme, poverty and prices in rural India. *Journal of Asian and African Studies, 45*(6), 645-669.

Gangopadhyay, S., Ramaswami, B., & Wadhwa, W. (2005). Reducing subsidies on household fuels in India: How will it affect the poor? *Energy Policy, 33*(18), 2326-2336.

García-Frapolli, E., Schilmann, A., Berrueta, V. M., Riojas-Rodríguez, H., Edwards, R. D., Johnson, M., Masera, O. (2010). Beyond fuelwood savings: Valuing the economic benefits of introducing improved biomass cookstoves in the purépecha region of Mexico. *Ecological Economics, 69*(12), 2598-2605.

Hanbar, R., & Karve, P. (2002). National programme on improved chulha (NPIC) of the government of India: An overview. *Energy for Sustainable Development, 6*(2), 49-55.

Harley, R. A., McKeen, S. A., Pearson, J., Rodgers, M. O., & Lonneman, W. A. (2001). Analysis of motor vehicle emissions during the Nashville/Middle tennessee ozone study. *Journal of Geophysical Research, 106*, 3559-3567.

Hegarty, D. (2006). Satisfying a burning need. *Philips Research Technology Magazine "Password", 28*, 13-02-2012.

Howells, M. I., Jonsson, S., Käck, E., Lloyd, P., Bennett, K., Leiman, T., & Conradie, B. (2010). Calabashes for kilowatt-hours: Rural energy and market failure. *Energy Policy, 38*(6), 2729-2738.

India Development Gateway. (2012). *Apply for LPG connection.* Retrieved May 21, 2012, from http://www.indg.in/e-governance/apply-for-lpg-connection

International Energy Agency (IEA). (2002). World energy outlook 2002 - special issues arising from the outlook.

International Energy Agency (IEA). (2003). *International energy agency implementing agreement on photovoltaic power systems - summary of models for the implementation of solar home systems in developing countries* (No. PVPS T9-02).

International Energy Agency (IEA). (2006). World energy outlook 2006.

International Energy Agency (IEA). (2011). Energy for all - financing access for the poor. special early excerpt of world energy outlook 2011.

IPCC. (2006). IPCC guidelines for national greenhouse gas inventories.

Kandpal, J., & Maheshwari, R. (1995). Combustion of biomass fuels in two cookstoves for their conservation. *Energy Conversion and Management, 36*(10), 1015-1021.

Kar, A., Rehman, I. H., Burney, J., Puppala, S. P., Suresh, R., Singh, L., Ramanathan, V. (2011). Real-time assessment of black carbon pollution in Indian households due to traditional and improved biomass cookstoves. *Environmental Science & Technology, 46,* 2993-3000.

Kees, M., & Feldmann, L. (2011). The role of donor organisations in promoting energy efficient cook stoves. *Energy Policy, 39,* 7595-7599.

Koirala, B. P., Ortiz, B., Modi, A., Mathur, J., & Kafle, N. (2011). Solar lighting systems delivery models for rural areas in developing countries. *Microperspectives for Decentralized Energy Supply,* TU Berlin. 268-273.

Kowsari, R., & Zerriffi, H. (2011). Three dimensional energy profile: A conceptual framework for assessing household energy use. *Energy Policy, 39,* 7505-7517.

Kurchania, A., Panwar, N., & Pagar, S. D. (2010). Design and performance evaluation of biogas stove for community cooking application. *International Journal of Sustainable Energy, 29*(2), 116-123.

Lucon, O., Coelho, S. T., & Goldemberg, J. (2004). LPG in brazil: Lessons and challenges. *Energy for Sustainable Development, 8*(3), 82-90.

Masera, O. R., Saatkamp, B. D., & Kammen, D. M. (2000). From linear fuel switching to multiple cooking strategies: A critique and alternative to the energy ladder model. *World Development, 28*(12), 2083-2103.

Ministry of New and Renewable Energy (MNRE). (2012a). *BIOMASS POWER AND COGENERATION PROGRAMME.* Retrieved 06/18, 2012, from http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/

Ministry of New and Renewable Energy (MNRE). (2012b). *Frequently asked questions (FAQs) on biomass power generation.* Retrieved 06/18, 2012, from http://mnre.gov.in/file-manager/UserFiles/faq_biomass.htm

Ministry of Petroleum & Natural Gas. (2012). *Price build-ups of petroleum products.* Retrieved 06/19, 2012, from http://ppac.org.in/writereaddata/Price%20Build%20up%20Sensitive%20Products.pdf

Morgan, J., & Olsen, W. (2011). Aspiration problems for the Indian rural poor: Research on self-help groups and micro-finance. *Capital & Class, 35*(2), 189-212.

Muthusivagami, R., Velraj, R., & Sethumadhavan, R. (2010). Solar cookers with and without thermal storage—A review. *Renewable and Sustainable Energy Reviews, 14*(2), 691-701.

NSSO. (2006). Energy sources of Indian households for cooking and lighting, 2004/2005.

NSSO. (2008). Household consumer expenditure in India, 2006-2007.

NSSO. (2010). Household consumer expenditure in India, 2007-2008.

NSSO. (2011). Key indicators of household consumer expenditure in India, 2009-2010.

Organisation for Economic Co-operation and Development. (2006). *World Energy Outlook 2006.* Organisation for Economic Co-operation and Development.

Pachauri, S., Mueller, A., Kemmler, A., & Spreng, D. (2004). On measuring energy poverty in Indian households. *World Development, 32*(12), 2083-2104.

Panwar, N., Kurchania, A., & Rathore, N. (2009). Mitigation of greenhouse gases by adoption of improved biomass cookstoves. *Mitigation and Adaptation Strategies for Global Change, 14*(6), 569-578.

Parikh, J. (2011). Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India. *Energy Policy, 39,* 7587-7594.

Pathak, H., Jain, N., Bhatia, A., Mohanty, S., & Gupta, N. (2009). Global warming mitigation potential of biogas plants in India. *Environmental Monitoring and Assessment, 157*(1), 407-418.

Planning Commission. (2002). *Evaluation study of the national project on biogas development.* New Delhi: Programme Evaluation Organization, Planning Commission, Government of India.

Planning Commission. (2006). *Integrated energy policy: Report of the expert committee*. Planning Commission, Government of India.

Planning Commission. (2012). *Press note on poverty estimates, 2009-10.* New Delhi: Planning Commission, Government of India.

Pohekar, S., Kumar, D., & Ramachandran, M. (2005). Dissemination of cooking energy alternatives in India—a review. *Renewable and Sustainable Energy Reviews, 9*(4), 379-393.

Pohekar, S., & Ramachandran, M. (2006). Multi-criteria evaluation of cooking devices with special reference to utility of parabolic solar cooker (PSC) in india. *Energy, 31*(8), 1215-1227.

Purohit, P., Kumar, A., Rana, S., & Kandpal, T. (2002). Using renewable energy technologies for domestic cooking in India: A methodology for potential estimation. *Renewable Energy, 26*(2), 235-246.

Purohit, I. & Purohit, P. (2007). CDM potential of box type solar cookers in India. *International Journal of Ambient Energy, 28*(1), 27-38.

Rajvanshi, A. K., Patil, S., & Mendonca, B. (2007). Low-concentration ethanol stove for rural areas in India. *Energy for Sustainable Development, 11*(1), 94-99.

Ranganathan, M., Prasad, R., & Singh, P. B. (2003). Participatory approach for linking rural energy transitions and developmental needs in Uttar Pradesh. *Boiling Point, 49*, 15-17.

Raman, P. & Ram, N.K. (2012) Personal communication on improved biomass cookstoves. The Energy and Resources Institute, New Delhi. 19/01, 2012.

Rao, P. S. C., Miller, J. B., Wang, Y. D., & Byrne, J. D. (2009). Energy-microfinance intervention for below poverty line households in India. *Energy Policy, 37*, 1694-1712.

Ravindranath, N., Balachandra, P., Dasappa, S., & Usha Rao, K. (2006). Bioenergy technologies for carbon abatement. *Biomass and Bioenergy, 30*(10), 826-837.

Reddy, B. S. (2003). Overcoming the energy efficiency gap in India's household sector. *Energy Policy, 31*(11), 1117-1127.

Reddy, B. S., & Balachandra, P. (2006). Climate change mitigation and business opportunities-the case of the household sector in India. *Energy for Sustainable Development, 10*(4), 59-73.

Reddy, B. S., Balachandra, P., & Nathan, H. S. K. (2009). Universalization of access to modern energy services in Indian households—Economic and policy analysis. *Energy Policy, 37*(11), 4645-4657.

Rehfuess, E., Mehta, S., & Prüss-Üstün, A. (2006). Assessing household solid fuel use: Multiple implications for the millennium development goals. *Environmental Health Perspectives, 114*(3), 373.

Seminar - Clean cooking – consumer choice and market development. The Energy and Resources Institute (TERI), New Delhi, India. (2012, February 16).

Rehman, I., Ahmed, T., Praveen, P., Kar, A., & Ramanathan, V. (2011). Black carbon emissions from biomass and fossil fuels in rural India. *Atmos.Chem.Phys, 11*, 7289-7299.

Reinmüller, D., & Adib, R. (2002). Reaching rural customers: The challenge of market-based rural electrification. *Refocus, 3*(3), 28-31.

Roden, C. A., Bond, T. C., Conway, S., & Pinel, A. B. O. (2006). Emission factors and real-time optical properties of particles emitted from traditional wood burning cookstoves. *Environmental Science & Technology, 40*(21), 6750-6757.

Rogers, E. M. (1995). *Diffusion of innovations,* Free Pr.

Ruiz-Mercado, I., Masera, O., Zamora, H., & Smith, K. R. (2011). Adoption and sustained use of improved cookstoves. *Energy Policy, 39,* 7557-7566.

Saxena, A., Pandey, S., & Srivastav, G. (2011). A thermodynamic review on solar box type cookers. *Renewable and Sustainable Energy Reviews, 15*(6), 3301-3318.

Shankar, S., Gaiha, R., & Jha, R. (2011). Information, access and targeting: The national rural employment guarantee scheme in India. *Oxford Development Studies, 39*(01), 69-95.

Shrestha, G., Traina, S. J., & Swanston, C. W. (2010). Black carbon's properties and role in the environment: A comprehensive review. *Sustainability, 2*(1), 294-320.

Shrimali, G., Slaski, X., Thurber, M. C., & Zerriffi, H. (2011). Improved stoves in India: A study of sustainable business models. *Energy Policy, 39,* 7543-7556.

Singh, L. (2012, March 12). *Conversation inJjagdishpur stove lab*. Jagdishpur, India.

Sinha, F. (2009). *State of microfinance in India.* Institute of Microfinance (InM).

Sinton, J. E., Smith, K. R., Peabody, J. W., Yaping, L., Xiliang, Z., Edwards, R., & Quan, G. (2004). An assessment of programs to promote improved household stoves in China. *Energy for Sustainable Development, 8*(3), 33-52.

Small Industries Development Bank of India (SIDBI). (2011). *Study on interest rates and costs of microfinance institutions* .ACCESS Development Services.

Smith, K. R. (2000). National burden of disease in India from indoor air pollution. *Proceedings of the National Academy of Sciences, 97*(24), 13286.

Smith, K. R., Mehta, S., & Maeusezahl-Feuz, M. (2004). Indoor air pollution from household use of solid fuels. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors, 2*, 1435-1493.

Smith, K. R., Uma, R., Kishore, V., Zhang, J., Joshi, V., & Khalil, M. (2000). Greenhouse implications of household stoves: An analysis for India. *Annual Review of Energy and the Environment, 25*(1), 741-763.

Solar Cookers World Network. (2012). *The history of solar cooking in india.* Retrieved 07/18, 2012, from http://solarcooking.wikia.com/wiki/India#The_History_of_Solar_Cooking_in_India

Subramaniam, M. (2000). Whose interests? *American Behavioral Scientist, 43*(4), 707-728.

TERI (2012). *LIGHTING A BILLION LIVES - how does it work?* Retrieved 07/18, 2012, from http://labl.teriin.org./index.php?option=com_content&view=article&id=6&Itemid=137#

The Economist. (2008, 04/24). Shovelling for their supper. *The Economist*

The Economist. (2010, 11/18). Microfinance: Leave well alone. *The Economist*

Troncoso, K., Castillo, A., Merino, L., Lazos, E., & Masera, O. R. (2011). Understanding an improved cookstove program in rural Mexico: An analysis from the implementers' perspective. *Energy Policy, 35,* 2799-2810.

Turare, C. (1998). Energy options for urban households in India. *Boiling Point, 41*, 26-28.

UNDP/World Bank. (2003). *Access of the poor to clean household fuels in India.* Retrieved February 1, 2012, from http://siteresources.worldbank.org/INDIAEXTN/Resources/Reports-Publications/Access-Of-Poor/FullReport.pdf

Venkataraman, C., Sagar, A., Habib, G., Lam, N., & Smith, K. (2010). The Indian national initiative for advanced biomass cookstoves: The benefits of clean combustion. *Energy for Sustainable Development, 14*(2), 63-72.

Wickramasinghe, A. (2011). Energy access and transition to cleaner cooking fuels and technologies in Sri Lanka: Issues and policy limitations. *Energy Policy, 39,* 7567-7574.

Appendix I: Table of past and running programs

Table I. Comparison of programs and commercial efforts

Name	Location	Start	Duration	Sponsor	Technology	Fuel	Financial mechanism	Key findings
NPIC	India, national level	1985	17 years	Government of India	ND IC	All biomass	Subsidies	* Unrealistic goals * Quality of stove problematic (lifetime, thermal and combustion efficiency, fuel suitability) * Lack of repair & maintenance facilities * Failed training program of stove installation personnel * Little to no after-sales monitoring
NPDB	India, national level	1981	20 years	Government of India	Biogas stove	Biogas	Central subsidy (+ state subsidy)	* Negative competition amongst implementation agencies * Unnecessary high subsidies * Lack of quality checks and monitoring * Lack of repair and maintenance trainings * Unreliable reporting
Solar cooker program	Gujarat, India	1984	10 years	Government of India	Box type solar cooker	No	Subsidies	* Cooking time too long * Cooking temperature too low * Different food taste * No suitable cooking space in urban areas
Deepam LPG scheme	Andhra Pradesh, India	1999	3 years	State Government AP	LPG stove	LPG	One-off subsidy	* Bad targeting of beneficiaries * Too far distance to distribution points * High refill costs and unexpected (illegal) charges and commissions * Fuel stacking instead of substituting firewood
Envirofit	India	2007	onwards	Shell Foundation	ND IC	All biomass	No	* Natural draft stove decreases quality and unfamiliarity issues * BoP not targeted
First Energy	India	2006	onwards	First BP, now private grants	FD IC	Biomass pallets	No	* Need for pellets keeps customers dependent after stove sales * High price increases after cut-off from sponsor (BP) led to reduction in device use * Commercial market more viable than domestic market * BoP not targeted
LPG program Brazil	Brazil	1975	25 years	Government of Brazil+National Oil company	LPG stove	LPG	Cross subsidizing	* Successful distribution system of concentrating local demand and automatic periodical supply (enabled through high urban population) * Cross-subsidizing combined with affordable, controlled LPG price * Introduction of subsidies and smaller cylinder sizes stimulate continuous use of LPG by poorer households after deregulation
NISP	China	1982	10 years	Government of China	Variety of stoves	Variety of fuels	Small government contribution	* Intensive trainings for government agencies, stove builders and end-users * Constant quality and efficiency of stoves * Adaption of stoves to local resources and preferences * Cost-effectiveness through low central subsidy and high household contribution (poorest households not targeted)

Study on transition	Sri Lanka	2006	1 year	UNDP	ND IC			* Labor opportunities for women are main driver for changing energy choices * High income does not lead to fully substituting biomass use because of taste preferences and free availability
Stove program Mexico	Central Mexico	2003	3 years	CONACYT	ND IC			* Pollution aspect is not most highly valued benefit of IC by end-users * Understanding of health issues spurs stove uptake – realized by meetings with local women * Community support is an important driver for IC use * Training of local builders is important

Appendix II: Questionnaires

1. Questionnaire end-user Jagdishpur

Held on 13-03-2012
Jagdishpur, Uttar Pradesh, India

Family size:
Nr. of adults (>12 years):
Nr. of children (<12 years):
Nr. of cattle:

I own a (tick boxes):	cycle □	cell phone □	TV □	bike □
	car □	pucca house □	piece of land □	

Usage

1. How long have you had an improved cookstove?
2. Do you use the improved cookstove for every meal?
3. If no, why not?
4. Do you use only your improved stove or also other stoves?
5. If multiple: which other stove types do you use?
6. Why do you use these other stove?
7. Do you find the improved stove convenient or difficult to operate?
8. Did you get workshops/trainings on how to operate the stove?
9. Do you think the food tastes the same with the improved stove as with a traditional stove?
10. Is the size of the stove appropriate/too small/too big to cook a meal for your family?
11. You can only cook one item at the time with the improved cookstove. Are you ok with this?

Purchase/acquisition

12. Where did you get your improved cookstove?
13. Did you get a choice regarding the stove model?
14. Did you pay for it?
15. If yes: how much? Would you have been willing to pay more?
16. If not: how much would you be willing to pay for it if you did not have one?

Service

17. Have you been to the local service facility for repair/maintenance?
18. If so, how long did this take?
19. Were you pleased with their service?
20. Do you think the prices for the services are affordable/too low/too high?

Benefits and barriers

21. What do you think of the design of the improved stove?
22. Do you think there could be improvements to the stove design?
23. What is, according to you, the main disadvantage of the improved stove?
    □ The need to chop biomass into small pieces
    □ The fact that it cannot be used to bake chapattis

□ The fact that it uses electricity
□ Other:

24. What is, according to you, the main benefit of the improved stove? (cross 2 most applicable):
    □ Higher efficiency so I need to collect less biomass
    □ Low smoke emission so I have less eye irritation/breathing problems
    □ Low smoke emission so the vessel and walls do not blacken as much
    □ Faster cooking so I have to spend less time in the kitchen
    □ Better ability to control the flame
    □ Other:
25. Do you think the improved cookstove has reduced your fuel consumption?
26. Do you think the improved cookstove has reduced smoke emissions from cooking?
27. Have you saved time by using the improved cookstove?
28. What do you use the spare time for? (cross 2 most applicable):
    □ Livelihood-related activities (agriculture, cattle, household practices)
    □ Spending time with my children
    □ Social activities
    □ Education (of myself or my children)
    □ Other:

2. Questionnaire end-user Mewat

Held on 28-03-2012
Mewat, Haryana, India

Questions on village level:

1. What type(s) of cookstove(s) are mainly used?
2. Why are these types used most?
3. If multiple: why are households using more than one cookstove?
4. Which food items are cooked on which stove types?
5. What are the fuel(s) mainly used for cooking?
6. Where do households get/buy the fuel(s)?
7. What aspect of traditional cooking do you think local women suffer from most?
8. What do you think is the main benefit of an improved cookstove?

Questions on household level (preferably women)

I suffer most from (cross 2 most applicable):

- Physical aches/bruises from collecting firewood ☐
- Tiredness from collecting firewood ☐
- Eye irritation/breathing difficulty from smoke during cooking ☐
- The fact that my infant's health is affected by smoke during cooking ☐

- The time consumption of firewood collection and cooking ☐
- Other:……………………………………………………………………………………….. ☐

If I had an improved cookstove, I would want it to (cross 2 most applicable):

- Have better efficiency so I need to collect less biomass ☐
- Emit less smoke so I would have less eye irritation/breathing problems ☐
- Emit less smoke so the vessel and walls would not blacken as much ☐
- Cook faster so I have to spend less time in the kitchen ☐
- Have a better ability to control the flame ☐
- Other:……………………………………………………………………………………………… ☐

If I had to spend less time on gathering firewood or on cooking, I would use my spare time for (cross 2 most applicable):

- Livelihood-related activities (agriculture, cattle, household practices) ☐
- Spending time with my children ☐
- Social activities ☐
- Education (of myself or my children) ☐
- Other:……………………………………………………………………………………………… ☐

3. Questionnaire carbon finance stove program developers

Distributed and answered through email
March 2012

Please answer the following questions on carbon finance methodologies for improves cookstoves:

<u>Emission reduction calculations</u>

There has been some critique from literature on the method to calculate emission reductions in the CDM and Gold Standard methodologies, and estimated values of CO_2 savings (per cookstove per year) differ with a factor of more than 10 between different projects.

1. How do you think these large differences come to exist?
2. Do you think the methodology provides a way to get accurate estimates of a project's emission savings? Why/why not?

Monitoring results

3. How many stoves have been distributed so far?
4. How many credits have been issued so far?
5. Do Kitchen Tests show fuel use savings similar to the values stated in the PDD?
6. What is the latest number on stove usage from monitoring surveys?
7. Have you had any unexpected monitoring results for other factors (fNRB, leakage, efficiencies, sales numbers)?
8. Has the number of projected annual emission reductions changed because of results from the monitoring program? If so, what is the new projection?
9. What percentage of the program budget goes into monitoring?
10. Do you think more extensive (but more costly) monitoring methods should be developed to reduce uncertainty in projections and increase the amount of carbon credits to be received?

General methodology

What do you think of the different parts of the methodology?

	Good	Not good	Why
Eligibility criteria			
Additionality assessment			
Sustainability Assessment			
Local Stakeholder Consultation			
Baseline assessment			
Monitoring plan			

11. What do you think are the main problems/barriers for carbon financed cookstove programs?
12. Do you think that carbon finance will become a main financing method for cookstove programs in the future (what happens after 2012)?
13. Do you have any additional comments on this topic?

Thank you very much for you cooperation!