Ministry of Foreign Affairs

IOB Evaluation

Impact Evaluation of Improved Cooking Stoves in Burkina Faso

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The impact of two activities supported by the Promoting Renewable Energy Programme

November 2013

Preface

The world today is confronted with enormous, interrelated challenges with regard to climate change, energy, economic sustainability, and poverty. About 2.5 billion people in the world rely on the traditional use of biomass, mostly firewood, for cooking. In many areas this implies pressure is put on the forest resources. Using wood energy for cooking may also bring a health risk, due to exposure to smoke. Every year, 3.5 million people die prematurely as a result of respiratory diseases caused by smoke inhalation related to these cooking methods. Internationally, access to renewable energy is becoming an increasingly important topic, as expressed in for example the designation of 2012 as the International Year of Sustainable Energy for All by the United Nations General Assembly and the process of climate negotiations. Although improved cooking stoves (ICS) have been promoted for decades, the renewed international attention stresses the importance of these stoves as low-cost solution to improve indoor air quality, help reduce greenhouse gases, relieve the daily workload of women and reduce expenditure on energy in poor households.

Prior to 2008, Dutch support to the renewable energy sector in developing countries was largely implemented through the Dutch-German partnership 'Energising Development' (EnDev). Since 2008, EnDev has been supported by the Promoting Renewable Energy Programme (PREP), which is the main instrument for implementing Dutch policy on renewable energy and development. One of the programmes funded under the partnership is *Foyers Améliorés au Burkina Faso* (FAFASO).

The Policy and Operations Evaluation Department (IOB) of the Dutch Ministry of Foreign Affairs recently evaluated the impact of FAFASO at household and entrepreneurial level. This report presents the results of impact studies conducted on two interventions by FAFASO but does not cover its entire programme. The two programme components evaluated are the improved cooking stoves for use in households in an urban environment and improved stoves for small-scale productive use, in particular in artisanal beer breweries. The findings of these impact studies feed into the overall policy evaluation of the Dutch renewable energy and development policy scheduled to be published in 2014.

To conduct the impact studies, IOB commissioned a consortium integrated by the German *Rheinisch-Westfälisches Institut für Wirtschaftsforschung* (RWI) and the Institute of Social Studies (ISS) at Erasmus University Rotterdam in the Netherlands. Between 2010 and 2013, the studies were conducted by Michael Grimm (University of Passau and ISS), Jörg Peters, Gunther Bensch and Katharina Peter (all RWI), and Luca Tasciotti (ISS). In 2010 and 2012, field surveys were conducted by interviewers from the Burkinabè social research institute *Bureau d'Études des Géosciences, des Énergies et de l'Environnement* (BEGE). The studies have been merged and rewritten into this single report by Willem Cornelissen (senior researcher ERBS B.V., Erasmus University Rotterdam) and Jolijn Engelbertink (IOB researcher).

Valuable comments and contributions have been made by members of the Reference Group: Frank van der Vleuten (Ministry of Foreign Affairs), Pieter van Beukering (IVM, VU University Amsterdam), Joy Clancy (Technical University Twente) and Marcel Raats (AgentschapNL). Special thanks and acknowledgement go to both Andrea Reikat (GIZ-FAFASO) and Oumar Sanogo (IRSAT) in Burkina Faso for their assistance to the research team and their valuable comments on draft reports. Rita Tesselaar and Henri Jorritsma (both IOB) provided input and suggestions during the evaluation process. Senior evaluators Piet de Lange and Ferko Bodnár provided valuable commentary on the draft report. Last but not least, special thanks are due to all respondents to the survey interviews and focal group discussions.

IOB assumes final responsibility for the contents of this report.

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List of acronyms and abbreviations

BMZ	*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* (German Federal Ministry for Economic Cooperation and Development)
CCT	Controlled Cooking Test
CFA F	*Communauté Financière Africaine franc* (African franc)
Diff-in-Diff	Difference-in-differences
DGIS	Directorate General for International Cooperation of the Ministry of Foreign Affairs of the Netherlands
EC	European Commission
EnDev	Energising Development
EU	European Union
FAFASO	*Foyers Améliorés au Burkina Faso* (Improved Cooking Stoves in Burkina Faso)
GIZ	*Gesellschaft für Internationale Zusammenarbeit* (German Agency for International Cooperation; prior to 2011: GTZ)
GWh	Giga Watt hour
Hh	Households
ICS	Improved cooking stove(s)
IOB	Policy and Operations Evaluation Department of the Ministry of Foreign Affairs of the Netherlands
IRSAT	*Institut de Recherches en Sciences Appliquées et Technologies* (Research Institute for Applied Sciences and Technologies)
LPG	Liquified Petroleum Gas
NGO	Non-Governmental Organisation
OLS	Ordinary Least Squares
param	parameter
PREP	Promoting Renewable Energy Programme
PS	Propensity scores
PSM	Propensity score matching
SE	Standard error
UK	United Kingdom
UN	United Nations

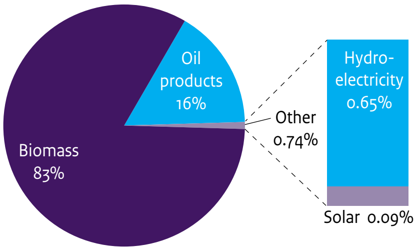
Exchange rates

EUR 1 = CFA F 655 (official exchange rate 2013)
EUR 1 = CFA F 175 (purchasing power parity 2010)

Burkina Faso Facts and Figures

Map of Burkina Faso

Figure A *Percentage of total energy consumption in 2008*



Population, 2012	16.5 million[1]
GDP growth 2012	4.16%
GDP per capita 2012	542 USD
Main export product	Cotton
Poverty ratio at national poverty line	47% of population[2]
Human Development Index ranking	183 out of 187
Top 3 causes of premature mortality	Malaria; Diarrhoeal diseases; Lower respiratory tract infections[3]

Energy

Total Primary Energy Supply	137.0 Petajoule – of which 80.5% renewables (biomass)
Energy self-sufficiency	80.5%[4]
Energy use per capita	43 kWh (among the bottom 15 countries ranked according to energy use)
Electricity Access rate	14.6% (2012)[5]
Carbon dioxide (CO2) emission	1.45 million metric tons (2011, 153 out of 188 countries)[6]

1 http://data.worldbank.org/country/burkina-faso.
2 http://data.worldbank.org/country/burkina-faso.
3 Global Burden of Diseases Study 2010 (2012).
4 Renewable Energy Country Profile 2008, IRENA.
5 World Bank Electricity Sector Support Project, July 2013.
6 Energy Information Administration. International Energy Statistics, 30th May 2013.

Summary and main findings

Background

Since the early 1990s, access to energy – particularly to renewable energy – for the poor in developing countries has been part of Dutch development cooperation. The Ministry of Foreign Affairs' main resource envelope to facilitate access to renewable energy in developing countries has been the EUR 500 million 'Promoting Renewable Energy Programme' (PREP, 2008-2013). The goal of this investment, as formulated in the environment and renewable energy policy of 2008, is to contribute to poverty reduction and to reduce the negative climatic effects of energy use.

Between 2005 and 2009, most Dutch contributions to the energy sector in developing countries were delegated to the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the *German Gesellschaft für Internationale Zusammenarbeit* (GIZ). The umbrella programme for the Dutch-German partnership agreement for the energy sector was Energising Development (EnDev). In 2008, EnDev became an integral component of PREP.

Improved cooking stoves (ICS) have been promoted for decades, but renewed international attention stresses the importance of stoves as a low-cost solution to improve indoor air quality, to help reduce greenhouse gases, to relieve the daily workload of women and to reduce expenditure on energy for poor households. To date, EnDev has implemented ICS activities in about 15 countries. The ICS project F*oyers Améliorés au Burkina Faso* (FAFASO), established in 2005, can be considered illustrative for these activities. The main objective of FAFASO is to establish a sustainable market for fuel-efficient domestic and industrial cooking stoves. Thereto it provides training: to whitesmiths, for the production of metal stoves for domestic use in urban areas; to potters, for the production of ceramic stoves for domestic use in rural areas; and to bricklayers, so they can build large fixed stoves for productive use. It also assists in acquiring raw material for quality stoves, assures quality through certification and the entitlement to use the Roumdé label, it provides promotional material and organises awareness campaigns. Contrary to many other ICS programmes, FAFASO neither disseminates ICS directly, nor provides subsidies on the price.

This report combines the results of two rigorous impact studies on activities implemented by FAFASO: one study on portable metallic ICS for domestic use and one on fixed ICS for use by artisanal beer brewers (most of whom are female). The evaluation was set out to answer two main questions: firstly, if the development of a market for ICS has triggered uptake of ICS by households and productive units and, secondly, what the impacts have been in terms of reducing wood energy use, saving money and time, and improving the workload and health of the users. A mix of methods was used, thus both quantitative and qualitative techniques. For the quantitative part, a cross-sectional approach was applied to study the ICS for domestic use, comparing ICS owners to a control group of households that did not own an ICS. Using matching techniques, each household with an ICS was paired with a similar household without an ICS. In total, 1,473 households were surveyed in Ouagadougou and Bobo-Dioulasso between January and March 2011. The study of the beer brewers drew on an existing baseline study, but complemented it with additional interviews. In 2010, 219 brewers were interviewed; in a follow-up study in 2012, the number of brewers interviewed was 261.

The results of these two studies underpin the following main findings:

Effectiveness

1. *A market for ICS has emerged.*

FAFASO's approach has led to the development of a market for ICS. The training of whitesmiths has led to the capacity to produce large numbers of ICS locally that are adapted to the Burkinabè circumstances and preferences. The stoves for domestic use are being traded and retailed. Awareness campaigns and sales promotion have contributed to the development of effective demand. The quality control initially managed by the programme has been taken over by the producer associations. The Roumdé stove sets the quality standard, has become a popular gift and is being imitated.

2. *The targets set for the uptake of improved stoves in domestic settings have been easily reached. The adoption of ICS by artisanal breweries has also been successful, although in 2012, after two years of high demand, the market had apparently reached its saturation point.*

FAFASO neither actively distributes ICS nor subsidizes the price; the uptake of ICS by households is an outcome. During the first four years of FAFASO's operation (2005-2009), 68,200 ICS for domestic use were sold in Burkina Faso, and halfway through the second phase of the programme (2011), a further 39,500 ICS had been sold (at a price of EUR 3.00-4.50 each). The 107,000 stoves for domestic use sold reached well over half a million persons. This quantity represents 170% of the target initially set by the programme.

Of all households in the targeted neighbourhoods of the two cities Ouagadougou and Bobo-Dioulasso, 9.6% own a certified (Roumdé) stove. This coverage is less than statistically expected, probably because stoves sold in the cities are further retailed and used in rural areas.

Regarding the large Roumdé stoves designed for small businesses, the total potential market in the two cities is about 3,500 artisanal breweries. In a two-year period (up to 2013) 2,380 of such stoves were built. Early 2013, 49% of all artisanal breweries in Ouagadougou and surroundings and 54% in the urban area of Bobo-Dioulasso owned an ICS. Although this suggests that there is still scope for expansion, in practice the uptake of ICS has been declining since 2012, probably because the larger breweries have already acquired an ICS, whereas smaller breweries perceive an ICS as less attractive because of the high cash outlay for investment and the maintenance costs.

3. *A high percentage of households and of brewers actually use the stoves.*

Households not only buy the Roumdé stoves, they also use them. Previous schemes by the government of Burkina Faso to distribute imported ICS have failed: the stoves were either not used at all, or used for a short period only. The vast majority (85%) of owners of a domestic ICS uses the stove regularly. In 37% of ICS-owning households, the ICS has become the single most often used cooking stove, while in another 16% of the households, it is used as frequently as other stoves (together these percentages add up to 53%). Although locally manufactured imitation Roumdé stoves sold in the market are cheaper, they are generally of poor quality. Although these stoves meet a market demand, the Roumdé stoves set the quality 'norm' and have become a popular gift.

Of the artisanal breweries that produce beer (*dolo*) with more than a single stove and own an ICS, 85% use one or more improved stoves. It should be noted however that most brewers (57%) produce the dolo on a single stove and only 17% of them uses an ICS.

4. FAFASO is cost-effective.

To the household, buying a Roumdé stove is a profitable investment. The savings in firewood (on average EUR 1.42 monthly) enable the investment to be amortised in 2.5 to 4 months. Constructing an ICS for brewing costs approximately EUR 42. The amortisation period depends on the type of cauldrons used (clay or aluminium) and their replacement, but varies between 7 and 21 weeks.

The Energising Development programme strives to keep programme costs relatively low: preferably below EUR 20 per person provided with access to energy. FAFASO, funded through EnDev, remains far below that target, with an average cost of EUR 5 per person.

Impact

5. The use of improved stoves for cooking saves fuel wood, but 20% less than envisaged.

In both studies, the main impact indicator is the fuel wood consumption. Controlled cooking tests in which the most used improved stoves for domestic use in Burkina Faso were compared to the three-stone fire revealed that savings in wood vary from 29% to 43%. In daily practice however, the ICS are approximately 20% less efficient than indicated in a controlled cooking test, one reason being that ICS owners tend to cook more dishes (the *rebound effect*).[7] The savings are, however, significant, substantial and robust.

Breweries save on average 18% in wood (if they combine traditional and ICS stoves) and 36-38% if they use ICS only. This is less than the 60-70% savings arrived at in controlled cooking tests. The reason is that the brewer may continue to stoke the stove with large tree trunks that damage the opening to the combustion chamber and generally makes sub-optimal use of the combustion qualities of the ICS.

[7] See: IOB systematic literature review (IOB, 2013, p. 15).

6. Annually about 15,000 tons of fuel wood is saved as result of ICS usage.

By using an ICS, households save on average 3.5 kg of firewood or 1.9 kg of charcoal weekly. Given the number of stoves actually in use, this is equivalent to 2,660 tons of firewood and 1,535 tons of charcoal (firewood equivalent: 4,600 tons) per year for the two cities.

To beer brewers, using the Roumdé stove represents a saving of 42 kg of firewood per brewing. Assuming that the 2,380 ICS installed are used for brewing twice a week during 39 weeks per year, the saving is 7,700 tons of firewood annually. Adding these savings in firewood to those of ICS for domestic use, about 15,000 tons of fuel wood is saved annually. This vast volume, however, represents less than 1.0% of total annual firewood consumption in Burkina Faso.

7. Time savings are modest. Savings in expenditure are modest for domestic ICS, but substantial for ICS for brewing.

In the urban areas, households do not collect firewood but purchase it from retailers or at markets nearby, so time savings in acquiring firewood as result of owning an ICS are minimal. ICS may lead to a reduction in time spent cooking. Among the surveyed households, the average time saved in cooking the main midday or evening dish is 13 minutes, while the savings for all cooking during a day varies between 7 and 18 minutes. This saving in time is too small to expect that any alternative time use can be identified.

Only 2% of the breweries surveyed (mainly the smaller ones operating in the surrounding rural areas) collects fuel wood. There is no time saving in purchasing wood. The time used for brewing has remained unaltered, since this is determined by the fermentation process and in practice, by tradition.

To households that cook solely with firewood, the ICS implies financial savings of about 12% on fuel for cooking. This corresponds to EUR 1.42 per month, which is less than the monthly savings of EUR 5 anticipated at the start of the programme. Because the cost of fuel for cooking represents about 8% of the total household budget, the savings on firewood are only 1-2% of the total household expenditure. The saving cannot be expected to have significant implications for spending on other household budget items such as education or healthcare. Nevertheless, buying a Roumdé stove for domestic use is a profitable investment that can be amortised in 2.5 to 4 months, while the lifespan of such a stove is at least two years.

Constructing an ICS for brewing costs approximately EUR 42. The financial savings per brew are on average EUR 3.20. The amortisation period depends on the type of cauldrons used and their replacement frequency, but varies between 7 and 21 weeks.

8. The Roumdé is not designed to reduce smoke exposure. There are no significant impacts on health.

In various countries ICS have been explicitly designed to reduce indoor air pollution (e.g. by having a chimney) and hence to help reduce smoke-related respiratory diseases and eye problems, in particular among women and small children. The Roumdé stove, however, has been designed solely to save fuel wood and not to reduce smoke exposure. The combustion efficiency implies only limited reductions in the emission of hazardous particles and gases. Furthermore, most households in Burkina Faso cook outdoors and hence direct exposure to these emissions is less. The Roumdé therefore does not have a measurable effect on the self-reported health conditions of ICS users.

Sustainability

9. *Whether the markets established for improved stoves will be sustained in absence of external intervention cannot yet be ascertained.*

In addition to the genuine Roumdé stoves for domestic use, imitations are produced and sold: in Bobo-Dioulasso as many as seven times more ICS imitations than Roumdé stoves were found. Often clients do not recognise quality differences in terms of efficiency-enhancing characteristics. Imitation ICS are also fuel-efficient, albeit much less so than the Roumdé, and are offered at a competitive price (on average EUR 2.20 as compared to the Roumdé price of EUR 3.00-4.50). This makes the imitation ICS an attractive alternative for households with a smaller budget.

In urban areas, further uptake of ICS will be challenged by LPG stoves. Since many urban households use LPG already, the price of this fuel will determine whether ICS remain a serious alternative. From a clean energy perspective, in urban areas the use of LPG should prevail over the use of ICS.

1

Introduction

Since the early 1990s, access to energy – particularly to renewable energy – for the poor in developing countries has been part of Dutch development cooperation. The Ministry of Foreign Affairs' main resource envelope to facilitate access to renewable energy in developing countries has been the EUR 500 million 'Promoting Renewable Energy Programme' (2008-2013). The Policy and Operations Evaluation Department (IOB) of the Ministry of Foreign Affairs of the Netherlands has commissioned a series of impact studies on the topic of renewable energy and development cooperation[8]. These impact studies aim to provide insight into the impact of programmes funded under the 'Promoting Renewable Energy Programme (PREP)' (see Box 1).

Box 1 *Promoting Renewable Energy Programme (PREP) 2008-2013*

In 2008, the then Netherlands' minister for development cooperation announced that the Netherlands would make available an additional EUR 500 million for renewable energy in developing countries through the so-called 'Promoting Renewable Energy Programme' (PREP), with the ultimate aim of helping ameliorate poverty and reducing the negative climatic effects of energy use. The programme comprises four interlinked activities:

1. Investing directly in the production of and access to renewable energy in priority countries and regions;
2. Improving the sustainability of production of biomass for energy purposes;
3. Influencing the policy of partners responsible for investment in renewable energy;
4. Developing capacity and knowledge in developing countries with regard to renewable energy.

PREP encompasses an array of sub-funds, programmes, projects and activities. Most of these sub-funds and programmes have either been made available to special regional (or global) funds, or delegated or outsourced to third parties for administration or implementation (or both). It also encompasses energy-related Public Private Partnerships and projects by non-governmental organizations (NGOs). PREP has funded activities in over 30 countries, mostly in Sub-Saharan Africa.

An evaluation of the Dutch renewable energy policy and PREP in particular is scheduled for 2014. It will build upon the different impact studies. In 2010, various activities in Burkina Faso, Rwanda and Indonesia were selected to provide information on the effects of interventions supported by PREP. The activities selected were domestic solar energy systems, solar lamps, biogas, improved cooking stoves (ICS) and rural electrification through micro

[8] Terms of Reference impact evaluation of Energy and Development Cooperation supported by the Netherlands, Sept 2009. See the IOB website www.iob-evaluatie.nl/node/331.

hydro plants and (to a lesser extent) the generation of geothermal energy. IOB commissioned the *Rheinisch-Westfälisches Institut für Wirtschaftsforschung* and the International Institute of Social Studies to conduct the impact assessments, including one on improved cooking stoves.

Between 2005 and 2009, most Dutch contributions to the energy sector in developing countries were delegated to the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the *German Gesellschaft für Internationale Zusammenarbeit* (GIZ). The umbrella programme for the Dutch-German partnership agreement for the energy sector was Energising Development (EnDev). In 2008, EnDev became an integral component of PREP.

About 2.5 billion people in the world rely on the traditional use of biomass, mostly firewood, for cooking. Improved cooking stoves (ICS) have been promoted for decades, but renewed international attention stresses the importance of stoves as a low-cost solution to improve indoor air quality, to help reduce greenhouse gases, to relieve the daily workload of women and to reduce expenditure on energy for poor households. To date, EnDev has implemented ICS activities in about 15 countries. The ICS project *Foyers Améliorés au Burkina Faso* (FAFASO), established in 2005 and operative since 2007, can be considered illustrative for these activities.

This report presents the results of two impact studies on activities implemented by FAFASO, funded by the Dutch-German partnership Energising Development. A major objective of the FAFASO programme is to establish a sustainable market for the dissemination of improved cooking stoves for domestic and productive use. FAFASO also supports the use of ICS in social institutions (schools and health centres).

1.1 The energy context in Burkina Faso

Burkina Faso has no fossil energy resources (crude oil, gas and coal) of any significance. Approximately 83% of all energy used comes from biomass and 16% from oil. All petroleum products are imported, since the country has no oil-refining capacity. Imports amount to less than 10,000 barrels per day (2009). Energy imports, that represent 10-20% of the country's gross imports over the past ten years, are increasing. Apart from biomass, the country's national energy production is restricted to electricity generation: 73% is thermal and 27% hydro-electric. Production and distribution of electricity is largely controlled by the state-owned *Société National d'Électricité du Burkina Faso* (SONABEL), established in 1968. In 2012, 14% of all households in Burkina Faso had access to electricity (up from 8.5% in 2002).[9] There are large differences between urban and rural areas: the electrification rate is above 50% in Ouagadougou and Bobo-Dioulasso, but less than 2% in rural areas. Electricity supply is not reliable and rationing is not uncommon.

9 Sources: EnDev, 2009 and World Bank Electricity Sector Support Project, July 2013.

As is the case throughout most of Sub-Saharan Africa, the country's main energy source is biomass (wood and charcoal), providing 83% of all energy used. The Living Conditions Survey (Sagnon & Sawodogo, 2006) revealed that the main energy source for cooking for 90.7% of households was fuel wood, with a further 3.8% using charcoal. Liquid gas was used by 4.8% of the households, but almost exclusively by urban dwellers. Electricity is hardly ever used for cooking. As the population is growing, there is increasing pressure on forest resources.

The country's long-term policies on energy generation, transmission and distribution are laid down in government's key Strategy for Accelerated and Sustainable Development for 2011-2015 and the policy document *Vision 2020, De l'accès aux services énergétiques modernes* (Ministère des Mines, des Carrières et de l'Énergie, October 2007). The latter plan envisages an increase in the use of modern sources of energy by promoting both the generation and importation of electricity. However, the annual increase in these modern sources, being mainly electricity, is barely keeping up with demand caused by population growth. The policy documents state that electricity will enhance the functionality of service provision (education, health, local government, water supply), while in the rural areas an important role will be played by multifunctional service platforms.[10]

According to the policy documents mentioned above, fuel wood will remain the most important source of energy, but its efficiency will be enhanced by the dissemination of improved stoves: the penetration rate of improved stoves in urban areas is expected to increase from 17% (2007) to 63% in 2015 and 80% in 2020. The use of improved stoves in rural areas should increase from 20% to 63% by 2015 and to 90% in 2020.[11] The Strategy for Accelerated and Sustainable Development for 2011-2015 treats energy issues broadly as the need to improve access for the poor to reliable and affordable services. It also specifically states that technological development can contribute to covering household energy needs by means of anaerobic digesters to produce biogas. Priority is given to the need for electrification, modern domestic fuels and management of traditional biomass. Burkina Faso, as a member of the CILSS (the Permanent Interstate Committee for Draught Control in the Sahel) has elaborated a national strategy for household energy. The strategy is primarily oriented on managing forest resources viably, liberating the market for substitutes (gas and petrol), fiscal reform and promoting economical cooking equipment.[12]

Since 2010, two ministries have been responsible for matters relating to energy: the *Ministère des Mines, des Carrières et de l'Énergie* and the *Ministère de l'Environnement et du Cadre de Vie*. In the Ministry of Mines and Energy, *la Direction Générale de l'Énergie* (DGE) is concerned with energy issues and policies. Which of the two ministries is responsible for improved stoves remains undefined, but since 2011 they have coordinated their approaches and activities.

10 Small machinery stations for communal use. A drive shaft is propelled by a diesel generator or hybrid energy system and this power can be used to drive small equipment such as flour mill or a circular saw.

11 Vision 2020. *De l'accès aux services énergétiques modernes*. Ministère de Mines, des Carrières et de l'Énergie, Octobre 2007.

12 Vision 2020. *De l'accès aux services énergétiques modernes*. Ministère de Mines, des Carrières et de l'Énergie, Octobre 2007.

1.2 Energising Development

Origin

During the 'Energy for Development' conference (2004) organised as a follow-up to the World Summit on Sustainable Development in Johannesburg (2002), the then Netherlands' Minister for Development Cooperation announced her government's commitment to provide access to modern energy to 10 million[13] people in energy poor countries by 2015. Since Dutch development cooperation lacked experience and expertise in the energy sector, the implementation would have to depend on third parties.

The considerations reflect the development paradigm (sector-wide approach) current at that time:

- It was the Ministry's opinion that budget support to the energy sector was inappropriate, since that sector is shaped by complex relations among public and private actors;
- Co-financing with international financing institutes such as the World Bank or regional development banks was considered undesirable, since these institutions had promoted the privatisation of the energy sector and had scaled down their own investment portfolio for energy. The international development banks were not eager to enter into a co-financing arrangement for investments in energy;
- The European Commission (EC) did not have the administrative and financial procedures in place to enable co-financed worldwide programmes.[14]

A suitable candidate for the implementation of an energy programme worldwide was the German *Gesellschaft für Technische Zusammenarbeit* (GTZ; since January 2011 GIZ) that at the time was implementing small-scale energy projects in Africa and Asia. The Netherlands Directorate General for International Cooperation (DGIS) entered into an implementation agreement with GTZ in 2005. The resulting Energising Development programme (EnDev)[15] was the world's first sector-specific delegated cooperation at global level[16] and the first donor-supported programme that set a quantified outcome target at international level.

At the start of the programme, all sources for generating energy were accepted, since it was considered to be in the interest of the population of developing countries not to impose

13 The figure of 10 million persons was the outcome of downsizing a political proposal that per person in the Netherlands, one person in a developing country would be given access to energy. At that time the population of the Netherlands was 15.6 million.

14 The EC opened up its administrative procedures to accommodate delegated cooperation in 2007.

15 Since 2012, the name 'Energising Development' has also been used by the European Commission for its initiative to provide access to sustainable energy for an additional 500 million people in developing countries by 2030 as a European Union (EU) commitment within the framework of the UN Sustainable Energy for All Initiative (SE4All). President José Manuel Barroso at the EU Sustainable Energy for All Summit in Brussels, April 2012.

16 In 2009, the partnership between the Netherlands' Ministry of Foreign Affairs and GIZ was replaced by one between the Netherlands' ministry and the German *Bundesministerium für Wirtschaftliche Zusammenarbeitung und Entwicklung* (BMZ).

any restriction beforehand. In 2006, however, the explicit preference for energy produced by renewable sources was added.[17]

Activities under EnDev provide energy access to households, social institutions and small and medium-sized enterprises in developing countries in Africa, Asia and Latin America in the following four areas:

1. Energy for cooking: the establishment of self-sustaining markets for producing and selling fuel-efficient (improved) cooking stoves, tailor-made to suit the specific (local) cooking habits and the purchasing power of the targeted households;
2. Energy for lighting/household applications: the provision of modern energy for domestic lighting and small electrical appliances (for example information and communication technologies);
3. The provision of electricity for schools, clinics and hospitals and community centres, for example for keeping medicines cool;
4. The establishment of economically sustainable electricity production and distribution schemes for rural communities through for example micro-hydropower or solar systems;
5. Energy for productive use/income generation: provision of modern energy services to small and medium-sized enterprises, cooperatives and craftsmen for generating income.

The EnDev-supported energy technologies are solar energy in various forms (small off-grid systems, solar systems, productive use, water heating), hydro energy (pico, micro and small electricity generation), biogas, electricity grid extension and improved cooking stoves.

At its start in 2005, the features of EnDev were that the Dutch government granted EUR 60 million for a four-year period, while the German government made the implementation infrastructure available, as well as additional financial resources for activities in certain countries. The programme was to be deemed successful if 3.1 million persons were given access to modern energy services in a sustainable way; 60-80% of the resources were to be earmarked for activities in Africa. At the end of the first phase (2008, extended to 2009), EnDev had grown to 23 programmes implemented in 22 countries.[18]

In 2007, the government of the Netherlands presented its new development cooperation framework '*Een Zaak van Iedereen*', in which energy was an explicit priority.[19] For the years 2008-2011, EUR 500 million was budgeted for renewable energy for development programmes. The ultimate goal of this investment was to contribute to poverty reduction

[17] Source: Ministry of Foreign Affairs, DMW and FEZ. *Kader voor Output-doelstelling*. April 2006.

[18] The precise number of countries varies from year to year. In 2013 EnDev was being implemented in 18 countries: Bangladesh, Benin, Bolivia, Burkina Faso, Burundi, Ethiopia, Ghana, Honduras, Indonesia, Kenya, Mali, Mozambique, Nepal, Nicaragua, Peru, Rwanda, Senegal and Uganda.

[19] Ministry of Foreign Affairs, 2007, Note: *Een Zaak van Iedereen: Investeren in ontwikkeling in een veranderende wereld*. TK 31250, nr.1, 16 October 2007.

and to reduce the negative effects of energy use on climate.[20] This 'Promoting Renewable Energy Programme' (PREP) also encompassed the EnDev 2 Partnership Agreement for the period 2009-2012 (later extended to 2013).[21] EnDev 2 anticipated that of an additional 3 million people would benefit from the programme. Initially, EnDev 2 was funded by DGIS and BMZ, but over time other donors and financiers joined in (the Norwegian Ministry of Foreign Affairs; the Australian Agency for International Development; the UK Department for International Development; and the Swiss Agency for Development and Cooperation). Additional contributions to country projects are made by the ACP-EU Energy Facility and Irish Aid. By 2013, the total budget amounted to EUR 185.8 million, which at a benchmark cost of EUR 20 per person brings the overall EnDev goal to around 14 million people. Since 2005, EUR 245.8 million has been committed to the programme. EnDev is scheduled to run until December 2018.

Table 1 Budgets for phases 1 and 2, Energising Development

	EnDev 1	EnDev 2	Sum
Year commissioned	2005	2009 plus post EnDev2 commitments	
Budget (in million EUR)	60.0	185.8	245.8

Source: IOB summary, based on http://endev.info/content/Results_in_Numbers (Viewed 23 September 2013).

The approach

Since 2005, EnDev has been developing new markets for pro-poor energy access and upscaling successful programmes with a broad spectrum of technologies and a variety of instruments. EnDev's particular feature is a competition-based cost-efficiency benchmark approach for implementing the projects. In its search to ensure sustainable energy solutions, EnDev considers it essential to provide energy technologies at a price affordable to the target population. It also strives to keep the programme cost relatively low, namely below EUR 20 per beneficiary. The introduction of these technologies is market-driven, so the solutions may differ from country to country. EnDev projects implement additional components such as awareness-raising campaigns, vocational training and assisting entrepreneurs to start energy-related businesses. Among other things, this entails providing information, technology transfer, technical assistance and capacity building. In certain cases EnDev provides subsidies to kick-start markets or buy down capital investments, but it never pays operational costs.

20 Ministry of Foreign Affairs, DMW, 2008, Policy note *Milieu en hernieuwbare energie in ontwikkelingssamenwerking*, July 2008.

21 Memorandum of Understanding, signed by the Dutch Minister of Development Cooperation and the German State Secretary of the *Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* (BMZ), and operationalised through a Partnership Agreement with the *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ, since 2011 GIZ). BMZ is the leading partner in this worldwide programme, with the Netherlands initially as 'silent partner'. After more financing partners joined in, the organisational structure changed to a Board comprising the main financing partners, with the Netherlands and Germany as joint 'executive entity'.

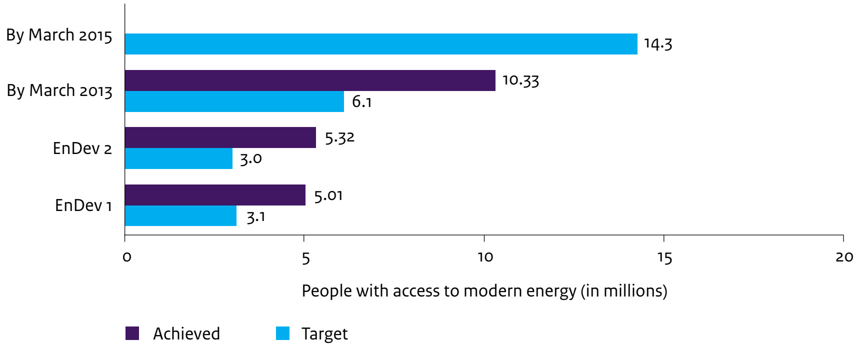
A strategic component of the EnDev approach is the assistance to energy policy and strategy development at various levels in both public and private sector domains. This may encompass technical support to ministries or energy agencies and support services to energy suppliers and distribution companies as well as to associations of energy businesses. This strategic view also implies EnDev's active involvement in international initiatives, such as:

- The Global Alliance for Clean Cookstoves;
- Lighting Africa;
- The Africa Electrification Initiative;
- The UN Sustainable Energy for All (SE4All) initiative, especially the discussion on energy access definitions, i.e. the SE4All global tracking framework.

The results

EnDev has become an acknowledged and leading actor in the area of renewable energy in developing countries. Its activities are subject to permanent monitoring and evaluation[22] and the combination of policy support and market development has contributed to transformative changes in the renewable energy sub-sector in countries such as Bangladesh (solar systems), Peru and Kenya (improved cooking stoves) or Senegal (mini-grids). During both EnDev 1 and EnDev 2 the programme far exceeded the quantitative targets set. According to its own monitoring system, by March 2013, the programme had achieved the milestone of providing 10 million persons with access to energy. In addition, more than 11,600 social institutions and 24,300 enterprises obtained access to modern energy services.[23]

Figure 1 *Targets and achievements of Energising Development*



Source: Energising Development monitoring system.

[22] Since the start of EnDev, GIZ has contracted the services of the implementation agency of the Netherlands' Ministry of Economic Affairs, AgentschapNL, for monitoring and evaluation.

[23] The EnDev counting system is conservative as compared to the standard measurement frame adopted in 2013 by the Sustainable Energy for All (SE4All) initiative.

1.3 FAFASO

The EnDev programme in Burkina Faso is exclusively dedicated to fuel wood usage and encompasses improved cooking stoves (ICS) and, more recently, charcoal production. Although several types of ICS have been promoted in Burkina Faso since the 1970s (with strong government support during the 1980s), the production/construction knowledge was not sustainable, and when the programme *Foyers Améliorés au Burkina Faso* (FAFASO) was established in 2005 (starting up in 2007), there was neither production capacity nor a market structure for improved stoves.

The main objective of FAFASO is 'to provide access to modern cooking technologies to the urban and rural population with the aim to reduce the pressure on wood energy'.[24] Table 2 presents the key characteristics of FAFASO. Through FAFASO, EnDev supports the development of a market in which households autonomously decide to buy a stove at a price that they can afford and that is sufficiently profitable to enable the producer to continue offering the product. The programme also focuses on efficient fuel wood use solutions for cooking in social institutions (for example schools) and processing agricultural produce (for example shea butter, beer brewing).

Table 2 Key characteristics of FAFASO

Name of the intervention	*Foyers Améliorés au Burkina Faso* (FAFASO)
Implementation period	2006-2013
Implementing partners	Government institutions, producer associations, NGOs, *Institut de Recherches en Sciences Appliquées et Technologies* (IRSAT)
Project budget	EUR 2.8 mln (EnDev 1 + 2)
Promotion of technology	Improved stoves; charcoal production
Target for domestic ICS use	565 000 persons
Target for productive ICS use	4500 Small and Medium Enterprises (beer brewers and shea butter producers)
Target for social institutions ICS use	450 institutions

Note: Data do not include additional funding and amended targets (2012).

An important difference between EnDev and earlier ICS promotion programmes in Burkina Faso is that FAFASO does not provide direct price subsidies but instead only supports training of producers (whitesmiths and potters), the establishment and organisation of producer associations, the advertisement campaigns and awareness raising, and the organisation of quality assurance. To achieve quality assurance and easy recognition in the market, a special label has been introduced for the ICS: Roumdé, which means 'the

[24] GIZ Factsheet Burkina Faso, 2011.

preferred' in the national language Mooré. The label, a red humanised smiling stove (see photo 1), is used consistently in all marketing channels, including retail points and TV commercials.

Photo 1 *ICS Roumdé label*

The FAFASO activities developed are, among others:
- Training ICS producers in technical and marketing skills;
- Supporting the self-organisation of ICS producers in associations;
- Supporting the marketing campaigns of producer associations (including media-based marketing);
- Developing the product and production concept for ceramic stoves (for rural areas);
- Establishing and strengthening a quality control system;
- Launching publicity campaigns for ICS and informing people about the disadvantages of charcoal;
- Product rationalisation, and introduction of more effective carbonisation methods.

This approach has various advantages, among them keeping the investment component relatively low; the project is very cost-efficient. Although PREP is based on an average cost of EUR 50 per beneficiary (EUR 500 million to provide access to energy to 10 million persons), the Energising Development programme strives to keep the programme cost far lower, at EUR 20 per beneficiary. Within the portfolio of EnDev, FAFASO's costs are even below that target, being less than EUR 5 per beneficiary.

The preferred fuel of the urban middle class is charcoal. It is less bulky and hence more convenient to handle than fuel wood. The charcoal sector in Burkina Faso is well organised, with controlled transport within and among the regions, and controlled production sites. From an ecological perspective the sector would benefit from the introduction of efficient charcoal production technologies. This report however, is limited to the evaluation of improved stoves and does not encompass EnDev activities related to charcoal. With that restriction in mind, the FAFASO activities can be subdivided by type of product/use: (1) stoves for domestic use in urban areas; (2) stoves for domestic use in the rural areas (and the urban periphery); and (3) stoves for productive use or for use by social institutions.

Stoves for use by urban households

Between 2006 and 2011, FAFASO restricted its activities to the promotion of portable domestic stoves in the two largest population centres of the country: Ouagadougou and Bobo-Dioulasso. With 1.6 and 0.5 million inhabitants respectively, the two cities account for about 15% of the country's total population. The stoves selected to bear the Roumdé label were locally developed ones of a simple design and robust quality, with sound fuel wood-saving characteristics. Three metal stoves were found suitable for domestic use: the *Ouaga Métallique*, the *Burkina Mixte*, and the *Multimarmite* (the latter is the most popular Roumdé stove: see Figure 2). The ceramic stove is for use in rural areas.

Figure 2 *FAFASO-improved cooking stoves*

Improved cooking stoves ('Roumdé')				
	Ouaga Métallique	Burkina Mixte	Multimarmite	Céramique
				
Material	Metal	Metal	Metal	Clay
Fuel	Firewood	Firewood or charcoal	Firewood or charcoal	Firewood
Price (2012)	1500-2500 CFA	1500-2500 CFA	2000-3500 CFA	750 CFA

Source: IOB. Photos: FAFASO.

The *Burkina Mixte* and the *Multimarmite* can be used with firewood or charcoal, but the *Ouaga Métallique* operates with firewood only. These stoves were developed in the 1980s by IRSAT.[25] The Roumdé stoves have been designed to save wood, but not explicitly to reduce smoke emission. Unlike some stove models used in Latin America and Asia, the Roumdé models do not have a chimney. Any smoke reduction that does occur results from more efficient combustion. IRSAT determined the fuel efficiency gains in 'controlled cooking tests' conducted in the field laboratory tests, in which local women cooked typical meals under day-to-day conditions, using different stove types. These tests were conducted with traditional three-stone open fire stoves as control (counterfactual). They revealed that the savings in wood are 29% for the *Multimarmite*, 35% for the *Burkina Mixte* and 43% for the *Ouaga Métallique* (Sanogo, 2008).[26] The cost of the stoves ranges from 2,000 to 3,500 CFA F (equivalent to EUR 3-5) and their lifespan is approximately two years. Cheaper stoves similar to the Roumdé stoves are available at the market, but they do not carry the Roumdé label

[25] At the time called '*Institut Burkinabè de l'Énergie (IBE)*'.

[26] There is no internationally recognised standard to label a stove as 'improved'. In practice, however, it is common to require that an 'improved' stove should save at least 40% of the fuel in a field test compared to a three-stone fire place and/or considerably reduce the indoor air pollution (Owsianowski and Barry, 2008).

since they do not exhibit all the quality features. Popular are the metal Malagasy stoves (*Fourneau Malgache*) used mainly as charcoal burner to heat water and to cook small meals.

Compared to other ICS that are promoted internationally, the Roumdé ICS perform at the lower end of the fuel efficiency spectrum, because they are uniquely made of metal and lack components that retain heat, such as a ceramic inner part. In addition, the Roumdé ICS do not improve the combustion process in a way that substantially reduces the particulate matter or carbon monoxide emissions. Internationally, there are technologically more advanced biomass stoves that may reduce these emissions to zero. The Roumdé stoves, however, are adapted to the cooking habits and purchasing power of the majority of the population in Burkina Faso.

FAFASO has a market development strategy based on engaging the producers and serving their interests. Two hundred small-scale producers of the metal stoves have been trained in technical and marketing skills. About half of them have been trained outside the two cities, in around 30 towns throughout the country. In line with the German Country Strategy for Burkina Faso at the time, the further marketing support to these producers has been geographically concentrated and not spread out all over the country. Out of the total group of stove producers, about 150 have been organised in producer associations. FAFASO strengthens these associations through publicity and awareness-raising campaigns. In the two large cities a commercial structure for marketing has been established (including, among others, specialised retail outlets). By 2013, this commercial structure was being run autonomously by the producers' associations, which had also taken over the quality control from IRSAT.

Photo 2 *'Multimarmite' stoves for sale. Real or imitation Roumdé?*

Photo: Jolijn Engelbertink.

For the impact evaluation of the ICS in the urban context, see Chapter 2.

Stoves for use by rural households

EnDev 2 developed separate plans for the promotion of improved stoves in small towns and rural areas. Activities were initially concentrated in towns in the expectation that from there the ICS would spread out and penetrate the surrounding villages. Since households in the urban periphery and rural areas use a different kind of stove, in 2008 FAFASO integrated ceramic stoves into its activities, followed in 2009 by fixed mud stoves. The Roumdé ceramic stove can achieve the same fuel efficiency, but is cheaper than the metal stove (Figure 2). It serves rural populations and is virtually unknown in the urban context. Since early 2009, some 250 potters have been trained to make improved ceramic stoves in three regions: the Centre (around the capital), the South-West and the East.

In the past, projects dealing with improved stoves in the rural areas relied heavily on fixed mud stoves. Since these stoves were constructed from locally available material and could be built by a member of the household, they were considered to cost nothing. During the 1980s, the Burkina Faso government counted on there being a snowball effect, assuming that trained stove builders would transfer their knowledge to their neighbours and family. Although at the time over 80% of the villages had households with mud stoves, these stoves are no longer to be found. By 2012, FAFASO was uncertain whether or not to continue to promote mud stoves, since the appropriate construction material cannot be found everywhere, and the sustainability of the construction skills had proven to be disappointing. This report does not contain an impact evaluation of ICS in rural areas, since at the start of the evaluation (2010) this programme component was considered too new for its impacts to be assessed in 2012.

Stoves for use by social institutions or for productive use

Portable metal stoves can be constructed in larger sizes for use by restaurants, in school canteens, boarding schools or community centres. Since 2007, approximately 6,000 of these large stoves have been sold. For facilities in the rural areas (such as boarding schools) the large metal stoves (costing approximately EUR 40 each) are considered to be too expensive and so modified mud stoves are installed instead. Since 2013, FAFASO has also been equipping health centres with improved stoves, since these serve as showcases for clean kitchens and may inspire users (patients or family members who cook in the kitchens) to start using an ICS at home. FAFASO supplies these social institutions with large models of metal or mud stoves, since these devices are not available on the market.

In most cases, stoves for productive use are product-specific. Industries that are major consumers of fuel wood are those producing shea butter (extracted from the fruit of the Karité tree), cracking cashew nuts, or manufacturing bricks (see Box 2). The traditional beer brewers, *dolotières*, are the largest consumers of fuel wood in the urban centres. Although estimates vary, data from elsewhere in Africa suggest that breweries consume between 10% and 20% of the total urban volume of firewood turnover.

Box 2 *Stoves for productive use*

Special stoves for productive use have been developed and commercialised. FAFASO commissioned IRSAT to conduct tests on these improved stoves for the shea butter industry and cashew nut production, as shea butter has become an important export product of Burkina Faso (for the cosmetics and chocolate industries in Europe and the United States). In most shea butter producing regions, the Karité trees are planted and protected, but since the processing requires much fuel wood (to toast the nuts and to boil the emulsion later in the process), it exhausts the wood resources in the regions concerned, and leaves a monoculture of Karité trees. Since the shells of the shea nuts are a good fuel, some semi-industrial production units in Bobo-Dioulasso use them for this purpose. Since 2013, FAFASO has been training masons in Koudougou (*Centre-Ouest*), Manga (*Centre-Sud*) and Bobo-Dioulasso to construct stoves for shea butter producers.

Fuel-efficient techniques are being similarly tested and developed for cashew transformation. The cashew shell contains prussic acid, which can be removed by heating the cashew in the shell. Comparable tests are being conducted on néré fruits, which are used to produce soumbala, a yellow condiment used in many African dishes. These stoves are being developed in collaboration with producers' associations.

The approximately 3,500 local (female) artisanal beer producers (*dolotières*) in Ouagadougou and Bobo-Dioulasso are large consumers of fuel wood. In urban areas, breweries are typically located in backyards and have one or more stoves, additional cauldrons and barrels to stock raw materials, intermediate outputs, residuals and the final product, the *dolo*. Wood is stocked at the side or outside the yard. The woodpiles can be large, since most breweries purchase wood for several brewings at a time. In rural areas the stoves are often not in private yards but in a public space, typically a central square. On average, beer brewers brew twice a week, each time preparing around 120 litres of dolo. The 'traditional improved' mud stoves are built by professional builders, whereas the brewer herself has to supply the raw materials (argil, sand, water). Prices depend on the number and size of pots to be integrated into the stove, and vary between EUR 8 and EUR 30. Since mid-2008, FAFASO has trained stove builders to construct beer stoves in five regions, but has focused further support on Ouagadougou and Bobo-Dioulasso.

IRSAT has developed special mud stoves for breweries that may achieve economies of up to 80% compared to the traditional three-stone stove and 50% compared to the 'traditional improved' stove models. The improved Roumdé stoves for breweries are made of clay and bricks rather than metal. The stoves are fixed and comprise between two and five cauldrons (different sizes exist), the so-called *marmites* (if made of aluminium) or *canaris* (if made of clay). Aluminium is more widespread in Ouagadougou and clay in Bobo-Dioulasso. At the front of the stove is the opening to the combustion chamber through which the firewood is loaded, typically using entire tree trunks that are gradually fed into the oven. A Roumdé for brewing costs about CFA F 27,500 (or EUR 42) without the cauldrons. Aluminium cauldrons are in fact more expensive than the Roumdé itself and much more expensive than clay cauldrons, but they also have a longer lifespan. Cauldrons made of clay often crack if the stove is overheated. Aluminium cauldrons may melt, but this happens very rarely. Changing the cauldrons of a Roumdé is considered to be expensive, since the top of the stove (the upper mantle) needs to be broken open. For that reason some *dolotières* switch from clay cauldrons to aluminium ones when buying a Roumdé.

The installation of the improved stoves was accompanied by awareness-raising campaigns among *dolo* producers and by the installation of test stoves in breweries where the *dolotières* had a model or leader role (‘*femme leader*’).

Box 3 *Dolo*

Brewing *dolo* is a tradition: the formula and the art are passed from one generation to the next. Brewing is exclusively done by women (the *dolotières*), typically Christian or animist, since Muslim women are not allowed to make alcohol. *Dolo* is made from sorghum or millet (both drought-resistant crops) that is crushed and ground into paste, the malt. Water is added to the malt and the mash is cooked for up to two days. By adding yeast for fermentation, the alcohol is produced. The beer is low in alcohol (2-4%) and can be kept for one to two days only.

When the *dolo* is ready, the women fill big plastic barrels with the beer, which is sold directly to customers or – only in Ouagadougou – to retailers. Most *dolotières* have a so-called *cabaret*: typically some benches in a shady spot outside the courtyard, where customers can sit. Usually, the *cabaret* scene is one of socialising while drinking *dolo* from a *calabashe* (half a calabash shell). Drunkenness is rare and perceived as socially unacceptable behaviour. For take-away the breweries usually use empty soda bottles or plastic containers. A litre bottle of *dolo* is sold for about CFA F 150 (EUR 0.23), only a quarter of the price of ‘modern’ industrial beer.

Chapter 3 presents the evaluation of the ICS for productive use, particularly by brewers.

1.4 Evaluation questions

The evaluation of ICS in Burkina Faso is one in a series of IOB commissioned impact assessments in the area of renewable energy activities. The central research question for these evaluations is: ’What have been the effects – positive or negative, intended or not – on living conditions of target groups of the energy and development cooperation programmes and projects supported by the Netherlands and how sustainable are the results achieved?'[27]

The interventions in the energy sector in Burkina Faso to be evaluated were selected in 2010, based on the application of (among others) the following predetermined criteria:

(i) the policy relevance of the activity to Burkina Faso;
(ii) the number and relative concentration of the installations and/or beneficiaries (including the geographical distribution over rural and urban areas);
(iii) the mix of actors;
(iv) the feasibility of applying quantitative impact assessment methods.

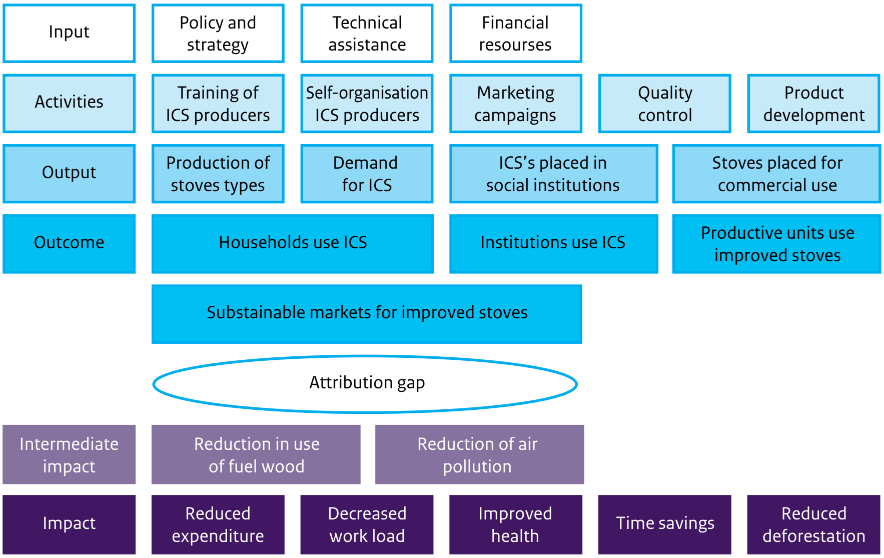
The two interventions identified for impact evaluation were FAFASO and the solar energy programme Yeelen Ba.[28] This selection was endorsed by the Burkinabè authorities and the implementing agencies.

The activities of FAFASO are restricted to the development of a market for ICS, hence the output of the programme is that ICS are actually being produced and sold. The outcome is whether households or productive units actually buy and use the stoves.

An important impact indicator is the reduction in wood fuel consumption. The rationale is that because the stoves have higher combustion efficiency, less wood fuel is used and thus less wood fuel is purchased or collected, which alleviates the pressure on scarce wood reserves. Reduced wood fuel consumption may lead to various impacts at household level, such as savings on expenditure and time, reduced workload, and improved health conditions. Having established that a household has reduced its consumption of wood energy, it is justifiable to assume that smoke emission has also diminished and that this has had a positive effect on health. Figure 3 presents the results chain graphically. This results chain is only partly valid for the case of ICS for productive use. By reducing expenditure on fuel, the ICS may help improve the profitability of the brewing process. For both the domestic and productive ICS it holds that the anticipated savings in the use of wood energy help slow down deforestation. Since women are generally primarily responsible for cooking in the household, in the study on ICS for domestic use, information and data have been disaggregated by gender. Since *dolo* brewing is almost exclusively done by women, and women also market the beer, specific gender disaggregation was not necessary in the evaluation of the ICS for productive use.[29]

[27] Framework Terms of Reference impact evaluation of Energy and Development Cooperation supported by the Netherlands, Sept 2009.
[28] The findings of the impact study of the solar energy activities will be published in 2014 at www.iob-evaluatie.nl/node/331.
[29] Only three of the respondents were male.

Figure 3 *Results chain for FAFASO*



Source: IOB.

The evaluation questions have been derived from the theoretical results chain presented in Figure 3. For both studies these have been grouped together as follows:

Outcome

- Who (gender-specific) in the household made the decision to buy an ICS?
- How many households/*dolo* brewers own an ICS? How many use the ICS and how frequently do they use it?
- Which socio-economic groups own and use a domestic ICS?

Impact

- How much fuel wood is effectively saved per meal per household)/per litre of *dolo* (taking into account cooking behaviour)?
- What is the effective use (per week or month) of the ICS, taking into account simultaneous use of other stoves and LPG?
- How much firewood is saved in total (per time unit)?
- What are the time savings of persons (m/f) responsible for fuel wood provision? How is the freed-up time used?
- What changes have occurred in household expenditure on energy in total and on cooking energy in particular? How are these savings being used?
- What are the changes in health-related outcomes (symptoms of respiratory disease, eye infections)?
- What (if any) are the unintentional or negative impacts?

Sustainability

- What is the technical sustainability of the ICS (either domestic or for brewing)?
- Is the market for improved stoves likely to last once FAFASO withdraws its support? Can uptake of improved stoves be further expanded for both domestic and productive use?

2

Improved cooking stoves at household level

2.1 Introduction

This chapter presents the impact assessment of the FAFASO programme on improved stoves for domestic use.[30] FAFASO does not disseminate ICS directly, but supports the development of a self-sustained market by providing training to whitesmiths and assisting them to procure raw materials that enable them to produce ICS that meet the quality standards set for the Roumdé label. FAFASO also trains wholesalers and retailers and invests in awareness campaigns and marketing to distribute these stoves in the two major cities of Burkina Faso: Ouagadougou and Bobo-Dioulasso. In the period from the start up to the baseline study of the evaluation in 2011, FAFASO helped establish a market in which about 107,000 stoves were sold, reaching well over half a million persons.

As indicated in the systematic literature review (IOB, 2013), what is known about the impact of improved cooking stoves at household level is mainly limited to the related indoor air pollution and its consequences on human health. Findings from rigorous studies conducted mostly in Latin America reveal substantial health benefits if improved stoves are used for cooking (e.g. Smith-Sivertsen et al., 2009; Masera et al., 2007; GIZ, 2011). More recently these findings have been challenged by other researchers, based on randomised control trials in India (Hanna et al., 2012) and Ghana (Burwen and Levine, 2012) which have not found lasting health impacts or substantial reductions in use of fuel wood.[31] Crucial in identifying impacts of ICS is the behaviour of the households that acquire the stoves. Cooking tests under fully or partly controlled circumstances do not adequately reflect the results obtained in real life. The impact study presented below was intended to avoid this limitation.

2.2 Methodology

In the absence of sound baseline data and considering that in 2010, when the impact research was being planned, the FAFASO urban ICS component had already been operating for over three years, a cross-sectional approach was used (see Annex 2). Outcomes for the 'treated group' (the ICS users) were compared to a 'control group' of similar households not using an ICS. Ideally, control households should be identical to the treatment households, except for not owning an ICS. The assumption is that if they had not acquired an ICS, the ICS users would have acted like ICS non-users. In order to substantiate this assumption, multivariate regression techniques were combined with matching processes to control for all observable differences between the two groups that could be of importance in

[30] This chapter summarizes the research commissioned by IOB and conducted by Gunther Bensch, Michael Grimm, Katharina Peter, Jörg Peters and Luca Tasciotti (2013) 'Impact Evaluation of Improved Stove Use in Burkina Faso – FAFASO'. March 2013. Rheinisch-Westfälisches Institut für Wirtschaftsforschung, Essen, Germany. International Institute of Social Studies, Erasmus University, Rotterdam, the Netherlands.The report is available at the IOB website: www.iob-evaluatie.nl/node/331.

[31] Although both studies claim to reflect 'real life' circumstances, in literature doubts have been expressed. In the case of Hanna et al. (2012), the low take-up of the randomly distributed ICS may not simulate the actual adoption pattern (Grimm & Peters, August 2012).

influencing potential impacts, such as educational background and income. Unobservable factors such as being aware of smoke-related problems or an intrinsic tendency to save on wood fuel might pose a problem insofar that they are correlated with both ownership of an ICS and the outcomes of interest. The possible existence of such unobservable factors was scrutinised by qualitative interviews with key informants and with ICS-owning and non-owning households. In total 1,473 households were surveyed in Ouagadougou and Bobo-Dioulasso between January and March 2011.[32]

Based on projected FAFASO dissemination figures at the start of the programme, a penetration rate was assumed of between 5% and 20% of households in Bobo-Dioulasso and Ouagadougou. In practice however, this proved to be an overestimate: fewer households actually owned an ICS. According to the predetermined sampling plan, a fixed number of interviews would be conducted in each city sector, but the researchers soon realised that this would yield too many households without an ICS and insufficient households with an ICS. It was therefore decided to augment the 1,158 randomly sampled households with a targeted sampling of ICS users, to ensure a balanced comparison between owners and non-users. For every third household surveyed without an ICS, an additional interview was conducted with an ICS-using household from the same sector.[33] The household without an ICS was nonetheless interviewed, but using a short questionnaire only. Hence, the full sample of 1,473 households comprises two subsamples: (1) a *representative sample* comprising all sampled households excluding the deliberately oversampled ICS users, (2) an additional sample of ICS owners. In order to ensure the findings were representative, weighting factors computed on the basis of the representative sample were applied throughout the analyses (Table 3).

Table 3 Composition of survey population

Sampling	Representative sampling				Over-sampling	Total
Sampled households	ICS non-owners		ICS owners	**Total** (representa-tive sample)	ICS owners	
Questionnaire	Long	Short	always long	long and short	always long	
Ouagadougou	568	240	76	884	248	1,132
Bobo-Dioulasso	172	67	35	274	67	341
Total *(long questionnaire sample)*	740	-	111	-	315	1,166
Total *(full sample)*	740	307	111	1,158	315	1,473

Source: Improved Stove Dataset 2011.

32 For a more elaborate overview of the methodology, identification strategy and sampling techniques used, see the report on FAFASO ICS for domestic use (Bensch et al., 2013) at www.iob-evaluatie.nl/node/331.

33 A sector is the lowest administrative unit in urban Burkina Faso.

2.3 Adoption

Prior to examining the impact of ICS on variables such as fuel wood consumption, time use or health, it is necessary to look more closely at the dissemination of and adoption of improved stoves.

Which socio-economic groups own an ICS?

The socio-economic characteristics of the sampled households show that on average the households had 6.5 members, a third of whom were below the age of 15. Some 82% of all households were headed by men, who were on average 46 years old. About 67% of all household heads belonged to the ethnic group of Mossi, the dominant group in Ouagadougou. Over 40% of the household heads had not had any formal education. Only 32% of all household heads had had secondary schooling or more. About 48% of all household heads were independent workers, mostly informally self-employed, while 13% were employed in the public sector. The monthly per capita household expenditure was about 24,350 CFA F, which is equivalent to EUR 37 a month or EUR 1.25 a day at market exchange rates. About a quarter of the households were living in houses built of clay, half the houses were built of concrete, and 68% of the households had electricity. Summing up: the surveyed areas are characterised by households with a low degree of education and low level of income, for which an ICS (at a cost of EUR 3.00-4.50) can be expected to be an expensive asset.

Users and non-user households did not differ in terms of general demographic characteristics, but did show significant variation in characteristics such as education and living conditions. On average, ICS owners had a higher level of education, more often lived in brick or concrete houses and more often had access to electricity. ICS owners were more likely to be employed in the public sector. Although these characteristics are related to household income, the difference between ICS owners and non-owners in monthly household expenditure per capita is relatively small: 11-12%.[34]

When correlations were determined in a multivariate setting, i.e. a number of factors were simultaneously controlled for, four factors were found to be significant for the ownership of an ICS:

(i) the sex of the household head;
(ii) the education of the household head's spouse (often the person who does the cooking);
(iii) access to electricity;
(iv) the person said to take decisions on expenditure (specifically, the case in which the head of the household and spouse consider themselves as being jointly responsible for the household budget) (see Annex 1, Table A1).

[34] See: www.iob-evaluatie.nl/node/331, Bensch et al. (2013), Table 4.

Although the penetration rate for Ouagadougou is very similar to that for Bobo-Dioulasso, differences emerge when data are disaggregated by per capita household expenditure quintiles. In Ouagadougou, the penetration rate increases per expenditure quintile, while in Bobo-Dioulasso the expenditure quintile seems to be hardly important (ranges between 10.7-11.7%) apart from the lowest quintile. The robustness of these results was checked by computing ICS ownership rates by asset index quintiles, which is another proxy for income that is widely used in the literature. The asset index is based on the reported ownership of a large number of assets other than cooking devices and is determined using principal component analysis.[35] Similar to expenditure per capita, a clear gradient is discernible, except for the second quintile (see Table 4). It can be concluded that ICS ownership increases with asset ownership.[36]

Table 4 Distribution of ICS owners and non-owners, in percentages

		Quintiles					Total
		1	2	3	4	5	
Total (N=1,166)	By per capita expenditure quintile	6.3	8.3	9.5	12.3	11.5	9.6
	By asset quintile	7.7	6.3	9.3	11.7	12.9	9.6
Ouagadougou (N=892)	By per capita expenditure quintile	6.5	7.8	8.6	11.6	13.0	9.5
	By asset quintile	7.6	5.5	9.7	11.7	13.1	9.5
Bobo-Dioulasso (N=274)	By per capita expenditure quintile	4.4	11.0	11.7	10.7	11.7	9.9
	By asset quintile	8.4	7.1	11.0	8.2	14.9	9.9

Source: Improved Stoves Dataset 2011.

Note: Representativeness is ensured through reweighting, i.e. results are representative for the population in both cities (except the top-end neighbourhoods). Quintiles are specific for both locations. Expenditure refers to per capita total yearly household expenditure and includes expenditure on food (whether consumed at home or in restaurants), clothing, health, energy, rent, telecommunication, transportation, education, ceremonies and remittances sent to other households. Consumption of self-produced food is not included in the aggregated expenditure because it is low in an urban setting. The asset indicator has been computed using information about the ownership of a bicycle, a scooter, a car, a house, a fridge, an air-conditioning system, a fan, landline phone, a mobile phone, a dvd player, a black–and-white television, a colour television, a personal computer and livestock.

Who (gender-specific) in the household made the decision to buy an ICS?

Whereas decisions on household spending are generally made by men, in two-thirds of cases the decision to buy the ICS was made by the female spouse or female head of household. Only in 12.6% of the cases had the male head of household decided to buy the

[35] See e.g. Filmer and Pritchett (1999 and 2001) and Sahn and Stifel (2000 and 2003).

[36] However, this higher correlation is partly driven by the fact that the asset index cannot be expressed in per capita terms but is measured in per household terms.

Roumdé ICS. A particular feature of the ICS is that it had often been given to the family as

a gift by persons who were not part of the household. Choosing to give the Roumdé probably has to do with it having a higher price than other wood-burning stoves: a gift should be of quality.

The main reason given by ICS owners for buying an ICS was quick cooking. Fuel savings were the second most often mentioned motive, followed by smoke reduction, the cleanliness of the kitchen and the stove's portability. This ranking holds both for the Roumdé ICS as well as for imitation ICS. The main difference between the Roumdé and its imitations rests in the appreciation of the attractiveness of the stove. The Roumdé is appreciated for its beauty. Of the households that had deliberately decided against buying an ICS, most (60%) stated that the reason was that it is too expensive compared to the current alternative. Whereas households usually pay on average 1,400 CFA F for an imitation ICS (the range was from 1,000 to 2,000 CFA F), a Roumdé stove is twice as expensive, with prices ranging between 2,000 to 3,500 CFA F. Further interviews revealed that the households that considered the ICS to be 'too expensive' compared prices only and were wholly or largely unaware of the fuel-saving benefits of the Roumdé stove.

2.4 Effectiveness

FAFASO was not the first programme on ICS in Burkina Faso. Previous programmes, most of them with strong government support, did not sustain over time. In fact, at the start of the programme, households were rather reluctant regarding ICS. There was no real demand for the product.

FAFASO did not distribute ICS, it provides training: to whitesmiths, for the production of metal stoves for domestic use in urban areas; to potters, for the production of ceramic stoves for domestic use in rural areas; and to bricklayers, so they can build large fixed stoves for productive use. It also assists in acquiring raw material for quality stoves, assures quality through certification and the entitlement to use the Roumdé label, it provides promotional material and organises awareness campaigns.

FAFASO has been successful in its approach to develop a market for ICS. The training of whitesmiths has led to the capacity to produce large numbers of ICS locally that are adapted to the Burkinabè circumstances and preferences. It is this adaption to preferences and purchasing capacity in combination with the awareness campaigns that has renewed interest by clients and hence has contributed to a growing demand for ICS. The stoves for domestic use are being traded and retailed. The quality control initially managed by the programme has been taken over by the producer associations. Currently, the Roumdé stove sets the quality standard, has become a popular gift and is being imitated.

Photo 3 *Animation and sales of Roumdé stoves for domestic use at the market*

Photo: Eric Mai, 2010.

How many households own an ICS? How many use the ICS and how frequently do they use it?

During EnDev 1 (2005-2009), FAFASO was implemented solely with Dutch and German financial resources. During that period over 68,000 ICS were sold for domestic use, thereby reaching 550,000 people. During the EnDev 2 phase, another 39,500 stoves were produced and sold in Ouagadougou and Bobo-Dioulasso up to the first quarter of 2011, which was when the evaluation began. Additional resources were subsequently made available to FAFASO and the initial target for EnDev 2 of 300,000 persons to benefit from ICS (see Table 5) was raised to 500,000. Since 2012, FAFASO has been gradually phasing out its support to producers in the two major cities and extending its activities into peri-urban and rural areas.

Table 5 **Realisation of targets set by FAFASO**

Phase	Objective		Realised		Project budget in EUR
	ICS ownership	Persons	ICS ownership	Persons	
EnDev 1	39,500	265,000	68,208	550,635	1.3 mln
EnDev 2	Not defined + 450 institutions + 4,500 productive users	300,000[a]	39,492[b]	Not defined	1.5 mln
Total		565,000	107,700		2.8 mln

Source: FAFASO monitoring system, March 2012; EnDev Progress Report 2012.

Note a: For the EnDev2 phase FAFASO assumes an average household size of 7.8 persons in Ouagadougou and of 6.8 in Bobo-Dioulasso. However, census data of 2006 reveal that an average household in urban areas in Burkina Faso comprises 5.0 persons (Sagnon & Sawodogo, 2006). The IOB survey suggests an average household size of 6.5 persons in Ouagadougou and of 6.8 persons in Bobo-Dioulasso. This implies that FAFASO has overestimated the number of persons in Ouagadougou by approximately 20%.

Note b: up to the end of the first quarter 2011.

The IOB survey data indicate that about 9.6% of all households in the surveyed areas of Ouagadougou and Bobo-Dioulasso own an ICS. The figures for the entire urban areas may even be slightly less, because the group with the highest income is not targeted by the project and was therefore not sampled.[37] In households with an ICS it is either the only stove or is owned together with other types of stove, such as LPG stoves. Among the ICS users, 17% regularly use the three-stone system as well, while 27% use the Malagasy stove frequently in addition to the ICS. Among the households that do not own an ICS, the most frequently used cooking facilities are the three-stone system (40.5%) and Malagasy stoves (50.6%).

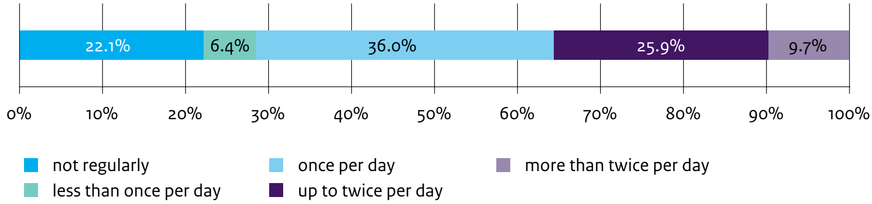
The penetration rate of 9.6% is less than expected, given FAFASO data on the number of stoves sold (Table 5). If all ICS had remained in either of the two cities and achieved the assumed lifespan of two years, and assuming that the average number of Roumdé stoves per ICS-owning household is 1.12 (as the survey indicated), the penetration rate as of March 2011 would correspond to about 20%. There are various possible reasons for the discrepancy. A likely explanation is that some of the stoves sold in Ouagadougou and Bobo-Dioulasso are taken elsewhere, either as a gift or to be sold. They probably mainly end up in rural townships, since in the traditionally small rural villages the metal stoves are less popular. Another possible explanation is that stoves actually have an active lifetime of less than two years and hence have to be replaced more frequently. However, this is not corroborated by the quantitative and qualitative findings of the survey, which show that 72% of the surveyed stoves had been used for over two years. A third option is that the low penetration rate is the result of a biased sampling. This can be excluded, since by comparison with census data, the sample is representative in terms of the main household characteristics.[38]

Among the ICS owners, 15.1% in Ouagadougou and 1% in Bobo-Dioulasso do not use the ICS at all, or only in exceptional cases. Asked why they tend not to use the ICS, most households stated they resorted to the wood-burning ICS only when there was a shortage of LPG. Another reason was that the ICS is used only for celebrations or as back-up. The proportion of ICS not used regularly for cooking is slightly higher: 22.1 % (the ICS can be used for other purposes, such as to heat water for washing). At the other end of the spectrum, 37% of the ICS-owning households used the Roumdé as the sole most often used cooking device. On average, an ICS is used 8.3 times per week.

37 The survey excludes the top-income neighbourhood 'Ouaga 2000' in Ouagadougou, whose residents are mainly expatriates and high government officials. In this area cooking is done with electricity or LPG.

38 It cannot be completely ruled out that Roumdé ICS have been falsely recorded as imitations, even though the intensive training of interviewers and their feedback from the household visits indicate that this is unlikely. On the other hand, given that respondents were asked questions related to ICS in different parts of the interview, it seems unlikely that they forgot to mention them because they did not use these stoves.

Figure 4 *Frequency of use of ICS for cooking*



Source: Improved Stove Dataset 2011.

2.5 Impacts

The impact analysis has been based on households that cook any of their meals with firewood or charcoal. Accordingly, households that use only LPG for cooking have been excluded. These households are not a sound benchmark for assessing the effectiveness of ICS use, since they are at a higher level of clean energy use. When analysing the energy used to prepare individual dishes, only observations for firewood or charcoal were included.

Reduction in use of wood energy

How much wood fuel is effectively saved per meal per household (taking into account cooking behaviour)?
IRSAT has carried out controlled cooking tests (CCTs) on the Roumdé ICS. The three main types required 29% to 43% less firewood as compared to the three-stone system (Sanogo, 2008). However, a CCT provides an estimate of the potential fuel efficiency, whereas the effective savings in real-life use by households may deviate, for various reasons. First, households use different cooking stoves simultaneously (three-stone, charcoal, LPG) for various dishes. Second, fuel savings depend on the type of dish[39] (e.g. for breakfast, or midday or evening), while CCTs are typically conducted for the midday meal. Third, a cook preparing a meal under the observation of researchers, as is the case in a CCT, is likely to behave differently than under 'normal' circumstances (the Hawthorne effect) in which the cook multitasks and hence does not devote the same attention to the cooking (and the stoves) as during a CCT. Fourth, the combustion efficiency of a stove may deteriorate over time due to inappropriate maintenance. Fifth, a CCT is conducted with few cooks only and does not capture the heterogeneity across households, where income, education, age and other factors influence how stoves are used in practice. Sixth, in a CCT the cook may not be familiar with the different types of stoves, but with only a few.

The behavioural response to a new device in the household is important. Because the ICS is more fuel-efficient, the cook will make savings, but what will the cook do with these

[39] In the study, dishes refer to the different components of a meal, and each dish may be prepared on the same or different stoves or fireplaces.

savings? If the cook or household is accustomed to using a certain quantity of fuel wood to prepare a meal, the ICS allows the cook to do more with the same quantity: the cook may therefore prepare more hot meals or keep some water warm during the day, whereas previously the water was heated only at certain times. This phenomenon is called the 'rebound effect' (see Herring et al., 2009). Likewise, in areas where fuel has to be purchased anyhow (the urban areas) and where households can choose between fuels (firewood and LPG, for example) the ICS may change the balance in favour of firewood, particularly for certain dishes or meals for which taste preference counts (the taste of having been prepared on an open fire). To take the effects of behaviour into consideration, the wood fuel savings can best be assessed by carrying out a representative household survey, as done in this evaluation. This method also has shortcomings, however, such as reliance on the accuracy of respondents' answers and memory. Although statistical cross-checking increases the reliability of the information obtained, in an ideal situation the survey should have been combined with actual measurements.

The survey conducted in the two main cities of Burkina Faso reveals that households using a Roumdé ICS (firewood) for cooking use 26% to 28% less firewood than households using the three-stone system. IRSAT also used the three-stone stove as benchmark in its CCT. However, the IOB survey indicates that three-stone systems are not commonly used in the urban areas and that in households without an ICS, less than 25% of all dishes are prepared on three-stone stoves. Comparing the Roumdé ICS to a Malagasy stove, the savings are 20-25%, while compared to an imitation ICS, the savings are about 10% (although in the latter case the figure is not statistically significant; see Table 6 and Annex 1, Table A3). If the household uses charcoal instead of firewood, the ICS user saves about 15% of charcoal compared to users of the Malagasy or an imitation ICS.

Table 6 Savings in firewood and charcoal from using an ICS, in percentages

Study	Firewood ICS savings (in %)	Charcoal ICS savings (in %)	Compared to:
IRSAT CCT	29 – 43	-	Three-stone stove
IOB survey	26 – 28	-	Three-stone stove
IOB survey	20 – 25	15	Malagasy stove
IOB survey	10*	15	Imitation ICS

** not statistically significant.*

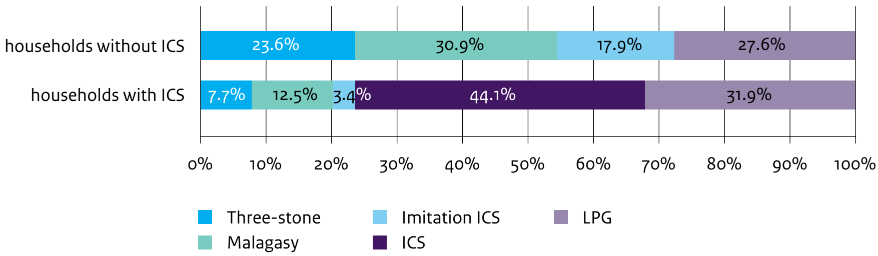
Note: Saving ranges depend on the econometric model applied. See Table A3 in Annex 1.

Although the saving rates are less than those obtained in a CCT, they are still significant and show that Roumdé ICS are 10-30% more efficient than other cooking devices.

What is the effective use (per week or month) of the ICS, taking into account simultaneous use of other stoves and LPG? And how much firewood is saved?

For 53% of the ICS owners, the ICS is the most frequently used stove, either alone or in combination with one other stove: in 37% of the households the ICS is the sole most often used cooking stove; in 16% owners use their ICS and another stove equally frequently. Figure 5 presents the use of different stove types across all households, for owners and non-owners of ICS. Of all the dishes prepared in ICS-owning households, 44% are cooked on an ICS, followed by LPG stoves (32%). Among the ICS owners, only 20% of the dishes are prepared on traditional stoves, such as the Malagasy or the three-stone stove. Three per cent of dishes are cooked on an imitation ICS. ICS owners also prepare hot dishes more often than non-owners: 20 and 18 times per week, respectively. ICS owners also more often use two or three stoves simultaneously to prepare a meal, particularly the midday meal.[40] Among households that do not own an ICS, over half of the dishes are cooked on three-stone and Malagasy stoves, whereas 18% of the dishes are prepared on an imitation ICS. LPG stoves are used more or less equally frequently by households that own an ICS and households that do not. This suggests that traditional wood-burning stoves and imitation ICS tend to be replaced by a Roumdé rather than by LPG. This is an important observation, since the actual savings on wood fuel consumption depend on which type of stove has been replaced.

Figure 5 *Type of stove used, as percentage of total cooking devices*



Source: Improved Stove Dataset 2011.

Note: The proportions shown in the Figure are calculated as ratio of the times the respective stove is used per week and the total times stoves are used per household. Example: a household uses two stoves to cook 21 dishes a week: this gives a denominator of 42. The total does not sum to 100% as other unspecified stove types are in use (0.4%). N=1,108.

Since a considerable proportion of the households still cook on a traditional stove or the three-stone fire place, the potential for further dissemination of ICS is substantial and thus so is the potential to save firewood. The transition to LPG seems to be progressing slowly. Based on a matching approach that accounts for potential dynamic behaviours such as rebound effects and fuel switching (e.g. from LPG to charcoal) and extrapolating the representative survey sample to the target population, the annual savings in firewood in Ouagadougou plus Bobo-Dioulasso are 2,660 tons. Since only around 60% of ICS are stoked with firewood and the remainder are stoked with charcoal (or combinations), an additional annual saving of 1,535 tons of charcoal has been achieved. Assuming a modest effective conversion of 3:1 from fuel wood to charcoal, the firewood equivalent would be

40 Only three of the respondents were male.

approximately 4,600 tons. In sum, this would imply an annual saving of 7,260 tons of firewood.

Reliable data on total wood fuel consumption in Burkina Faso that may help to put these figures into perspective are difficult to obtain. According to FAO, the country's annual consumption of firewood is about 4.1 million tons (FAO, 2009). The Ministère de l'Environnement et du Cadre de Vie (2004, p. 5) estimated the figure to be 3.5-5.0 million tons annually. Compared to both sources, the estimated savings in fuel wood are modest and in terms of national consumption represent 0.26% for charcoal and less than 0.2% for firewood.

Box 4 *Cooking stoves in schools*

There are no statistics concerning the number and types of stoves used in schools in Ouagadougou and Bobo-Dioulasso. Twenty randomly chosen schools were surveyed in the two cities; only one happened to cook with Roumdé stoves. Despite a letter circulated by the Ministry of Education in 2010, in which all primary education schools were called upon to prepare a midday meal for their students and to opt to use Roumdé stoves for cooking, most schools prepare these meals on three-stone fires. In most Burkinabè schools, the only meal offered to the students daily is green beans, or rice with white or red beans.

The fact that schools hardly use ICS can be explained by the absence of specific programmes or projects to introduce improved stoves in educational centres. FAFASO has not done so since this would be counter to the general approach of not disseminating ICS directly but instead relying upon the market mechanism. A school administration, with the consent of the parents' association, could decide to purchase an ICS if they had the means to do so, but schools have no specific budget to improve cooking facilities. Private schools attended by students from families in the higher income brackets predominantly use gas to prepare meals.

A more detailed study was conducted in nine of the 20 primary schools visited. Seven of these nine had a canteen which provided free midday meals to all pupils (three of these seven schools charge a token 1,000 CFA F [1.25 EUR] per pupil per year). Most schools ask pupils to bring one to three bundles of firewood each month, but have to buy in additional fuel wood as well.

Time

What are the time savings to persons responsible for acquiring the wood fuel? How is the freed-up time used?
Improved cooking stoves may affect time allocations of household members in two ways: first, the ICS may affect the time required for cooking; second, if less fuel wood is used, time

spent on obtaining fuel, be it in terms of collecting or buying, may be saved. If time has indeed been saved, the freed-up time can be used for other activities in a so-called second-round effect (Blackden and Wodon, 2006). Since the evaluation focuses on urban areas, the respondents reported they rarely collect fuel wood and mostly purchase it. Only 0.4% of the households interviewed mentioned that they collect part of their fuel wood. Both firewood and charcoal are purchased near the house. ICS owners spend on average 4 hours and 4 minutes per week on buying wood, whereas households that do not own an ICS spend 5 hours and 6 minutes per week. Although this difference of around one hour per week implies a time saving of about 20%, which is consistent with the savings in firewood consumption, it is difficult to consider this to be a net time saving, since buying firewood is usually not the sole purpose of going out of the house. There was no difference between ICS owners and non-owners in time spent buying charcoal. In consequence, the reduction in wood consumption does not produce significant time benefits in terms of collecting wood or time spent on purchasing it.

In order to analyse the time spent on cooking, a regression model (Ordinary Least Squares – OLS) was applied for wood fuel use per dish, with cooking duration per main dish (in minutes) as the dependent variable. The findings suggest no time savings for a charcoal-fuelled ICS compared to the Malagasy reference stove, but some statistically significant time savings were found in preparing dishes with an ICS stoked with firewood. When firewood is used, the total cooking time for the main dishes using a three-stone fireplace takes on average 131 minutes daily. If use is made of a Malagasy stove, the cook saves one minute per day; if use is made of an imitation ICS, the cook saves 3.5 minutes daily and when an ICS is used one saves on average 13 minutes per main dish prepared for the midday or evening meal. This time reduction, however, does not necessarily translate proportionally into savings in the daily time devoted to cooking. The regression results show time savings amount to mere 7 minutes per day for the households that most often use an ICS for cooking and 18 minutes for the group of households that use the ICS and other stoves equally frequently (see Annex 1, Table A4). These results do not seem to be driven by the number of full meals prepared, since ICS-owning and non-owning households do not differ in this domain. They both prepare on average 1.35 full meals per day. It should be noted that in the group of ICS users, not necessarily all meals are prepared with an ICS. The ICS is frequently used in combination with traditional stoves (for example, for side dishes), which may extend the duration of meal preparation. Overall, the time saving effects for ICS users are too small to justify analysing how households use this freed-up time. An option could have been to restrict such an analysis to the subgroup for which most time is freed-up (households using both ICS and other stoves), but this sub-sample consists of just 52 households and cannot be considered as representative.

Household expenditure

What changes have occurred in household expenditure on energy in total and for cooking energy in particular? How are these savings being used?

Whether the use of an ICS also leads to less expenditure on fuel for cooking was explored further by using two different specifications to account for the simultaneous use of different stove types in households. First, one specification in which households are distinguished on the basis of the stove used most frequently: (a) a three-stone, Malagasy or imitation ICS, (b) an ICS or (c) an ICS in combination with other stoves (the right-hand side of Annex 1, Table A4). Second, a specification that compares households on the basis of the relative use of stove types to cook dishes. For both specifications, calculations were done for two models: one focused solely on firewood consumption (and hence firewood expenditure) and the other focused on wood fuel consumption in general, controlling for charcoal use. In each case, an OLS model was calculated, and a propensity score weighted regression. To ascertain whether the savings are different at the lower end of the income distribution spectrum, the estimations were done separately for the three lowest household expenditure quintiles.

The quantitative analysis (see Annex 1, Table A2), which focuses on households only cooking with wood fuel, suggests that households frequently using an ICS spend on average about 12% less on cooking than households that mostly use other types of stoves. There are no significant savings for households that mostly use an ICS in combination with another stove. Using the sample mean (excluding LPG users, a) 12% saving in expenditure on fuel for cooking corresponds to 930 CFA F or EUR 1.42. This is consistent with the 10-20% savings in the quantity of firewood used, but far less than the 5 EUR per month savings expected by FAFASO in 2007 (FAFASO, 2007).

This analysis includes the number of cooked dishes per week as a control variable, because cooking frequency obviously influences expenditure on fuel and may therefore also influence the decision to obtain an ICS. Households in which cooking is done for more persons, or households where the dishes prepared take longer to cook, use more fuel and hence obtain larger savings with an ICS, enabling them to amortise the investment faster. On the other hand, there are households that do not cook a midday meal because of the distance between home and work. The qualitative research indicates that households that cook more often with wood fuel are more inclined to buy an ICS (self-selection). However, it should be noted that households may cook more once they start using an ICS; if they do so, they save less (the rebound effect). In order to assess the relevance of this alternative, it is advisable to do the same analysis without controlling for cooking frequency. The estimated savings rate for total fuel expenditures then decreases by about one percentage point, suggesting that ICS users do indeed cook more often, which partly offsets the savings that could be obtained as a result of the higher efficiency of an ICS. From an economic point of view, the fact that the household can now afford to cook more has an intrinsic value for the household and this is covered by the savings foregone, the savings achieved by using an ICS.

To sum up, ICS users save about 12% in expenditure on fuel for cooking (around 10% for users of firewood only). Since ICS users seem to cook more hot dishes than users of traditional stoves, the theoretical savings are higher. Expenditure on fuel for cooking represents about 16% of total household expenditure in the lowest decile of the income distribution, about 8% in the fifth decile and about 2.3% in the top decile. Hence, even for the lowest income bracket, the financial savings represent less than 2% of total household expenditure and cannot be expected to have any significant impact on other items of expenditure such as schooling or health. Nevertheless, these savings do imply that – depending on the intensity of the use – the investment in an ICS can be recouped within a year, and on average within four months.

Health

What are the changes in health-related outcomes (symptoms of respiratory disease, eye infections)?
How much an ICS actually reduces smoke emission depends on the type of ICS. Whether ICS have any effect in eliminating household air pollution at all is even questioned in literature (see Duflo et al., 2008). Chimney stoves or advanced biomass stoves are able to reduce emissions or exposure to emission to close to zero. The Roumdé stove however, is designed to be fuel-efficient and not directly to reduce smoke exposure. Hence there is no reason to expect that the Roumdé stove will yield emission reductions that lead to improved health for the household members. Even if the firewood and charcoal savings of 10% to 30% were translated into proportional reduction in emission – which has not been tested in a laboratory – it is unlikely that this would produce noticeable effects on the health of individuals. However, ICS use might alter cooking behaviour in a way that benefits health beyond what could be expected from the mere reduction of smoke. In Senegal, for example, a very basic ICS apparently induces health benefits, partly because it is used more frequently outdoors (instead of indoors), the cooking time is shorter and cooking requires less permanent attention, so that women spend less time near the stove (Bensch and Peters, 2012).

The availability of an ICS may also induce changes in the cooking behaviour that aggravate the health situation instead of improving it: for example, if the ICS replaces cleaner stoves, such as those fuelled with LPG. This is hardly the case in Burkina Faso, where the Roumdé has mainly replaced traditional stoves. Another problem is the *risk rebound*: the cleaner cooking may tempt the household to move the site for cooking from outdoors to indoors, and because the stove is better insulated, the cook may spend more time closer to the stove.

Most empirical studies on the relation between health aspects and changes in indoor air pollution as a result of the introduction of an ICS encompass all household members and focus on short-term effects of exposure, such as eye irritations and problems such as cough, asthma or difficulties in breathing as proxy variables for respiratory diseases. A disadvantage is that the symptoms are 'self-reported' and can also be induced by causes other than kitchen smoke. In this study, the analysis focused on the household member responsible for cooking, as this is the person who is the most exposed. In 82% of households this is one individual. Of all households, 24% reported that the cooking was done exclusively indoors and in most of them in a separate kitchen building; only 3% of households cook in a room also used as living room and bedroom. Cooking outdoors is the norm: 71% cook mainly outdoors, although during the three-month rainy season almost all households are forced to cook indoors. During that period the exposure to smoke increases, and this is exacerbated by damp wood fuel, which burns with more smoke. Good air circulation can reduce the exposure to smoke: in more than 85% of the households reported to keep windows or doors open while cooking indoors.

Table 7 provides an overview of the incidence of health problems potentially related to smoke exposure as reported by household members. On aggregate, respiratory diseases and eye problems are relatively rare, which complicates the further quantitative analysis of these incidents. Less than 6% of the cooks in the interviewed households stated they suffered from these ailments. Furthermore, the data suggest that richer households more often report health problems even though they tend to use cleaner cooking fuels. This might be due to self-selection of less healthy people (whether perceived or factual) in the group of ICS owners (see Pitt et al., 2006). Probably more importantly, this result can be explained by reporting heterogeneity: given the same objective health status, poorer individuals tend to underreport their health problems because they are less aware of health problems or have lower health expectations (Bonfrer et al., 2013; Bago d'Uva et al., 2008; Lindeboom and Van Doorslaer, 2004; Salomon et al., 2003). This phenomenon may also explain why the results show – counter-intuitively – that ICS owners perceive domestic air quality to be worse than do non-owners.

Table 7 Incidence of health problems potentially related to smoke exposure among households using wood fuel

As reported by household members, in %	ICS owners			ICS non-owners		
	Mean	Bottom Quintile	Top Quintile	Mean	Bottom Quintile	Top Quintile
Household member variables						
Number of observations	2081	371	365	3601	1005	427
Household member suffers from respiratory disease	3.6	0.8	6.1	2.6	1.3	3.3
Household member suffers from eye problems	3.2	1.1	3.9	2.9	0.5	4.5
Variables relating to the household member responsible for cooking						
Number of observations	478	73	100	757	185	111
Household member responsible for cooking suffers from respiratory disease	5.6	2.8	7.0	3.2	1.6	3.8
Household member responsible for cooking suffers from eye problems	5.3	1.4	5.1	5.2	0.5	7.9

Source: Improved Stove Dataset 2011.

Both the use of an ICS and income are positively correlated with health problems, but overall the results are not conclusive. Across all stove types, only the exclusive use of charcoal significantly reduces the probability of eye problems, which is plausible. These analyses underline the conclusion that there is little justification for expecting that using the Roumdé stove will improve health. Even if there are positive health impacts, these are unlikely to be large, which is not surprising since the Roumdé is mainly intended to save wood fuel. The induced smoke reductions are not strong enough to affect health.

2.6 Sustainability

Are current users likely to continue using the improved stoves?

The quality of the FAFASO ICS is generally perceived as good and the replacement rates are low. Over 70% of stoves in the survey were older than two years. The main challenge for FAFASO will be to maintain the quality of the stoves. Previous stove programmes mainly failed because they could not maintain the higher quality. So far, the quality assurance has largely depended on the FAFASO activities. FAFASO is in the process of devolving this quality assurance task to the producer associations.

A further challenge may be the existence of the imitation ICS that also generate benefits to their users and provide an intermediate alternative to the Roumdé. The imitation ICS are cheaper and that may tempt current ICS users to buy an imitation, instead of the genuine Roumdé ICS. The widespread usage of imitation ICS next to Roumdé ICS suggests that the Roumdé does not stimulate producers of the imitation stoves to improve the quality of their products up to Roumdé standards. The moment FAFASO support is phased out, Roumdé producers might be tempted or forced to lower their quality standards in order to compete with the cheaper imitations. This is speculation. The way the project could prevent this happening is to take preventive measures by investing much effort in institutionalising the established structures, particularly in terms of quality standardisation.

Can the market count on enduring supply and demand?

Although ICS sales in the urban and peri-urban areas of Ouagadougou and Bobo-Dioulasso have picked up in recent years, dissemination of the ICS in rural areas of Burkina Faso will be more difficult, as here firewood is typically collected and not bought and hence the households do not have to pay money for fuel wood. Thus to a household that collects fuel wood, the ICS will not bring cash savings and hence the outlay on the ICS cannot be recouped by savings in fuel wood use. The low penetration rate in urban areas compared to the sales data suggests that a large number of stoves have been brought to rural areas, suggesting that in these areas there is a demand for ICS. In urban areas, further uptake will depend on the price of LPG. Many households already use LPG as cooking fuel. The use of LPG will probably increase in the near future and in consequence the market for wood-burning stoves may shrink. From a clean fuels perspective, though, this would be a positive development. At the same time, the market for improved wood-burning stoves is likely to remain sufficiently large in order to stimulate whitesmiths to produce and sell Roumdé ICS.

Since owners of an ICS save 3.5 kg firewood (priced at 50 to 100 CFA F per kilo) per week compared to households with traditional stoves, the savings are around EUR 1.42 per month. This implies that the payback period of a Roumdé (2,000 to 3,500 CFA F) is on average two and a half to four months. The expected lifespan of the Roumdé is about two years, although the survey revealed that many Roumdé stoves were being used regularly for longer. While buying a Roumdé would be the rationally best choice, in reality consumers are not always well informed or are simply cash-constrained. To poor households, the cash outlay for the purchase is a burden and these households may be either unable to save or to obtain formal or informal credit. Poor households may not be able to buy an ICS, although FAFASO reports that some traders would in principle allow buyers to pay for their stove in instalments.

Environmental sustainability

The main impact of using the Roumdé stove is the saving in fuel wood. These savings are significant, substantial and robust. Savings in wood fuel are superior to those obtained by any other cooking device using firewood or charcoal. The rebound effect, however, is that users of an ICS seem to cook more hot meals, thereby reducing the potential benefit. Nevertheless, at aggregate level about 2,700 tons of firewood and 1,535 tons of charcoal are saved per year, which is substantial in absolute numbers, but small as compared to the annual wood fuel consumption in the country.

It can be concluded that ICS contribute to limiting the wood consumption in Burkina Faso but still require scarce fuel wood to be used. In spite of the success of the FAFASO intervention, which is to achieve a reduction in the weekly demand of 3.5 kg fuel wood per household, this does not eliminate the continuous growth in demand for firewood. To stem this demand in the long term, cleaner sources of cooking energy such as LPG will have to replace the use of firewood as main cooking fuel.

3

Improved cooking stoves for productive use: beer brewing

3.1 Introduction

In general, improved cooking stove interventions focus on the preparation of meals within individual households. Besides the domestic use, *Foyers Améliorés au Burkina Faso* also targets social institutions, restaurants, producers of shea butter and breweries of traditional beer. The intervention consists of the training of builders specialised in constructing stoves for commercial or task-specific use, as well as awareness raising and marketing campaigns. In 2006, FAFASO placed test stoves for commercial use in 20 restaurants in Ouagadougou (since 2009 also in Bobo-Dioulasso), while subsequently the programme organised special exhibitions and workshops, principally addressing restaurant owners who are well connected and are leaders in their sector (*restauratrices leader*). Since 2008, attention has focused on the artisanal beer brewers (*dolotières*) in Ouagadougou and surroundings and Bobo-Dioulasso (the urban area only). This chapter reports the findings of an impact evaluation of FAFASO's promotion for using ICS in the *dolo* industry.[41]

3.2 The intervention: stoves for breweries

To brew *dolo*, the mash has to be heated for at least a day (and usually 2 days); this requires a substantial amount of fuel wood. Traditionally, the *dolo* mash is boiled in large clay pots on a three-stone fire place. The fire is fed with large tree trunks. In Ouagadougou and Bobo-Dioulasso, the breweries use at least 20% of all firewood in the urban areas.

The FAFASO improved stoves aim at reducing the quantity of fuel wood used per brewing. To the brewer in Ouagadougou or Bobo-Dioulasso, reduced wood consumption means less fuel wood has to be purchased (in urban areas brewers do not collect fuel wood). For this industrial use the Roumdé stoves are made of clay and bricks rather than metal, while the cauldrons are usually made of aluminium. In Bobo-Dioulasso more use is made of clay cauldrons, one reason being that consumers say that *dolo* tastes authentic only when brewed in clay cauldrons.

In 2008, FAFASO started to train stove builders to construct stoves specifically for dolo brewing that are designed to economise on the firewood used during the brewing process. The training was concentrated in communities[42] in the *Est and Sud-Ouest* regions and later in 2008 and in 2009 extended to the *Centre-Est* region and the *Plateau Central*. In 2012 the Boucle de Mouhon was added (through a partnership with the Dutch NGO SNV). This also encompassed the cities Ouagadougou and Bobo-Dioulasso (both 2010), but, unlike the

[41] This chapter summarises research conducted on behalf of IOB by Michael Grimm and Jörg Peters, 'Impact Evaluation of Improved Stove Use among Dolo-beer Breweries in Burkina Faso – FAFASO'. Final Report July 2013. International Institute of Social Studies, Erasmus University, Rotterdam, The Netherlands and University of Passau, Germany. Rheinisch-Westfälisches Institut für Wirtschaftsforschung, Essen, Germany. The report can be accessed on the IOB website at www.iob-evaluatie.nl/node/331.

[42] Communities are groups of villages that constitute a small administrative unit.

training in rural areas, this was accompanied by awareness campaigns among urban *dolo* producers. A complementary component was the installation of test stoves in breweries run by a *dolotières* with a leading role among her peers. The awareness and information campaigns targeting the *dolo* brewers, as well as the technical quality of the stoves were intended to achieve a behavioural change resulting in cost savings and subsequently leading to more profit for the brewers.

Over 2010 and 2011 FAFASO spent about EUR 100,000 on developing a market for improved *dolo* stoves. These costs refer to direct cash outlays for the training of the stove builders and the marketing activities, but do not encompass the share of FAFASO's recurrent costs and other general programme costs.[43]

Photo 4 *An improved traditional stove for brewing*

Photo: FAFASO.

Photo 5 *A Roumdé used for brewing, with a damaged surround*

Photo: RWI/ISS.

3.3 Methodology

The evaluation is based on a mixed methods approach using information from (i) documentation gathered during field visits, in-depth interviews with stakeholders and experts as well as focus group discussions, and (ii) a representative survey.

(i) *Documentation, expert interviews, field visits and focus group discussions*
Interviews were conducted with FAFASO project management and project field workers, stove builders and a *dolo* producers' association. In-depth interviews were conducted in ten breweries with both the woman owning/renting or managing the brewery and her support staff, to get a better understanding of the organisation and process of *dolo*

[43] The costs refer to training courses (each costing about EUR 10,000 to EUR 12,000), refresher courses for stove tecnicians, the marketing activities including a TV advertisement, trade fairs, the installation of demonstration stoves and the production and distribution of publicity material on stove use.

production and with a view to designing an adequate survey questionnaire. After the survey, focus group discussions were organised, in which preliminary results were shared and checked against the perceptions and experiences of the brewers.

(ii) *Representative survey*
In 2010, IRSAT conducted a census of all *dolo* breweries in greater Ouagadougou and Bobo-Dioulasso, including their surrounding (rural) villages. The census revealed there were 2,397 active breweries in and around Ouagadougou and 1,144 in Bobo-Dioulasso (Sanogo et al., 2011). From this list, IRSAT randomly selected 219 breweries: 158 in Ouagadougou and 61 in Bobo-Dioulasso. The sample size was based on power calculations that would allow the difference in wood consumption between different types of stoves to be distinguished with sufficient statistical precision (Sanogo et al., 2011). With the help of a *dolo* producers' association, the selected breweries were then contacted and interviewed. The questionnaire collected information about the socio-demographic characteristics of the breweries and the people working there, the brewing process, including wood consumption, and the potential use of improved cooking stoves.

Although the 2010 census was primarily intended to serve FAFASO project implementation only, IOB decided to use the same sampling frame for its 2012 survey. As many breweries as possible from the 2010 sample were put on the IOB survey list, and new breweries were added to make up for breweries that had ceased to operate. Exactly two years later, in September 2012, in total 261 breweries (178 in and around Ouagadougou and 83 in Bobo-Dioulasso[44]) were interviewed. Attrition turned out to be quite high, since only 88 of the 261 breweries had been interviewed in 2010. Replacement breweries were randomly drawn from the list of all breweries recorded in IRSAT's census. Table 8 documents the sample composition in 2010 and 2012.

Table 8 Sample composition of *dolo* breweries surveyed in 2010 and 2012

	Breweries interviewed in...		
	2010	2012	Both years
Ouagadougou	156	178	72
Bobo-Dioulasso	61	83	16
Total	**217**	**261**	**88**

Note: The survey was conducted in and around both cities, also around Bobo-Dioulasso, where FAFASO had not conducted any marketing activities.

Source: IOB, Brewery Surveys, 2010 and 2012.

44 While the training of masons took place in various regions, FAFASO activities related to *dolo* breweries were restricted to the cities of Bobo-Dioulasso and Ouagadougou (plus the surroundings of the latter).

Prior to the 2012 survey, a preparatory mission was conducted to develop the methodology and to enrich the 2010 questionnaire with additional questions on wood consumption, awareness of and attitude towards improved stoves.[45]

To assess fuel wood use in the brewing process, it would have been desirable to weigh exactly the amount of wood used per brewing. In 2010, IRSAT did so in three cases, where staff monitored a brewing process for the full two days and weighed all inputs including the wood. This was not feasible for a large sample and in addition, is prone to the Hawthorne effect, i.e. the brewers are likely to modify their behaviour simply because they know they are being observed. As an alternative to weighing, brewers were requested to estimate both the amount of firewood used and its value. This estimate is relatively precise, since in urban areas all wood is bought and brewers have a fairly good knowledge of how much wood they buy.

As noted in Chapter 2, a controlled cooking test (CCT) for brewing provides estimates of the *potential* savings, while the *effective* savings in real-world conditions may deviate from the potential for reasons such as using different cooking stoves simultaneously, sub-optimal use of the improved stove, or deteriorating combustion efficiency of the stove due to inadequate maintenance. The effective savings were assessed by means of a representative survey that captured the diversity of actual cooking practices.

Since breweries may or may not own an improved cooking stove (a binary variable), the difference-in-differences method could be employed. The key idea of the difference-in-differences estimator is to compare the changes in fuel wood consumption over time for breweries that used a Roumdé with those that did not, using two survey rounds. The advantage of the method is that selection effects can be controlled for as long as these stem from time-invariant characteristics, such as birth cohort, education or astuteness. In the study of the breweries, the drawback is the relatively small sub-sample of brewers interviewed in 2010 and 2012 (88 brewers in total). The representativeness was tested by regressing the variable 'surveyed in both years' on a set of characteristics observed in 2010. The regression revealed that only the size of the brewery could introduce a bias, since the size also has an effect on whether an improved stove is acquired. To further compensate for the small sub-sample surveyed in both 2010 and 2012, a cross-sectional approach was also applied. This was complemented with propensity score matching, comparing users and non-users in 2012, based on their propensity (probability) score of owning an ICS.[46]

While a brewer may or may not *own* an improved stove, this is not dichotomous for the brewing process, as a brewer may *use* both traditional and improved stoves simultaneously during the same brewing process. This makes it difficult to measure the amount of firewood used during the process. To overcome this problem, the concept of 'stove-days' was applied.

45 Both questionnaires, IRSAT 2010 and the RWI/ISS 2012 can be consulted as appendix to the FAFASO *dolo* breweries report (Grimm and Peters, 2013) at www.iob-evaluatie.nl/node/331.

46 For further explanation, see the FAFASO *dolo* breweries report (Grimm and Peters, 2013) at www.iob-evaluatie.nl/node/331.

If a brewer uses two stoves and one brewing lasts two days during which both stoves are continuously used, then each stove provides two stove-days. If one of the two stoves is an improved stove, the share of stove-days provided by an improved stove is 50%; if there are three stoves and only one is an improved stove, the share of the improved stove is 33%. Since the brewer knows how much fuel wood is consumed per brew and knows the duration of the brewing process, the relative reduction of fuel wood by the improved stove can be imputed.

3.4 Adoption

What are the socio-economic characteristics of brewers acquiring and using a Roumdé?
Theoretically, the adoption of an ICS depends on at least four sets of variables:

1. The energy inefficiency of the current brewing process. Breweries that have a high consumption of firewood per litre of *dolo* would gain most from an improved stove.
2. The access to information, i.e. *dolotières* need to be aware that improved stoves exist and what their potential is to make savings. Access to information is expected to be related to education, age, location and the interaction with other brewers.
3. The price of firewood: the higher the price of firewood, the greater the reward from being fuel-efficient.
4. The ability to pay and access to credit. Poor *dolotières* without access to credit are unlikely to acquire an ICS.

Based on these considerations, the quantitative analysis included the following explanatory variables: the age of the brewer; her education; the number of years she has been in business; the quantity of *dolo* she produces per brewing; as well as binary variables indicating whether the brewery is located in Ouagadougou or Bobo-Dioulasso and whether it is located in the urban area or in a rural community (FAFASO did not extend its training and marketing to rural communities around Bobo-Dioulasso). The survey did not contain good proxies for wealth or access to credit, as *dolo* brewers are wary of questions seeking information on income and wealth and this might have compromised their cooperativeness (in fact no such questions were asked).

Table 9 presents some characteristics of the *dolo* brewers surveyed. Worthy of note are the relatively advanced age of the women brewers, their low level of formal education and their long experience (some 15 years on average) in *dolo* brewing.

Table 9 Characteristics of *dolo* brewers surveyed

	2010	2012
Age (years)	43.7	45.9
At least primary schooling completed	24%	23%
Ethnic group:		
Mossi	67%	63%
Bobo	25%	27%
In *dolo* business (years)	14.4	16.4
Ouagadougou/Centre Region	72%	68%
Urban		30%
Total number of brewers surveyed	**217**	**261**

Note: Urban/rural was not coded in 2010.

Source: IOB calculations, based on Brewery Surveys 2010 and 2012.

Whether the characteristics of the *dolo* brewers influence the probability of Roumdé uptake, different regressions were conducted (see Annex 1, Table A5). It can be concluded that the probability of adoption is 20% higher if the brewer has completed primary education, while each additional year in business increases the probability of acquiring an ICS by about 7%. The age of the brewer does not have a significant effect on acquisition, while the ethnic affiliation does have some significance, but this is hard to disentangle from the location effect (dominance of Mossi in Ouagadougou and Bobo in Bobo-Dioulasso). There is a significant correlation with the quantity of *dolo* produced, but obviously the production capacity may be the result of having and ICS as well.[47] If the quantity of *dolo* is taken as regressor, the result suggests that for every percentage increase in the volume of beer produced, the probability of acquisition increases by 0.20%.

The second variable that could determine the adoption of an ICS is access to information. In the interviews, brewers without a Roumdé were asked whether they knew of the Roumdé and, if so, where they had heard about it. About 60% of the non-users did know of the Roumdé. Most (79%) of them had heard about it from neighbours and other *dolotières*. Another 10% knew the Roumdé from FAFASO marketing campaigns and 6% had heard about them from their stove builder.

Among those who had heard about the Roumdé, but who had not bought one, the following reasons for not buying an ICS prevailed:

- The perceived maintenance effort and costs. Changing the cauldrons of a Roumdé is more difficult and more expensive than with a traditional stove. Unlike a traditional

47 The variable 'quantity of *dolo* produced' may change after an improved stove has been acquired, so this variable can be considered as endogenous.

stove, where a cauldron can simply be removed, with a Roumdé the change requires breaking the mud or clay mantle of the stove (the top of the stove). The change of cauldrons needs to be done by a stove builder or by an experienced brewer and costs about CFA F 1,000 to 2,000.[48] Because the Roumdé is better insulated, the heat of combustion is more intense and clay cauldrons may burst and so need to be changed more frequently. Switching to aluminium cauldrons would partly solve the problem of maintenance, but it adds to the investment costs, since aluminium cauldrons cost between CFA F 20,000/30,000 and CFA F 50,000/60,000 (according to size). Increased maintenance costs are also related to the brittleness of the surround around the opening to the combustion chamber of the improved stoves. Since *dolo* brewers use large trunks of wood as fuel, damage to the surround often occurs, as the stove opening has been designed for smaller pieces of wood or at least more careful stoking. Repairing the surround and opening (door) is expensive in terms of time and money. A Roumdé stove is also reported to be more sensitive to rainfall and after the rainy season may need to be repaired professionally.

– The investment costs of buying a Roumdé were perceived as too high, particularly since a cash outlay is required. A related problem is that traditional stoves typically accommodate more cauldrons than a Roumdé. Hence a Roumdé offers less brewing capacity but occupies more or less the same space.

– A small group of brewers collects firewood (about 8% in Bobo-Dioulasso and 2% in and around Ouagadougou) and this group considers efficiency of wood consumption as less of an issue (and apparently value their own time at a low price). In the Bobo-Dioulasso region some brewers lease their stove, i.e. *dolotières* come to a brewery, brew the *dolo* and pay for stove use. These brewers prefer to use the stove they know (the traditional type), and the owner brewer may prefer to rent out such stoves since the risk of damage due to careless use is less (and hence so is the risk of maintenance costs).

The third and fourth variables that may explain the adoption of an ICS are related to price of fuel wood, investment costs and capacity to pay. These are dealt with in the sections below.

3.5 Effectiveness

Of the total population of dolo brewers in Ouagadougou and Bobo-Dioulasso, how many own a Roumdé? How many use the Roumdé and how often do they use it?
FAFASO does not actively disseminate the ICS. In consequence, the dissemination of stoves takes place through the market mechanism. It is an outcome of the project if stoves are sold by the stove builders and used by the brewers.

[48] Cost estimate by FAFASO.

According to controlled tests, the Roumdé stove can save between 60-70% of firewood compared to a traditional stove. However, if the improved stove is badly maintained or not properly used, these savings decrease rapidly. A damaged ICS may even require more firewood, as indicated by field tests conducted by IRSAT (Sanogo et al., 2011). For the period January 2010 to December 2012, FAFASO had set a target of disseminating in total 4,500 improved stoves to commercial users, among them the *dolo* breweries.[49] Table 10 shows the number of *dolo* stoves installed in 2010, 2011, 2012 and the first quarter of 2013. Up to the end of the first quarter of 2013, stove builders had installed 2,348 Roumdé stoves. The data show the number of installations peaked in 2010 in the regions *Sud-Ouest* and *Est* and in 2011 in Ouagadougou and Bobo-Dioulasso. In 2012 the number of installations decreased significantly. The number of improved stoves installed in Ouagadougou and surroundings and in the urban area of Bobo-Dioulasso suggests that about half of all breweries acquired improved stoves.

Table 10 Number of improved *dolo* stoves (Roumdé) installed, by location and year

Location	2010	2011	2012	2013 (first quarter)	Total
Ouagadougou	93	592	181	19	885
Bobo-Dioulasso	29	336	58	0	423
Sud-Ouest	280	241	143	48	712
Est	154	105	105	0	364
Total	**556**	**1,274**	**487**	**67**	**2,384**

Source: FAFASO, March 2013.

In 2010, a few months after FAFASO had started to market improved *dolo* stoves (first in Ouagadougou and later in Bobo-Dioulasso) only 12% of all brewers had acquired – and were using – an improved stove. Both in Ouagadougou and Bobo-Dioulasso the installation of Roumdé stoves peaked in 2011, whereas in 2012 the number of new installations decreased substantially. In 2012, almost half of all breweries in Ouagadougou owned at least one Roumdé stove, while 38% were exclusively using these stoves. In Bobo-Dioulasso only 18% breweries owned at least one Roumdé, which is almost the same percentage of brewers that used Roumdé stoves only (17%). The decline in new installations is explained by the limited number of potential clients (there are approximately 4,000 *dolotières*) and the fact that most *dolo* brewers interested in investing in improved stoves had already bought one by 2012. Possibly this was the result of an intensive publicity campaign extended over most breweries during the preceding years and of the fact that the most motivated brewers had already obtained an improved stove.

Among those breweries that produce with more than a single stove (43% of all breweries), the average share of improved stoves is much higher: 85%.

49 EnDev Progress Report 2011 (2012).

Table 11 presents general characteristics of both brewers and brewing, based on the 2012 survey only. Data are shown for Ouagadougou, Bobo-Dioulasso (combining city and rural surroundings) and for Bobo-Dioulasso city separately, since the FAFASO promotion and support activities were restricted to the urban area (for detailed data see Annex 1, Table A7). The brewers interviewed in Ouagadougou had 1.8 stoves on average, while breweries in Bobo-Dioulasso were smaller (1.5 stoves in Bobo-Dioulasso city, and less in the surroundings, where brewers often share stoves). The reported age of the stove (not necessarily the cauldrons) is relatively high: more than eight years on average, even older in Bobo-Dioulasso. Most breweries brew twice a week. In Ouagadougou, brewing takes more time than in Bobo-Dioulasso, since more *dolo* is brewed per brewing (on average almost 368 litres) than in Bobo-Dioulasso (on average 218 litres per brewing).

Table 11 Characteristics of breweries in 2012

	Ouagadougou	Bobo-Dioulasso and surroundings	Bobo-Dioulasso, city area only
	Mean	Mean	Mean
Number of stoves per brewer	1.79	0.48	1.50
Distribution of stoves by type per brewery:			
Number of traditional stoves	0.12	0.48	0.12
Number of improved traditional stoves	0.85	0.42	0.62
Number of Roumdé stoves	0.81	0.27	0.77
Share of breweries with at least one Roumdé stove	0.49	0.18	0.54
Age of stove (years)	8.51	10.34	9.38
Number of brewings per week	1.99	1.71	1.58
Share of breweries using only improved Roumdé	0.38	0.17	0.50
Quantity of *dolo* per brewing (in litres)	368.91	159.45	217.50
Expenditure on firewood per brewing (CFA F)*	8,956.90	4,149.67	7,375.00

*Note: * Excluding those who collect or cut their own firewood.*

Source: IOB calculations, based on Brewery Survey 2012.

Can uptake of improved stoves be further expanded?

A large Roumdé for professional use costs about CFA F 27,500 (or EUR 42) without the cauldrons. Depending on size, aluminium cauldrons cost between CFA F 20,000 (EUR 30) and CFA F 60,000 (EUR 90), about three times the price of clay cauldrons, but with a much longer lifespan. Note that on average, four cauldrons have to be replaced at the same time. Since when changing the cauldrons of a Roumdé the top of the stove has to be removed and rebuilt, some *dolotières* switch from clay cauldrons to aluminium ones when they buy a Roumdé.

The average brewery in Ouagadougou has a monthly turnover of about EUR 500-1,000 (assuming that a litre of *dolo* is sold at CFA F 100 to 200). Wood and other inputs (malt, yeast) require about EUR 200 per month, hence the average value added generated is remarkable, even if the variance around the mean is quite substantial.[50] On average, a brewing in Ouagadougou requires wood to a value of CFA F 8,957 (or EUR 13.70) or CFA F 24.2 per litre of *dolo*.[51] In Bobo-Dioulasso this is slightly more: an average of CFA F 25 per litre (CFA F 34 per litre in Bobo-Dioulasso city). Although fuel wood is slightly cheaper in Bobo-Dioulasso, the breweries use different stoves and cauldrons and buy their wood in smaller quantities, which implies that they pay on average a higher unit price. Apart from cash flow reasons, breweries may decide to buy small quantities to ensure, at least in the rainy season, that the fuel wood is dry. Only small breweries in the rural part of Bobo-Dioulasso collect their own wood.

Among those brewers that do not use an ICS, over 60% had heard about the improved stoves, but had not yet bought one. Brewers who had not yet adopted the technology were mostly those at the lower end of the size distribution. These smaller breweries face cash and credit constraints. Brewers perceive the up-front investment costs of a Roumdé as high. In addition, expensive metal cauldrons may also have to be purchased. Adding these costs to the cost the Roumdé stove itself, the brewery has to pay CFA F 47,500 - CFA F 87,500 up-front. Since to the artisanal brewers, household and production decisions are hardly separable and given the financial insecurity in which households in Burkino Faso operate, the investment strategy of brewers-households is usually not in irreversible assets (like a fixed stove) but in movable property (i.e. if cash has to be raised in case of an emergency; a fixed Roumdé for brewing cannot be sold). As known from the literature, despite the high marginal returns to investment, brewing households opt for cheaper solutions where financial risks are less (see e.g. Fafchamps and Pender, 1997; De Mel et al., 2008; Grimm et al., 2011; Fafchamps et al., 2011). In consequence, breweries may decide to adopt an inferior, but cheaper technology.

FAFASO could explore whether changes to the design of the stove could lead to less maintenance costs and also whether it would be feasible to establish a credit system to help artisanal brewers to spread the up-front investment costs over time.

[50] The survey did not directly ask for figures for turnover, value added or profits, as most *dolotières* would be reluctant to give an answer or, at least a 'correct' answer. Hence, these figures are derived from the information about the quantity of *dolo* produced, the average price per litre and the information about the cost categories.

[51] Excluding breweries that collect their firewood and hence did not declare any expenditure for buying wood.

3.6 Impacts

How much fuel wood, both in value and quantity, is effectively saved (per litre of dolo produced)?
In order to assess the impact of the use of Roumdé stove in monetary terms, two different methods were used: first, one based on the difference in firewood consumption between Roumdé users and non-users in 2012, and second, one based on the difference in the change in wood consumption between those breweries that acquired an improved stove between 2010 and 2012 and those that did not.[52] Improved stove use was modelled in two ways as well. First, by indicating whether the brewery used at least one Roumdé and second, the measurement of the use of the ICS among all stoves of the brewery, expressed in brewing stove-days.

The distribution of the value of expenditure on firewood per brewing expressed by the volume of *dolo* brewed does not show any systematic difference between breweries that use a traditional stove (or an improved traditional stove) and breweries that use a Roumdé stove for the bottom 65% of the breweries. The savings in fuel wood occur mainly for the 35% largest producers (in terms of volume of *dolo* brewed) with most benefits for the top 20%.

The key results from the econometric assessment are shown in Table 12. The results suggest that breweries that use at least one Roumdé (those brewers may still use traditional stoves simultaneously) spend about 18% less on firewood per brewing process than breweries that do not use a Roumdé stove but only a traditional or an improved traditional one. Because the 2010 survey does not allow traditional stoves to be distinguished from improved traditional ones, both categories are lumped together in the reference category. In consequence, what is estimated are savings relative to a mix of both types of stoves, hence savings are somewhat lower than if measured against traditional stoves only.

Since a substantial number of breweries use Roumdé and traditional stoves simultaneously, the estimates do not provide an estimate of how much firewood could be saved if *all brewing processes* were done on a Roumdé stove. To estimate this, the share of stove-days attributed to a Roumdé stove was used as treatment variable. This was only possible with the 2012 dataset. Also, the reference category was split into days that refer to a traditional stove and days that refer to improved traditional stoves. The estimated coefficient ranges between 0.36 and 0.38 (share of brewing stove-days with a Roumdé stove, see Annex 1, Table A6) depending on which version of the propensity score weights was used. This implies that a brewery that switches from a traditional stove to using only a Roumdé stove achieves savings in fuel wood per brewing of between 36% and 38%. This is approximately 40% less than what could have been theoretically achieved. Improved traditional stoves are associated with a saving rate of about 20% at least, although the estimate is not very precise.

[52] Because of the small number of observations in the panel sample, the latter model does not, however, include brewery fixed-effects, i.e. it is a difference-in-differences estimator, but not a fixed-effects panel estimator.

Although the results are quite robust, a few potential sources of bias have to be mentioned. First, the estimate might be downward biased, as the value of wood consumption might have been reported erroneously. Second, the estimate might be upward biased, if uptake is correlated with unobserved variables that are associated with less wood consumption, such as astuteness of the brewers, or – in the opposite direction – if Roumdé stoves were adopted by breweries that have unobserved characteristics associated with lower efficiency. However, the similarity between the saving rates identified through the matching estimator and the difference-in-differences estimator suggests that the bias that stems from unobserved characteristics is negligible. Finally, there could be a problem of reverse causality: breweries with a lower consumption of firewood per litre of *dolo* are better placed to invest in an improved stove than are less efficient breweries, which leads to an overestimated saving rate. The latter might be reinforced when credit markets fail, as is the case for *dolo* breweries. Summing up, there are biases in different directions, but they partly offset each other and therefore the estimate is believed to be sufficiently close to the real saving rate.

Table 12 Impact of Roumdé use on firewood expenditure by breweries

	Share of ICS	Savings in firewood
Average number of ICS per brewer	30-42 percent of all stoves are ICS; the larger the brewery, the higher the share of ICS	
Average savings in firewood of brewers using at least one ICS as compared to all brewers		18%
Average savings in firewood of ICS as compared to improved traditional stoves		20-21%
Average savings in firewood if only ICS are used (based on stove-days 2012)	100% are ICS	36-38%

Notes: The results of the regression analysis are shown in detail in Annex 1, Table A6.

Source: IOB estimations, based on Brewery Surveys 2010 and 2012.

Control variables indicate that production parameters such as the quantity of malt and water used, as well as the number of cauldrons in use are important determinants for firewood consumption. Whether the wood was bought from a small retailer or a wholesale dealer has little effect. The education level of the brewer also happens to be of little influence. What does matter is the location, either Ouagadougou or Bobo-Dioulasso, as this captures not only differences in the price of firewood, but also differences in how *dolo* is brewed (see Annex 1, Table A6).

Table 13 presents the estimated saving rate converted into savings per litre of *dolo* produced, both in terms of money and kilograms of firewood. The reported mean consumption of firewood per litre of *dolo* (i.e. dividing total expenditure on wood by the size of the brewing) costs CFA F 24.50. The Roumdé stove saves 36% of the firewood consumption, equivalent to CFA F 8.82 per litre. With an average price of CFA F 50 per kg firewood, the weight of the firewood saved per litre of *dolo* is 0.176 kg. The total savings per brewing amount to 42.3 kg of wood or CFA F 2,117. This is a substantial volume of fuel wood.

If the stoves are used twice a week for brewing, the value of the savings made on fuel suggests that the investment in a Roumdé stove can be amortised in 6.5 weeks if a simple traditional stove is used as reference and after 14.7 weeks if an improved traditional stove is used as reference. Given that the estimated lifespan of the Roumdé stove is at least two years, buying a Roumdé is a rational investment if the fuel wood has to be bought (and not collected), which is the case in well over 90% of the brewers in the sample. If maintenance costs (mainly replacement of cauldrons) are added, the amortisation period is extended to 7.5 weeks with the simple traditional stove as reference and 21.2 weeks with the improved traditional stove as reference.

Assuming that all the Roumdé professional stoves replaced a traditional stove, and that they have a lifespan of two years and are used for two brewings per week over 39 weeks per year, and based on the outcome of 36% reduction in fuel wood use, this represents EUR 1,085,173 of net savings per year (i.e. also accounting for the investment costs) to the breweries in the IOB sample. The total volume of wood saved by the 2,380 breweries with an ICS would be 7,500-7,700 tonnes per year.

Table 13 Wood savings related to Roumdé use by breweries, in terms of value and quantity

	Compared to traditional stove	Compared to improved traditional stove
Estimated saving rate	36%	16%
Mean firewood expenditure per litre of dolo	CFA F 24.50	CFA F 24.50
Firewood expenditure saved per litre of *dolo*	CFA F 8.82	CFA F 3.92
Firewood saved in kg per litre of *dolo*	0.176 kg	0.078 kg
Average size of a brewing (median)	240 litres	240 litres
Firewood saved per brewing in kg	42.336 kg	18.720 kg
Firewood saved per brewing in CFA F	CFA F 2,116.80	CFA F 936.00
Weeks required for amortisation, 2 brewings per week assumed	6.5	14.7
Weeks required for amortisation, incl. maintenance costs (CFA F 30,000 assumed per annum)	7.5	21.2

The price of firewood is CFA F 50.00 per kg; the price of a Roumdé stove is CFA F 27,500.

Source: IOB estimations, based on Brewery Surveys 2010 and 2012.

Whether a Roumdé stove really leads to savings in each individual brewery depends on an array of behavioural factors. More generally, tradition seems to play a very important role in *dolo* breweries: the art of making the beer is transmitted from generation to generation and does not necessarily follow economic principles in the strictest sense. For example, with one or two exceptions, breweries do not use LPG, although that would be more energy-efficient since the temperature can be regulated according to need over the two days of brewing. A commercial initiative to introduce LPG stoves for brewing in 2005 failed (a new initiative was launched in 2013). Brewers may continue to use the same quantity of fuel wood as with the traditional stove, since that is what they are familiar with, or to stoke the Roumdé stove – despite the narrow opening – with the same large tree trunks that are used to stoke traditional stoves. Even if the *dolotière* knows how to use the improved cook stove properly, there is a risk that it will be used wrongly, as other people work in the brewery (including *dolotières* who rent a cauldron for their brewing) and they may not know how to use the stove correctly.

3.7 Sustainability

In the evaluation, sustainability was considered at two levels. First, whether the current users will continue to use the improved technology of the Roumdé stove. And second, whether the market supported by FAFASO can continue to count on a sustainable supply and demand.

Are current users likely to continue using the improved stoves?
The main reason users gave for buying a Roumdé stove was its higher fuel efficiency, although they often mentioned that it requires much of effort and knowledge to achieve the full potential in energy savings of the stove and to benefit from it. Given the relatively high financial savings obtained from the combustion efficiency it is likely that current users will continue to use ICS. The adoption of an improved stove, however, is not necessarily accompanied by the behavioural change needed. Despite acquiring the new stove, some brewers and their helpers continue to work as they have always done and continue to use the same amount of fuel wood, even if less would suffice.

If the current stoves become irreparable there are sufficient stove builders to install stoves in the future.

Field visits indicated that many of the Roumdé stoves are in a poor state (more than suggested by the distribution of *reported* quality of stoves in the survey). In particular, the surround of the opening and the inside of the combustion chamber were often damaged, due to the practice of forcing large tree trunks through the small opening. However, only a few stoves were in a dire state. The cauldrons may also be damaged by the high temperature that is achieved with an improved stove as a result of the insulation and concentration of the combustion. This damage reduces the efficiency of Roumdé stoves. On-site tests conducted by IRSAT in breweries suggest that heavily damaged improved stoves are hardly better (and maybe even worse) than traditional stoves (Sanogo et al., 2011).

Respondents reported problems related to maintenance: 19% perceived the lifespan of an ICS as too short, while 15% complained about the low quality of the surround and another 4% referred directly to the maintenance costs. Changing the cauldrons of a Roumdé is often done by a stove builder and costs about CFA F 1,000 to 2,000[53] (although FAFASO has trained some *dolotières* to change the cauldrons themselves) and hence requires a cash outlay. Changing the cauldrons of a traditional stove is done by the brewer herself. Because of the intense heat they are subjected to, cauldrons made of clay have a relatively short lifespan and need to be changed regularly. Using aluminium cauldrons would avoid frequent replacements, but these cauldrons are expensive and hence add to the investment costs. A simple comparison of means shows that Roumdé users spend CFA F 30,000 annually on maintenance, which is over three times more than users of traditional stoves (CFA F 9,000 annually). In a multivariate regression framework, i.e. accounting for differences in size of the brewery and other factors, users of Roumdé stoves spend on average 50% more on maintenance than users of traditional and improved traditional stoves. Nevertheless, the costs of replacing cauldrons and repairing the surround of the opening to the combustion chamber is mainly a psychological burden, since the direct and indirect maintenance costs do not substantially affect the return on investment for ICS users.

Respondents also indicated that traditional stoves typically have five cauldrons, whereas most Roumdés have only four. Hence a Roumdé stove offers less brewing capacity but needs more or less the same physical space.

Can the market count on lasting supply and demand? Is the market for improved stoves for dolo brewing likely to last (once FAFASO withdraws its support)?

In 2010, FAFASO started to create a market for improved stoves for artisanal beer producers. By 2012, just two years later, about 50% of all breweries in Ouagadougou and Bobo-Dioulasso city had adopted the new technology. Since then, adoption has downturned. The exact reason for this reversal is unknown, but it could well be that most interested brewers have acquired an improved stove and hence the market is saturated. This assumption is supported by the fact that the improved stove is the most advantageous for larger brewers and most of these larger breweries have already acquired a Roumdé stove.

In Ouagadougou, there are as many improved traditional stoves as there are Roumdé professional stoves. These improved traditional stoves are less costly than the Roumdé model and 35% had been made by the brewer herself. The improved traditional stoves are more heterogeneous than the Roumdé and therefore it is difficult to estimate their real cost, as this depends on the stove's characteristics and size. On average, such stoves reduce fuel wood consumption by some 16%. Brewers who have not yet purchased a Roumdé stove may opt for an improved traditional stove instead of a Roumdé.

Whereas the association of brewers seems to be a dynamic and engaged group, the association of stove technicians is less dynamic, particularly in innovative potential. Stove builders seem to be inclined to offer lower quality instead of promoting quality and striving for further quality improvements. In 2012, FAFASO started to train '*dolo* masons' into construct stoves for the production of shea butter. This should enlarge their market.

[53] Source: Cost estimate by FAFASO.

Although the government of Burkina Faso agrees with the chosen strategy in principle, its active engagement in the area of promoting fuel efficiency in the use of biomass has been modest. The government's further commitment is needed in market-supporting areas such as awareness-raising, marketing campaigns and institutionalisation of the quality assurance, particularly after FAFASO involvement is reduced or withdrawn.

Whether FAFASO's objective of establishing a sustainable market for Roumdé brewing stoves will be achieved cannot yet be ascertained. It can be assumed that the current users will continue to use ICS, but substantial further uptake by smaller breweries is unlikely.

How sustainable is the activity of dolo brewing?
This study does not encompass a forecast for the demand for *dolo*. The producers' association reported that the market for *dolo* beer is shrinking in urban areas, since consumers are increasingly opting for 'modern' industrial beer. This change is not propelled by the slow, but gradual, increase in average income level, but more by youngsters' identification with a 'modern' urban lifestyle. Even if the urban higher income brackets stop consuming *dolo*, both tradition and the price difference between *dolo* and modern beer make it likely that *dolo* will continue to occupy its own market niche, but it is not expected that this segment will expand over time.

Annexes

Annex 1 Tables

Table A1	**Probit estimates of using an improved stove for domestic use**		
Independent variables	**Coefficient (SE), set 1**	**Coefficient (SE), set 2**	**w/t LPG only users Coefficient (SE)**
Head of the household is male (=1)	-0.170* (0.098)	-0.158* (0.095)	-0.140 (0.103)
Age of the head of the hh	0.002 (0.003)	0.001 (0.003)	-0.001 (0.004)
Household size	-0.002 (0.012)	-0.008 (0.012)	-0.010 (0.013)
Share of children aged 15 or less in the hh	-0.019 (0.185)	-0.030 (0.182)	-0.230 (0.202)
Share of people aged 65 or more in the hh	-0.211 (0.484)	-0.251 (0.487)	-0.011 (0.610)
Mossi – Ethnicity (=1)	0.031 (0.077)	0.040 (0.077)	-0.016 (0.086)
Head of the hh has primary education (=1)	-0.025 (0.092)	-0.026 (0.082)	-0.025 (0.088)
Head of the hh's spouse has primary education (=1)	0.157* (0.092)	0.131 (0.084)	0.079 (0.089)
Head of the hh has secondary education (=1)	0.025 (0.092)		
Head of the hh's spouse has secondary education (=1)	0.070 (0.096)		
Head of the hh employed in independent activity (=1)	-0.029 (0.070)	-0.032 (0.069)	-0.055 (0.074)
Ouagadougou (=1)	-0.059 (0.087)	-0.072 (0.088)	-0.013 (0.093)
Owner of the house (=1)	-0.056 (0.078)	-0.069 (0.078)	-0.090 (0.087)
Electricity in the house (=1)	0.272*** (0.086)	0.238** (0.117)	0.202* (0.123)
Head of the hh (male or female) is responsible for the budget	Ref.	Ref.	Ref.
Spouse of the head of the hh (female) is responsible for the budget	-0.162 (0.113)	-0.159 (0.112)	-0.214* (0.124)
Head and spouse together are responsible for the budget	0.189* (0.115)	0.199* (0.115)	0.119 (0.126)
Several hh members together are responsible for the budget	-0.266* (0.145)	-0.270* (0.146)	-0.299* (0.156)
Log of per capita monthly hh expenditure	0.069 (0.052)		

First asset quintile		Ref.	Ref.
Second asset quintile		-0.086 (0.110)	-0.060 (0.113)
Third asset quintile		-0.015 (0.136)	0.008 (0.142)
Fourth asset quintile		0.109 (0.138)	0.172 (0.148)
Fifth asset quintile		0.165 (0.142)	0.172 (0.152)
Constant	-2.090*** (0.555)	-1.307*** (0.203)	-1.065*** (0.230)
Pseudo R^2	0.021	0.023	0.025
Number of observations	1128	1128	972

Notes: 38 observations lost due to missing information on explanatory variables. Observations are weighted. Set 2 excludes the likely self-selection resulting from the educational level.
* p<0.10, ** p<0.05, *** p<0.01.

Source: Improved Stove Dataset 2011.

Table A2 Estimated impacts of ICS usage on monthly firewood and cooking expenditure (in CFA F, standard errors are shown in parentheses)

	Expenditure on firewood		Expenditure on fuel for cooking			
	households using only firewood		households using only firewood and/or charcoal			
			all households		lower three quintiles	
	Basic OLS (1)	PSM-w (2)	Basic OLS (3)	PSM-w (4)	Basic OLS (5)	PSM-w (6)
Most often used stove						
Non-ICS	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
ICS	-0.059 (0.092)	-0.112 (0.084)	-0.119* (0.065)	-0.121* (0.065)	-0.079 (0.070)	-0.076 (0.071)
ICS and non-ICS	-0.000 (0.449)	0.095 (0.444)	-0.005 (0.150)	0.000 (0.146)	-0.095 (0.190)	-0.070 (0.180)
LPG	.	.	0.204 (0.164)	0.216 (0.194)	0.245*** (0.086)	0.230*** (0.081)
Household uses charcoal only			-0.098 (0.074)	-0.086 (0.082)	-0.093 (0.081)	-0.072 (0.084)
Ln number of uses of wood fuel per week	0.456*** (0.112)	0.447*** (0.089)	0.342*** (0.070)	0.360*** (0.068)	0.358*** (0.087)	0.383*** (0.079)
Outdoor cooking	0.144 (0.107)	0.071 (0.092)	0.002 (0.077)	0.074 (0.083)	-0.042 (0.090)	0.011 (0.085)
Adult equivalents meal is cooked for	0.041 (0.044)	0.025 (0.034)	0.067** (0.033)	0.053* (0.028)	0.084** (0.041)	0.082** (0.038)
Adult equivalents meal is cooked for squared	-0.001 (0.003)	0.001 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.004 (0.002)	-0.003 (0.002)
Any person responsible for cooking has secondary education	-0.079 (0.111)	-0.054 (0.093)	-0.020 (0.069)	-0.014 (0.071)	0.034 (0.076)	0.056 (0.073)

Table continues next page.

Table A2 (continued)

	Expenditure on firewood		Expenditure on fuel for cooking			
	households using only firewood		households using only firewood and/or charcoal			
			all households		lower three quintiles	
	Basic OLS (1)	PSM-w (2)	Basic OLS (3)	PSM-w (4)	Basic OLS (5)	PSM-w (6)
Household head has secondary education	0.052 (0.125)	0.017 (0.106)	0.105 (0.075)	0.140* (0.078)	-0.001 (0.087)	-0.040 (0.079)
Household head is female	0.164* (0.094)	0.155* (0.087)	0.168** (0.081)	0.107 (0.081)	0.203** (0.087)	0.094 (0.084)
Household has bank account	-0.233* (0.140)	-0.250** (0.106)	-0.125 (0.083)	-0.170** (0.079)	-0.091 (0.093)	-0.118 (0.078)
Earth floor	0.092 (0.080)	0.011 (0.079)	0.014 (0.061)	0.017 (0.060)	0.006 (0.072)	-0.025 (0.069)
Hh has electricity	0.118 (0.092)	0.126 (0.077)	0.171*** (0.059)	0.235*** (0.057)	0.211*** (0.069)	0.252*** (0.063)
Ouagadougou	0.618*** (0.091)	0.474*** (0.083)	0.400*** (0.062)	0.357*** (0.061)	0.421*** (0.074)	0.441*** (0.069)
Ln total monthly household expenditure	0.165*** (0.052)	0.135*** (0.051)	0.148*** (0.041)	0.117*** (0.041)	0.175** (0.073)	0.193*** (0.069)
Constant	4.740*** (0.567)	5.344*** (0.499)	5.498*** (0.474)	5.767*** (0.500)	5.109*** (0.716)	4.797*** (0.629)
Number of households	222	219	533	524	400	392
Breusch-Pagan (Heteroscedasticity)	0.422	0. 422	0.135	0.135	0.012	0.012
R-squared	0.392	0.428	0.274	0.263	0.311	0.339

*Note: IOB estimations. Standard errors are clustered within households. * p<0.10, ** p<0.05, *** p<0.01.*

Source: Improved Stove Dataset 2011.

Table A3 Estimated impacts of ICS use on firewood and charcoal consumption per dish (kg, standard errors are shown in parentheses)

	Firewood total	Firewood total	Firewood per cap.	Charcoal total	Charcoal total	Charcoal per cap.
	Basic OLS (1)	OLS PS weighted (2)	Basic OLS (3)	Basic OLS (4)	OLS PS weighted (5)	Basic OLS (6)
Three-stone	Ref.	Ref.	Ref.			
Malagasy stove	0.004 (0.079)	-0.074 (0.075)	0.012 (0.081)	Ref.	Ref.	Ref.
ICS	-0.277*** (0.083)	-0.284*** (0.076)	-0.262*** (0.084)	-0.149* (0.089)	-0.126 (0.083)	-0.150* (0.091)
Imitation ICS	-0.155 (0.099)	-0.204** (0.103)	-0.137 (0.099)	0.151 (0.103)	0.159 (0.117)	0.162 (0.105)
Breakfast	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Midday meal	0.229** (0.102)	0.258*** (0.097)	0.208** (0.105)	0.249** (0.113)	0.183* (0.099)	0.225* (0.115)
Evening meal	0.253*** (0.086)	0.248*** (0.081)	0.194** (0.088)	0.106 (0.087)	0.098 (0.077)	0.032 (0.091)
One full meal per day	0.190*** (0.069)	0.162** (0.065)	0.211*** (0.070)	-0.098 (0.089)	0.013 (0.084)	-0.124 (0.091)
Side dish	-0.119 (0.087)	-0.125 (0.076)	-0.124 (0.088)	-0.053 (0.096)	0.013 (0.084)	-0.068 (0.101)
Quick dish (<30 min)	-0.475*** (0.088)	-0.512*** (0.081)	-0.418*** (0.089)	-0.568*** (0.091)	-0.638*** (0.089)	-0.546*** (0.092)
Outdoor cooking	0.090 (0.077)	0.044 (0.073)	0.088 (0.078)	0.021 (0.093)	0.028 (0.084)	-0.004 (0.097)
Several stoves used per meal	-0.041 (0.072)	-0.131** (0.064)	-0.034 (0.074)	-0.156 (0.109)	-0.236** (0.095)	-0.168 (0.115)
Fuel used for several dishes	0.022 (0.077)	0.033 (0.069)	0.013 (0.079)	0.222** (0.108)	0.174* (0.103)	0.177 (0.109)
Number of adult equivalents meal is cooked for	0.029 (0.033)	0.052 (0.032)	-0.226*** (0.034)	0.013 (0.053)	0.044 (0.050)	-0.328*** (0.058)
Squared number of adult equivalents meal is cooked for	0.002 (0.002)	-0.001 (0.002)	0.009*** (0.002)	0.001 (0.004)	-0.001 (0.003)	0.013*** (0.004)

Table continues next page.

Table A3 (continued)

	Firewood total	Firewood total	Firewood per cap.	Charcoal total	Charcoal total	Charcoal per cap.
	Basic OLS (1)	OLS PS weighted (2)	Basic OLS (3)	Basic OLS (4)	OLS PS weighted (5)	Basic OLS (6)
Household head female	0.005 (0.081)	-0.022 (0.069)	0.030 (0.081)	0.004 (0.102)	-0.009 (0.094)	0.040 (0.106)
Cook has completed at least secondary school	-0.015 (0.072)	0.058 (0.067)	-0.056 (0.072)	-0.056 (0.085)	-0.009 (0.081)	-0.074 (0.087)
Household has bank account	0.259*** (0.067)	0.185*** (0.064)	0.280*** (0.069)	0.179** (0.090)	0.107 (0.081)	0.236** (0.092)
Earth floor	-0.382*** (0.083)	-0.384*** (0.079)	-0.383*** (0.084)	-0.692*** (0.112)	-0.652*** (0.101)	-0.697*** (0.116)
Household has electricity	-0.108 (0.069)	-0.053 (0.065)	-0.090 (0.070)	-0.085 (0.106)	0.022 (0.091)	-0.108 (0.110)
Sector effects	yes	yes	yes	yes	yes	yes
Number of observations	982	982	977	776	776	772
Number of households	662	662	660	516	516	515
Distribution of stoves per household						
1 stove	419	419	419	320	320	320
2 stoves	181	181	179	148	148	148
3 stoves	50	50	50	40	40	39
4 and more stoves	12	12	12	8	8	8
t-Test ICS vs. Malagasy (*p*-value)	0.003	0.013	0.004			
t-Test ICS vs. Imitation ICS (*p*-value)	0.240	0.438	0.232	0.025	0.038	0.023
R-squared	0.288	0.269	0.298	0.325	0.268	0.422

*Note: IOB estimations. Standard errors are clustered within households. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.*

Source: Improved Stove Dataset 2011.

Table A4 Cooking duration per dish and per day, in minutes

Main dishes, midday and evening meals only				All meals, per day	
	Firewood only	Charcoal only			
	PSM-weighted	PSM-weighted		Basic OLS	PSM-weighted
			Stove used most often		
Three-stone	Ref.		Non-ICS	Ref.	Ref.
Malagasy stove	-1.054 (4.655)	Ref.	ICS	-6.542 (4.628)	-7.757* (4.539)
ICS	-12.845*** (4.282)	-2.054 (4.371)	ICS and non-ICS	-17.841** (7.139)	-19.409*** (6.818)
Imitation ICS	-3.462 (5.766)	14.277** -5.931	LPG	-10.289 (6.251)	-11.900** (5.001)
Sector effects	yes	yes	Sector effects	Yes	yes
Constant	131.246*** (11.148)	107.454*** (19.972)	Constant	112.081*** (11.682)	101.337*** (10.864)
Number of obs.	687	315	Number of obs.	923	911
R-squared	0.200	0.243	R-squared	0.484	0.485

Source: Improved Stove Dataset 2011.

Table A5	**Estimates of using an improved stove for productive use, marginal effects**	
Dependent Variable: Uses a Roumdé stove	**Coefficient of marginal effect (Standard error)**	**Coefficient of marginal effect (Standard error)**
(Natural logarithm) quantity of dolo per brewing (in litres)		0.199 (0.070)***
Age of dolotière	0.008[a] (0.022)	0.008 (0.022)
At least primary schooling completed (=1)	0.200 (0.078)**	0.170 (0.080)**
Mossi	0.214 (0.121)*	0.227 (0.123)*
Bobo	0.272 (0.185)	0.304 (0.183)*
In dolo business (years)	0.030 (0.012)**	0.024 (0.012)*
Ouagadougou/Centre Region	0.600 (0.089)***	0.542 (0.103)***
Urban	0.774 (0.104)***	0.740 (0.117)***
Ouagadougou X Urban (Interaction)	-0.547[b] (0.051)***	-0.552 (0.051)***
Pseudo R^2	0.236	0.261
Number of interviews	253	253

Notes: The coefficients show marginal effects, i.e. the change in the probability of uptake for one unit-change in the explanatory variable (or a change from 0 to 1 for binary categorical variables).

Consider

[a] *as example: the chance that a brewer uses a Roumdé stoves increases by 0.08% for each year of age.*

[b] *The interaction variable is needed to compensate for the overlap between urban residence and Ouagadougou residence.*

** = significant at 10%, ** = significant at 5%, *** = significant at 1%. Robust standard errors are shown in parentheses. For simplicity, the square age of the dolotière and the square years in dolo business, both with a coefficient of 0,000 have been suppressed. These do count, however, for the pseudo R^2.*

Source: IOB estimations, based on Brewery Survey in 2012.

Table A6 Details of regressions impact of Roumdé on firewood consumption

	OLS-CS 2012 PS weights I	OLS-CS 2012 PS weights II	OLS-CS 2012 PS weights I	OLS-CS 2012 PS weights II	Diff-in-Diff param.
Type of stove used					
Traditional/traditional improved stove	Ref.	Ref.			Ref.
Roumdé stove	-0.182*** (0.064)	-0.185*** (0.064)			-0.143 (0.340)
Type of stove used, by share of brewing days					
Traditional stove			Ref.	Ref.	
Improved traditional stove			-0.199	-0.214	
Roumdé stove			-0.358** (0.163)	-0.376** (0.153)	
Condition of stove by share of brewing days					
Good	Ref.	Ref.	Ref.	Ref.	
Cracked	0.036	0.071	0.053	0.094	
Shabby	0.104 (0.135)	0.070 (0.106)	0.080 (0.116)	0.071 (0.102)	
Ln Number of cauldrons	0.428*** (0.120)	0.314*** (0.096)	0.434*** (0.124)	0.307*** (0.095)	
Ln quantity of *dolo* per brewing (in litres)	0.045 (0.126)	0.138 (0.116)	0.065 (0.123)	0.157 (0.114)	0.083 (0.274)
Ln quantity of malt per brewing (in kg)	0.491** (0.205)	0.404** (0.168)	0.458** (0.197)	0.371** (0.166)	1.112*** (0.272)
Ln quantity of water per brewing (in barrels)	0.119 (0.172)	0.258* (0.141)	0.118 (0.165)	0.268* (0.136)	
Wood supply (share of breweries)					
Small quantities bought	Ref.	Ref.	Ref.	Ref.	Ref.
From cart	-0.037 (0.084)	-0.038 (0.075)	-0.045 (0.083)	-0.057 (0.073)	-0.250 (0.160)
From lorry	-0.007 (0.101)	0.022 (0.095)	-0.029 (0.112)	0.007 (0.104)	0.268 (0.249)
From (large) truck	0.155* (0.079)	0.102 (0.075)	0.157* (0.082)	0.102 (0.077)	0.343 (0.281)

Table continues next page.

Table A6 (continued)

	OLS-CS 2012 PS weights I	OLS-CS 2012 PS weights II	OLS-CS 2012 PS weights I	OLS-CS 2012 PS weights II	Diff-in-Diff param.
Ethnic group					
	(0.000)	(0.000)	(0.000)	(0.000)	
At least primary school completed (=1)	0.129 (0.113)	0.005 (0.080)	0.122 (0.107)	0.002 (0.078)	-0.184 (0.230)
Age *dolotière*	-0.059** (0.025)	-0.048* (0.025)	-0.064*** (0.024)	-0.054** (0.025)	
Age *dolotière* (sq.)	0.001***	0.001**	0.001***	0.001**	
Mossi (=1)	-0.166 (0.131)	-0.233** (0.117)	-0.196 (0.121)	-0.257** (0.116)	-0.415* (0.221)
Bobo (=1)	0.165 (0.117)	0.159 (0.110)	0.141 (0.121)	0.170 (0.112)	-0.719** (0.313)
Other (=1)	Ref.	Ref.	Ref.	Ref.	Ref.
In Dolo business (years)	0.006 (0.010)	-0.001 (0.011)	0.009 (0.011)	-0.002 (0.011)	
In Dolo business (years) (sq)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	
Ouagadougou/Centre Region	0.802*** (0.133)	0.705*** (0.129)	0.875*** (0.165)	0.799*** (0.160)	-0.299 (0.322)
Urban (=1)	0.968*** (0.095)	0.934*** (0.093)	1.013*** (0.126)	0.993*** (0.115)	
Ouagad. X Urban (Interaction)	-0.730*** (0.127)	-0.730*** (0.119)	-0.754*** (0.142)	-0.772*** (0.129)	
Time effect (2012)					-0.561*** (0.163)
Treatment group (user of Roumdé)					-0.038 (0.275)
Intercept	5.565*** (0.887)	5.416*** (0.792)	5.842*** (0.767)	5.714*** (0.768)	-1.235 (1.499)
R-squared	0.766	0.806	0.768	0.807	0.655
N	236	236	236	236	66

*Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors are shown in parentheses. The variable 'quantity of dolo produced' may change after an improved stove has been acquired, so this variable has to be considered as endogenous: the first (left) column shows the regression without the quantity of dolo produced, the second column shows the regression with this variable.*

Source: IOB estimations, based on Brewery Surveys in 2010 and 2012.

Table A7 Characteristics of breweries in 2012

	Ouagadougou		Bobo-Dioulasso		Bobo city only	
	Mean	standard deviation	Mean	standard deviation	Mean	standard deviation
Number of paid employees	1.09	2.05	0.37	0.74	1.00	0.98
Number of stoves	1.79	0.92	0.48	0.50	1.50	0.58
Distribution of stoves by type						
Number of traditional stoves	0.12	0.45	0.48	0.50	0.12	0.33
Number of improved traditional stoves	0.85	0.91	0.42	0.59	0.62	0.75
Number of Roumdé stoves	0.81	1.02	0.27	0.61	0.77	0.82
Share of breweries with at least one Roumdé	0.49		0.18		0.54	0.51
Number of cauldrons	6.58	3.52	5.89	2.65	8.08	3.07
Aluminium	0.93	0.25	0.01	0.11	0	0
Clay	0.04	0.21	0.98	0.15	1.00	-
Age of stove (years)	8.51	12.41	10.34	9.58	9.38	11.23
Condition of stoves (shares of stoves)						
Good	0.50	0.44	0.85	0.35	0.61	0.48
Cracked	0.36	0.45	0.11	0.30	0.31	0.43
Poor	0.14	0.31	0.04	0.16	0.08	0.20
Number of brewings per week	1.99	0.85	1.71	1.60	1.58	0.88

Table continues next page.

Table A7 (continued)

	Ouagadougou		Bobo-Dioulasso		Bobo city only	
	Mean	standard deviation	Mean	standard deviation	Mean	standard deviation
Share of brewing days by type of stove						
Improved traditional stove	0.51	0.42	0.95	0.48	0.38	0.50
Roumdé stove	0.44	0.48	0.17	0.38	0.50	0.51
Share of breweries using only improved Roumdé	0.38		0.17		0.50	0.51
Quantity of Dolo per brewing (in litres)	368.91	277.80	159.45	79.24	217.50	95.43
Quantity of malt per brewing (in kg)	85.37	77.72	41.26	16.77	57.24	18.55
Quantity of water per brewing (in barrels)	7.26	8.08	2.70	1.07	3.65	0.98
Expenditure on firewood per brewing [54]	8,956.90	9,939.61	4,149.67	2,968.83	7,375.00	2,096.72
Wood delivery (share of breweries)						
Collecting or cutting wood	0.02		0.08		0	0
Buys in small quantities	0.22		0.34		0.35	0.49
From cart	0.40		0.46		0.23	0.43
From lorry	0.03		0.01		0.38	0.20
From (large) truck	0.32		0.12		0.38	0.50
Number of observations	178	83	26			

Source: IOB estimations, based on Brewery Survey in 2012.

54 Not counting the brewers who collect or cut their own firewood.

Annex 2 Brief note on applied techniques

This study made use of 'mixed methods' to assess the impact of the introduction of improved cooking stoves. Mixed methods imply the integrated and mutually reinforcing application of both qualitative and quantitative techniques. In order to identify effects or impact, the challenge is to attribute observed results to the intervention. That is not simple, because an array of other (unobserved) factors that have nothing to do with the intervention, may have contributed to the results as well. The comparison to a counterfactual situation is therefore of utmost importance: it is not sufficient to have measured results before and after the intervention, but also to know what would have happened in absence of it.

Therefore, an unbiased assessment takes into account the influence of specific characteristics of the users to determine the effects of the intervention itself. In the case of improved cooking stoves, for example, researchers may observe that the use of improved stoves saves hardly any firewood. This is not because the ICS is not fuel efficient, but because users may change their cooking habits when using an improved stove, for example by preparing more dishes or by having warm water throughout the day. But even this effect may be attributed to other factors as well, such as a higher awareness of hygiene. That is why researchers prefer to compare the results in the intervention group (called the 'treatment group', in this case: the ICS owners) with a 'control group' (the group that does not own or use an ICS). If this control group has characteristics that differ from those of the intervention group, results may still be biased: for instance if the owners of ICS have larger families, or have completed a higher educational level. The neglect of selection effects may lead to biased estimates of effects (and therefore wrong conclusions).

Ideally, researchers select the treatment group and control group by random assignment. This is the best way to ensure that both groups have the same characteristics and that differences in results between both groups can be attributed to the intervention. This is common practice in medicine testing, for example. The generic term applied for these random assignments is 'randomised controlled trial – RCT'. In socio-economic studies, however, random assignment is difficult or impossible. Sometimes the control group can be constructed afterwards, instead of identified prior to the intervention. The researcher tries to find for each person (or household) in the treatment group one or more persons with the same characteristics (such as household characteristics, age, income, urban/rural, etc.) for the control group. A high degree of similarity between the intervention group and control group reduces the risk of potential selection bias attributable to differences in observable and as well unobservable characteristics. Forming pairs of persons (or households or breweries, like in this study) is complicated and time consuming, but statistical theory is helpful in this regard. The method of *propensity score matching* (PSM) forms pairs by matching on the probability of treatment, in this case of being owner of an ICS. In other words it determines the likelihood (propensity) that someone with the same characteristics acquires an ICS. The method uses all information available (such as household characteristics) to construct a control group. This concerns variables of which one can reasonably assume that they are unlikely to be affected by the intervention (e.g. educational attainment, ownership of certain assets). The PSM is particularly useful when it is not possible (or feasible) to conduct surveys at different moments in time (i.e. cross-sectional analysis). The matching procedure is based on regression techniques.

Regression analysis is a statistical technique for studying how a variable of interest (e.g. the use of firewood) is related to one or more other variables (such as the type of stove, but also household characteristics such as income or educational level). The analysis uses mathematical function relations between variables: $Y = a + bX + cZ$, where Y is the variable of interest, X may be the intervention and Z a control variable. The estimated *coefficients* a, b and c indicate how in the sample the variable of interest responds to changes in the other variables, for example the use of wood on improved cooking stoves (X), controlling for specific household characteristics (Z). Regression analysis therefore is also a technique to get unbiased estimates of the effect of an intervention as long as selection is based on observable characteristics (Z).

In general, statistical analysis is based on samples and not on the entire population. This implies the risk that the data in the sample suggest a relationship that in practice does not exist or does not occur (or that is larger or smaller). Several statistical measures have been developed to assess that probability, such as t-values and z-scores. These are based on *standard errors* that describe the error margin of a specific estimate. High t-values (or low standard errors) are a sign that the estimated coefficients reflect a true relationship and are not just the coincidental outcome of a particular sample. The normal benchmark for t-values and z-scores in the analysis of social data is an absolute value of about 2 or higher. With t-values so high one would only rarely (one case out of every 20 observations or measurements) be mistaken in concluding that a true relationship exists.

The most common regression technique is Ordinary Least Squares (OLS).[55] However, OLS cannot solve the problem of *selection on unobservables*: unknown differences between control group and intervention group that lead to different results (such as wood usage). As long as these unobserved variables do not change over time (such as education, rural/urban divide, etc.) this problem may be solved by using a difference- in-differences approach (Diff-in-Diff). This approach is applied if measurement of change in both the intervention group and the control group can be registered at two moments in time (a baseline and a follow-up survey). The Diff-in-Diff technique analyses changes over time (before and after the intervention): $(Y_1-Y_0) = a + b(X_1-X_0) + c(Z_1-Z_0)$. Now, if Z does not change over time, $Z_1=Z_0$ and therefore $(Z_1-Z_0)=0$. This means that the variable can have no impact on the change in the dependent variable (Y_1-Y_0). Diff-in-Diff allows controlling for all confounding factors that may have an impact on the outcomes of interest and that are constant over time: it is a way to eliminate or filter out *time invariant* unobservable variables.

In this study another regression technique is used as well: the *probit analysis* (probit estimation). OLS assumes a continuous variable (like time, or wood usage). Sometimes, however, the variable of interest is a *binary variable* (that only has two values, for instance a

55 The term OLS refers to the specific technique that is used for the computation of the coefficients.

household owns or does not own an ICS). With a *probit* analysis it is possible to estimate the *probability* that an observation with particular characteristics will fall into one of the two categories. And as probability is a continuous variable, it may be estimated using standard regression techniques. Propensity score matching, for instance, may use probit models for estimating the probability of pertaining to a specific category.

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Annex 4 About IOB

Objectives

The remit of the Policy and Operations Evaluation Department (IOB) is to increase insight into the implementation and effects of Dutch foreign policy. IOB meets the need for the independent evaluation of policy and operations in all the policy fields of the Homogenous Budget for International Cooperation (HGIS). IOB also advises on the planning and implementation of evaluations that are the responsibility of policy departments of the Ministry of Foreign Affairs and embassies of the Kingdom of the Netherlands.

Its evaluations enable the Minister of Foreign Affairs and the Minister for Foreign Trade and Development Cooperation to account to parliament for policy and the allocation of resources. In addition, the evaluations aim to derive lessons for the future. To this end, efforts are made to incorporate the findings of evaluations of the Ministry of Foreign Affairs' policy cycle. Evaluation reports are used to provide targeted feedback, with a view to improving the formulation and implementation of policy. Insight into the outcomes of implemented policies allows policymakers to devise measures that are more effective and focused.

Organisation and quality assurance

IOB has a staff of experienced evaluators and its own budget. When carrying out evaluations it calls on assistance from external experts with specialised knowledge of the topic under investigation. To monitor the quality of its evaluations IOB sets up a reference group for each evaluation, which includes not only external experts but also interested parties from within the ministry and other stakeholders. In addition, an Advisory Panel of four independent experts provides feedback and advice on the usefulness and use made of evaluations. The panel's reports are made publicly available and also address topics requested by the ministry or selected by the panel.

Programming of evaluations

IOB consults with the policy departments to draw up a ministry-wide evaluation programme. This rolling multi-annual programme is adjusted annually and included in the Explanatory Memorandum to the ministry's budget. IOB bears final responsibility for the programming of evaluations in development cooperation and advises on the programming of foreign policy evaluations. The themes for evaluation are arrived at in response to requests from parliament and from the ministry, or are selected because they are issues of societal concern. IOB actively coordinates its evaluation programming with that of other donors and development organisations.

Approach and methodology

Initially IOB's activities took the form of separate project evaluations for the Minister for Development Cooperation. Since 1985, evaluations have become more comprehensive, covering sectors, themes and countries. Moreover, since then, IOB's reports have been submitted to parliament, thus entering the public domain. The review of foreign policy and a reorganisation of the Ministry of Foreign Affairs in 1996 resulted in IOB's remit being extended to cover the entire foreign policy of the Dutch government. In recent years it has extended its partnerships with similar departments in other countries, for instance through joint evaluations and evaluative activities undertaken under the auspices of the OECD-DAC Network on Development Evaluation.

IOB has continuously expanded its methodological repertoire. More emphasis is now given to robust impact evaluations implemented through an approach in which both quantitative and qualitative methods are applied. IOB also undertakes policy reviews as a type of evaluation. Finally, it conducts systematic reviews of available evaluative and research material relating to priority policy areas.

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Over 500 million households worldwide rely on biomass for daily cooking. Wood energy is also used for small industrial processes. Fuel efficient cooking stoves are seen as low-cost solution to help reduce greenhouse gases, improve indoor air quality, relieve the daily workload of women and to reduce expenditure on energy.

IOB evaluated the impact of improved cooking stoves (ICS) for domestic use and artisanal beer brewing in two cities in Burkina Faso. In this context, the impact of ICS on the workload of women or health was found to be negligible, but users spend less on energy and a vast volume of fuel wood is saved each year.

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