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IS-Academy RENEW

An enabling environment for fostering sustainable cooking energy enterprises in Rwanda

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Acknowledgement/Preface

This report is part of the IS Academy project, the objective of which is to improve the understanding of renewable energy and energy efficient technologies for energy access in developing countries. This project is jointly carried out by ECN, IVM (Vrije Universiteit) and DGIS (Ministry of Foreign Affairs). The author would like to thank Jos Bruggink (ECN), Raouf Saidi (ECN) and Rahul Barua (IVM/ECN) for their contributions and for reviewing and commenting on the report. The author would also like to thank the experts that availed themselves to participate in this study.

Abstract

In recent years a paradigm shift has occurred in development towards harnessing latent entrepreneurship and leveraging the capabilities of the private sector to make markets work for the poor. The premise of this shift is that through economic development driven by the private sector the forces that perpetuate poverty in developing countries will be weakened, leading to sustainable poverty alleviation. The purported driving force for unleashing entrepreneurial capability are inclusive business models targeting the Bottom of the Pyramid, those living at the bottom tier of the economic pyramid living on less than $1 per day. Business models represent the core logic of a company, and are inextricably linked to the external environment, as businesses do not operate in a vacuum. In the external environment, barriers beyond the influence of the entrepreneur can impede the realisation of business opportunities. The role of the policy maker is thus (although not exclusively) to remove such barriers in order to create an enabling environment in which businesses can thrive. Through a case-study of sustainable cooking energy enterprises in Rwanda, the most salient barriers are articulated and potential policy mechanisms for removing these barriers and creating an enabling environment are presented.

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List of abbreviations

BDS	Business Development Services
BM	Business Model
BoP	Base of the Pyramid / Bottom of the Pyramid
CASE	Community-Aided Access to Sustainable Energy
CDM	Clean Development Mechanism
DFID	Department for International Development (UK)
DGIS	Directorate General for International Cooperation
DRC	Democratic Republic of the Congo
ECN	Energy research Centre of the Netherlands
FSC	Forest Stewardship Council
GHG	Greenhouse Gas
GoR	Government of Rwanda
ICT	Information and Communication Technology
IFDC	International Center for Soil Fertility and Agricultural Development
IMF	International Monetary Fund
IVM	Institute for Environmental Studies
KIST	Kigali Institute of Science and Technology
MNC	Multinational Corporation
MSW	Municipal Solid Waste
PM_{10}	Particulate Matter of a size 10 micrometres or less
PPP	Public – Private Partnership
PSF	Private Sector Foundation
SME	Small & Medium Enterprise
TBIF	Technology and Business Incubation Facility
VC	Value Chain
W2E	Waste to Energy
WHO	World Health Organisation

Executive Summary

As part of the IS Academy RENEW project, which has the overarching objective of improving the understanding of renewable energy and energy efficient technologies for energy access in developing countries, a study was performed on the cooking energy sector of Kigali, Rwanda, with the purpose of identifying barriers to entrepreneurialism in order that policy actions can be shaped to develop an enabling environment for sustainable cooking energy businesses. This case study involved a literature study and a 2.5 week mission to Rwanda, with qualitative interviews of key stakeholders in the sector.

Charcoal is the backbone of the cooking energy sector in Kigali, and a value chain analysis of the Kigali supply indicated that the fuel is essential for energy access, is a key driver for rural economic growth, has lower environmental impacts than widely believed and provides a certain level of energy security. Recent charcoal price increases largely attributed to a poorly functioning regulatory system indicate the supply chain is under pressure. Diversification of fuels is one strategy that can relieve pressure on the chain, however there exist many opportunities to improve the sustainability of this fuel along the value chain, with many wider co-benefits.

Given the current development paradigm that seeks to harness latent entrepreneurship and leverage the capabilities of the private sector to make markets work for the poor, this study looked at how these sustainability opportunities can be enacted through private enterprise. Business opportunities that improve the sustainability of, or provide alternatives to the charcoal chain were identified and analysed. The resulting business opportunities are summarised in Table 1.

Businesses that improve the existing charcoal chain		**Businesses that provide alternatives to traditional charcoal**	
	Plantation investment		Green charcoal
	Improved kilns		Waste to Energy
	Charcoal dust recovery		Briquette manufacture
	Improved charcoal stoves		Domestic LPG
	Pressure cookers		2nd generation kerosene stoves

Table 1 - Summary of business opportunities

Based on interviews with a variety of stakeholders including government officials, entrepreneurs, NGOs, international donors, local academics, investment groups, renewable energy associations and business people, the most salient external environmental barriers limiting the realisation of these business opportunities were identified and categorised. The focus of this study was on the external environment of the business, as this is in the realm of influence of the policy maker. The barriers across the different opportunities were grouped according to their type, and included regulatory, financial, entrepreneurial, technical, social and marketing barriers.

An analysis was performed on concrete actions that can remove the barriers in order to create an enabling environment. For example, regarding the financial barrier category, specific mechanisms included the improved provision of microfinance, growth finance, favourable tax regimes, sensitisation to the energy sector for financial providers, facilitated access to climate finance, advanced market commitments, enabling the leveraging of existing infrastructure and targeted grants and subsidies.

These barrier removal mechanisms were distilled into a set of policy recommendations to be enacted by the Government of Rwanda through its relevant ministries and local governments, the private sector in partnership with the government, and civil society. Fostering an enabling environment for sustainable cooking energy enterprises has many wider societal co-benefits, and is a cross-cutting policy initiative in that many other renewable energy enterprises are facing similar external environmental barriers.

Government of Rwanda	GoR & Private Sector Partnerships	International Donors & NGO's

• Official statement of support for charcoal highlighting the co-benefits that the value chain provides and a commitment to the long term legality of charcoal
• At the local rural level, revise the permit system through a participatory approach to encourage investment and improve transparency
• Strengthen the patrolling of forests to prevent illegal production
• Create and enforce minimum performance standards for energy briquettes
• Investigate a certification scheme for 'green' charcoal products
• Initiate environmental & energy efficient awareness raising programmes
• Continue safety awareness campaigns for LPG & kerosene use
• Create minimum standards for kerosene stoves
• Programs to sensitise the financial sector to energy related investments
• Targeted support for technicians in relevant fields
  o Technical training in waste to energy field
  o Capacity development for market data gathering
	• Investigate PPPs for dissemination of energy efficient cooking utensils, such as pressure cookers and cooking stoves, where the GoR raises awareness creating market pull, and private sector provides merchandise
	• Support pilot projects for green charcoal
	• Source sustainable cooking fuels in institutions (schools, hospitals, government buildings) through a competitive tendering process
		• Continued support for the finance sector, particularly microfinance and innovative financing models for SME's (growth finance)
		• Facilitate access to climate funds for 'green' charcoal & briquettes with capacity building
		• Investigate the appropriateness of 'Advanced Market Commitments' for the cooking energy sector
		• Investigate the establishment of a centre providing Business Development Services (BDS). The centre could facilitate:
		  o Identification and connection of potential partners (local & international) through a centralised scheme
		  o Training in general business skills
		• Continue and strengthen programs supporting the professionalization of the charcoal value chain, in particular the transfer of skills and management practices to plantation owners

Table 2 - Recommended policy actions for different stakeholders

1. Introduction

1.1. The IS-Academy

The IS-Academy, set up in 2005, is an initiative from the Dutch Ministry of Foreign Affairs aiming to encourage policy makers and academics to work together on international cooperation issues. The central idea is that both policy makers and academics can benefit from closer cooperation. The IS-Academy sets up and sponsors partnerships to work on specific projects, including areas such as civil society and good governance, migration and development, and education.

The IS-Academy project RENEW is undertaken by a partnership between ECN, the Institute for Environmental Studies (IVM) at Vrije Universiteit and the Directorate General for International Cooperation (DGIS). The overarching objective of this project is to improve the understanding of renewable energy technologies for energy access in developing countries (van Beukering et al, 2009). The program is comprised of three distinct research perspectives, targeting three African nations: Rwanda, Mozambique, and Kenya. The research perspectives are classified into distinct themes as follows:

Theme 1: Entrepreneurial perspective - An exploration of opportunities for business model innovation, to increase the viability of renewable energy technology enterprises.

Theme 2: Household perspective - An analysis of household decision-making processes under constrained circumstances regarding fuel choices and the uptake of renewable energy carriers.

Theme 3: Institutional perspective - An analysis of renewable energy technology diffusion, its evolution and prospects in Eastern Africa from an innovation systems perspective.

This paper contributes to Theme 1 – Entrepreneurial Perspective. Rwanda was selected to be one of the first countries to be targeted for the research, and as such is the focus of this paper.

1.2. Background

Rwanda is a landlocked country of approximately 11 million in East Africa. The country is bordered by Uganda, Tanzania, Burundi and the Democratic Republic of the Congo. Despite lying on the equator, Rwanda is a temperate country due to its altitude. The highest point in Rwanda is Volcan Karisimbi, with an altitude of 4,519m. Rwanda is one of the most densely populated countries in Africa, with a large rural population (82%). The capital Kigali is the by far the largest urban area, with a population of approximately 1 million (US Govt, 2010).

Figure 1 - Rwanda map
(US Govt, 2010)

Rwanda is economically a poor country, with an annual GDP of approximately US $5 billion, and is largely dependent on foreign budget support. The GDP/Capita is approximately $900 US, ranking Rwanda at 216 out of 227 nations. Despite a business environment[1] that has permitted an impressive growth rate in recent years, growth has been limited by energy shortages, instability in neighbouring states and inadequate transport linkages. The largest export earners are minerals (gold, tin ore, tungsten ore), coffee and tea (US Govt, 2010).

1.3. Primary energy balance & trends

Biomass has an important role to play in the Rwandan energy mix, contributing up to 85% of the gross primary energy supply. Rwandan energy strategy documents target a reduction in usage as a proportion of primary energy demand to 65% by 2020, however in absolute terms biomass use will increase 2.3% annually in the same period (MININFRA, 2009). The expansion of access to electricity is a major priority for the government. As charcoal is the preferred fuel for cooking in urban settings (GTZ/MARGE, 2009), with increased urbanisation and population growth, the demand for charcoal is likely to increase.

When conversion efficiencies are taken into account (Figure 2) it can be seen that a large proportion of the primary energy is lost in the production of charcoal.

[1] According to the World Bank's *Doing Business* project, Rwanda has risen 76 places in the country index in the ease of doing business category, from 143rd in 2009 to 67th in 2010 (World Bank Group, 2010)

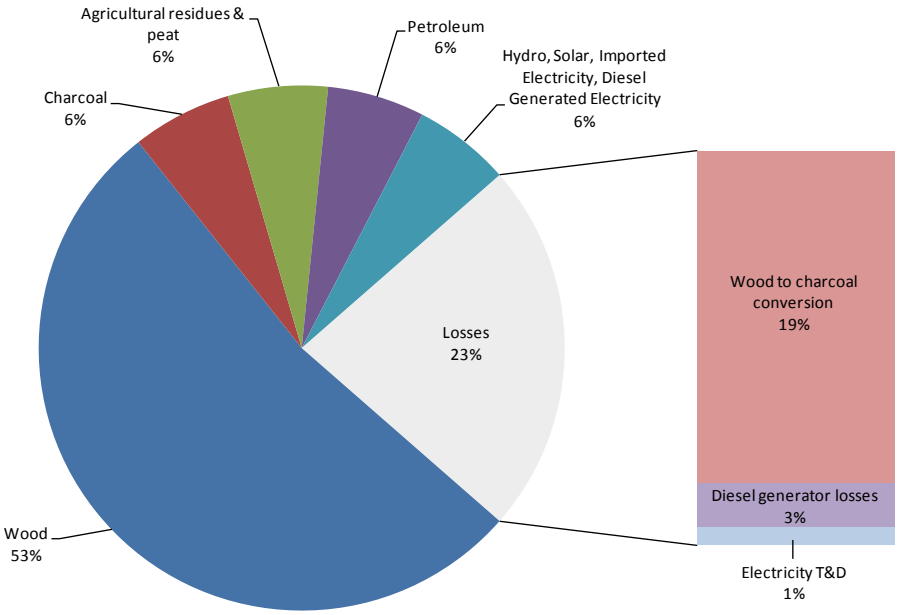

Figure 2 – 2007 Primary energy analysis
Drawn by the author, data taken from GTZ/MARGE (2009)

In order to get an idea of the order of magnitude of energy consumption, the total primary energy consumption in ToE is approximately 200 times smaller than that of Belgium; a country with a comparable population level and land area (US EIA, 2010).

1.4. Rwandan energy policy and Vision 2020

The Government of Rwanda (GoR) has a detailed energy policy covering the period 2008-2012. The mission of the energy policy is to "create conditions for the provision of safe, reliable, cost-effective and environmentally appropriate energy services to households and to all economic sectors on a sustainable basis" (MININFRA, 2009). Of note in the energy policy is that the GoR has identified that the private sector will need to play a much greater role across all energy sectors than in the past in order to achieve the rapid growth required.

Rwanda Vision 2020 details the long-term development aspirations of the country. This 'blueprint' is based on several pillars, including reconstruction of the nation, transformation of the agricultural sector, development of the private sector, comprehensive human resources development, infrastructural development and the promotion of regional economic integration and cooperation (MININFRA, 2009). Once again, development of the private sector is highlighted as an important governmental priority.

As such, Theme 1 of the IS-Academy falls on a fertile policy environment in Rwanda.

2. Research aims and scope

2.1. Research context

Alleviating poverty is one of the major challenges of modern times. Previous waves of poverty alleviation were driven primarily by civil society, developed country and local governments, and multi-lateral institutions. A marked transition has occurred in recent years, with the current development paradigm seeking to harness latent entrepreneurship and leverage the capabilities of the private sector to make markets work for the poor. Through competition, deregulation, liberalisation and open trade, it is hoped that the forces that perpetuate poverty in many developing countries will be weakened (Pfeffermann, 2000). A large domain of research, of which Theme 1 of the IS Academy is part of, endeavours to articulate the role of the private sector in alleviating poverty through economic development.

One of the early influential pieces of work in the field was from Prahalad and Hart (2002), who mainstreamed the idea that Multinational Corporations (MNCs) can profitably perform business at the base of the pyramid (BoP) whilst contributing to alleviating poverty by engaging the poor as consumers (Prahalad & Hart, 2002). BoP markets, according to their definition, refers to those in the lowest tier of the world economic pyramid (see Figure 3). According to their estimates this represents a multi-trillion dollar market that remains largely untapped, presenting a major business opportunity. By providing previously unavailable or better quality products and services, MNCs would contribute to poverty alleviation, knowledge & technology transfer and infrastructure development, all whilst generating a profit.

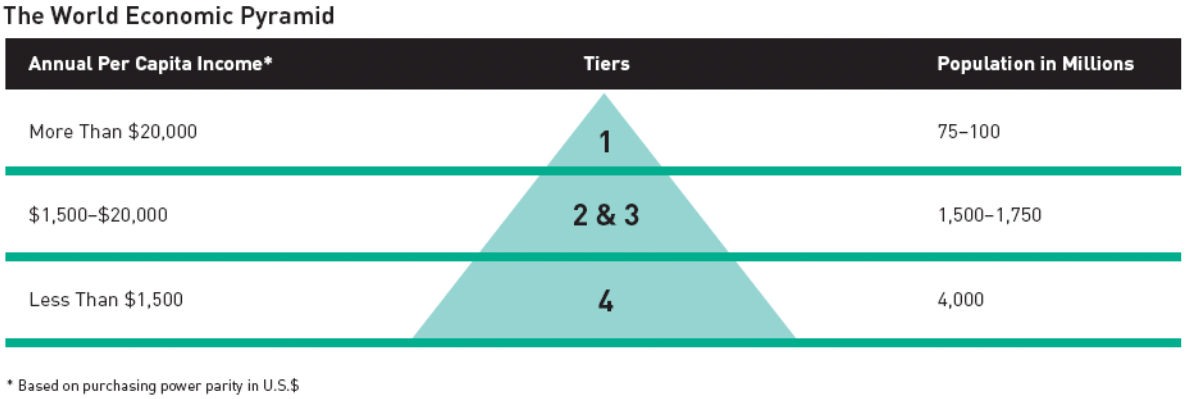

Figure 3 - The four tiers of the world economic pyramid
(Prahalad & Hart, 2002)

Despite the attractiveness of the 'BoP proposition', this theory received some strong criticism that posited that this idea was "*riddled with fallacies…at best a harmless illusion, and potentially a dangerous delusion*" (Karnani, 2006). Karnani contends that the BoP proposition overlooks the vulnerability of the poor, overemphasises microcredit, underemphasises fostering modern enterprises at scale, and grossly underemphasises the role and responsibility of the state in poverty reduction (Karnani, 2006). It is argued that small to medium enterprises (SMEs) are better suited for market opportunities at the BoP than MNCs, as SMEs create more jobs thereby raising the real income of the poor.

One of the proponents of the original BoP proposition was part of a group that revised the theory after judging that many 'first generation' BoP endeavours "*failed to hit the mark*" (Simanis & Hart, 2008). Recognizing that the perspective of the poor was neglected by companies 'pushing' their products onto shantytown dwellers and rural villagers, they developed the BoP protocol 2.0, which has a central theme value co-creation. Rather than treating the poor as mere consumers, the poor are to be engaged as business partners (Simanis & Hart, 2008).

A focal point of the BoP literature is the business model. Varying definitions of the business model concept exist, however the general consensus is that a business model defines the 'core logic' of how a business operates (Shafer & Smith, 2005). A concise definition from Osterwalder and Pigneur (2010) introduces the idea of value in the business model:

"A business model describes the rationale of how an organization creates, delivers, and captures value."

Innovative and inclusive business models are seen to be at the core of realizing the business potential of BoP markets in a way that delivers the most benefit to the poor.

As the strategic management literature evolves, research is focussing on characterising BoP markets and firms, exploring opportunities for business model innovation, and empirically testing BoP theories. Klein (2008) is an example of such an attempt. Klein empirically proved that business challenges are fundamentally different at the BoP and that the importance of these business challenges varies across different stages of the organizational life cycle and different investment climates (Klein, 2008).

This research is intended to also fall within this general body of literature, thereby furthering the understanding of doing business in BoP markets.

2.2. Scope of current research

Business models do not operate in a vacuum and external environmental factors beyond the influence of the entrepreneur can act as barriers impeding the realisation of business opportunities. A favourable external environment can thus enable successful, high-impact business models.

The external environment can be framed through regulatory, technological, societal, socio-economic, market, macro-economic and industrial factors (Osterwalder & Pigneur, 2010). Many of these factors are in the realm of influence of the policy maker. The role of the policy maker is thus largely (although not exclusively) to remove external barriers in order to create an enabling external environment[2] more likely to foster enterprise development.

[2] The advantage of a market-level intervention (targeting the external environment) rather than a firm-level intervention (support of a particular enterprise) is that the potential for market distortion is reduced and achieving scale will not rely on external funding.

A deeper understanding of the external environmental barriers can inform effective policy design. The scope of the current research is thus intended to improve this understanding. Rather than take a purely theoretical perspective, a case-study of a specific sector was performed, enriching the general body of knowledge with a concrete example.

2.3. Sector selection

In order to select a particular energy sector, rather than define the sectors in terms of supply type (biomass, gas, hydro), an energy service provision perspective was adopted. Typical examples of energy services include cooking, lighting and heating. Given that most of the energy consumed in Rwanda is used for cooking purposes, and that there are large amounts of energy being lost in the charcoal chain (suggesting sub-optimal performance), it was decided to focus on the cooking energy service sector.

Research indicated that rural and urban energy service provision is very different. Cooking in rural areas is mainly performed almost exclusively using woodfuels (GTZ/MARGE, 2009). Charcoal is an urban fuel, despite being produced in rural areas. It was thus decided to analyse cooking energy service provision in urban areas. Given that Kigali is by far the biggest urban area, and other major cities have different energy utilisation characteristics (GTZ/MARGE, 2009), the analysis was further limited to Kigali.

In order to better understand the current status of cooking energy utilisation in Kigali, an energy access map was developed. This energy access map indicates household fuel cooking choice in terms of household income and fuel life-cycle GHG intensity[3]. The energy access map for Kigali households is presented in Figure 4. The GHG intensity values are based on work by Bailis (2005) undertaken in Kenya, converted and extended by the author for the Rwandan case (see Appendix 1). The income distribution of fuel use was taken from GTZ/MARGE (2009), and modified slightly based on trends and anecdotal evidence from the field. It should be noted that whilst care has been taken to provide accurate values, the energy access map only provides a rough indication of income level use and relative GHG intensity. A thorough study is required to more accurately quantify these values.

[3] It could be argued that given the small contribution of Rwandan GHG emissions to overall global emissions the GHG impact of different fuels is irrelevant. However, given the current global focus on climate change mitigation and corresponding funds that have been made available as a result (such as the $30 billion quick-start fund), including mitigation aspects may allow Rwandan entrepreneurs to leverage external funding.

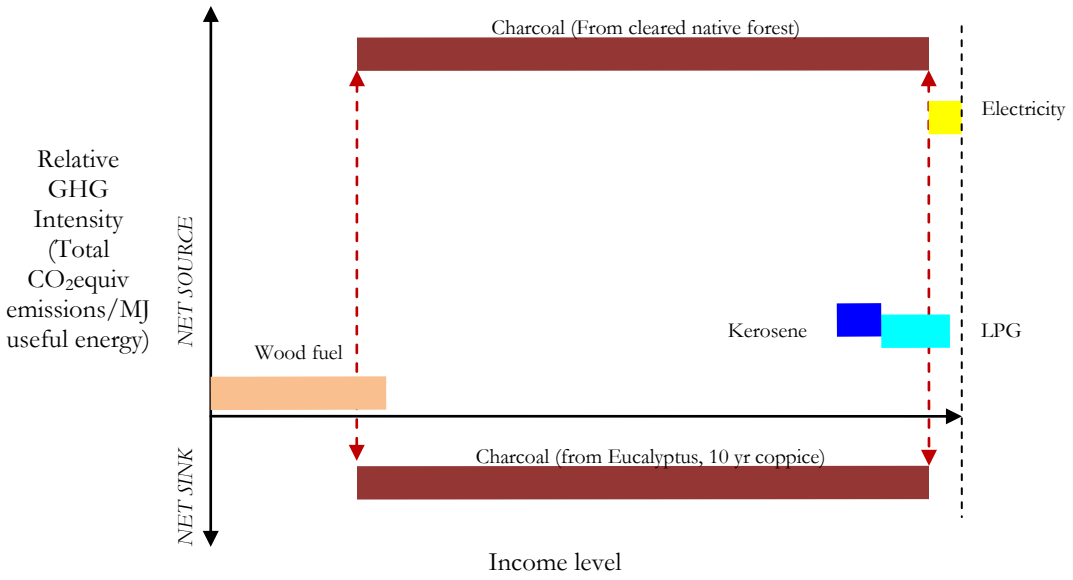

Figure 4 – Cooking energy access map for Kigali
Compiled by the author. Vertical axis not to scale. (see appendix for calculations)

As indicated clearly in the energy access map, charcoal is the cooking energy service provider for the majority of households in Kigali. Charcoal has a large range in the life-cycle GHG emissions[4] per MJ of useful energy. The highest intensity arises from charcoal produced from native forests without regeneration. The lowest intensity occurs when the plantation is Eucalyptus, and coppice[5] managed on a 10 year cycle. Given that actual forest management practices for charcoal fuel in Rwanda varies between the two extremes, the likely overall value should be somewhere in between.

An observation that may seem counter-intuitive is that different energy sources are utilised at the same income level. This is due to several factors, including cultural, financial and personal preference. This will not be expanded upon further here, but highlights that fuel transitions do not occur in a step-wise fashion with increasing income.

2.4. The charcoal industry: backbone of the cooking energy service sector

Charcoal production in Rwanda is performed by a large, informal, private sector. Despite its negative connotations as a 'dirty' fuel, charcoal is a source of energy that provides an important basic energy service to most households in Kigali. Although considered by many to be renewable at present, with future population growth and urbanization (currently at a rate of 4.2% (US Govt, 2010)), there will be greater pressures on the charcoal chain, especially in a country with a high population density such as Rwanda. This will undoubtedly result in reduced environmental performance (such as deforestation)

[4] It should be noted that GHG emissions as defined here only include those targeted by the Kyoto Protocol (Bailis, 2005). Inclusion of black carbon could alter these results significantly.
[5] Coppicing involves cutting trees to near the ground and allowing shoots to grow from the stumps.

and/or increasing prices, reducing the availability of the fuel. It is important to anticipate this increased pressure on the chain, and encourage measures to improve the long term sustainability of the charcoal industry or for the provision of suitable alternatives. The basic energy service provided by this industry needs to be maintained (at the very least) or improved with a reduction in price / increase in quality (in the best case).

2.5. Statement of the research question

The purpose of this research is **to analyse barriers to business opportunities that improve the sustainability of, or provide alternatives to, the Rwandan charcoal chain**.

In order to perform this analysis, the following sub-questions were developed:

- What is the state of the charcoal value chain in Rwanda, and what are the business opportunities for improving the sustainability of, or providing alternatives to, the chain?
- What are the barriers to these business opportunities?
- What are the policy enabling actions to overcome these barriers?

2.6. Expected contribution

Although the Government of Rwanda has made significant progress in improving the general business environment in recent years, there still exist many barriers for cooking energy businesses. This research will contribute directly to national policy development for creating an enabling environment for business in the cooking energy sector. The potential role of international donors & NGOs in this context will also be articulated. Despite the specificity of the context, the barrier analysis will provide further insight into the more general barriers faced by renewable energy and energy efficiency businesses trying to operate in BoP markets.

3. Research methodology

In order to perform the case-study an inductive, qualitative approach was adopted. This approach involved semi-structured interviews and observational methods in addition to secondary research from the literature and online sources. A list of those consulted during the research can be found in Appendix B.

The general methodology for the research is summarised in Figure 5 below.

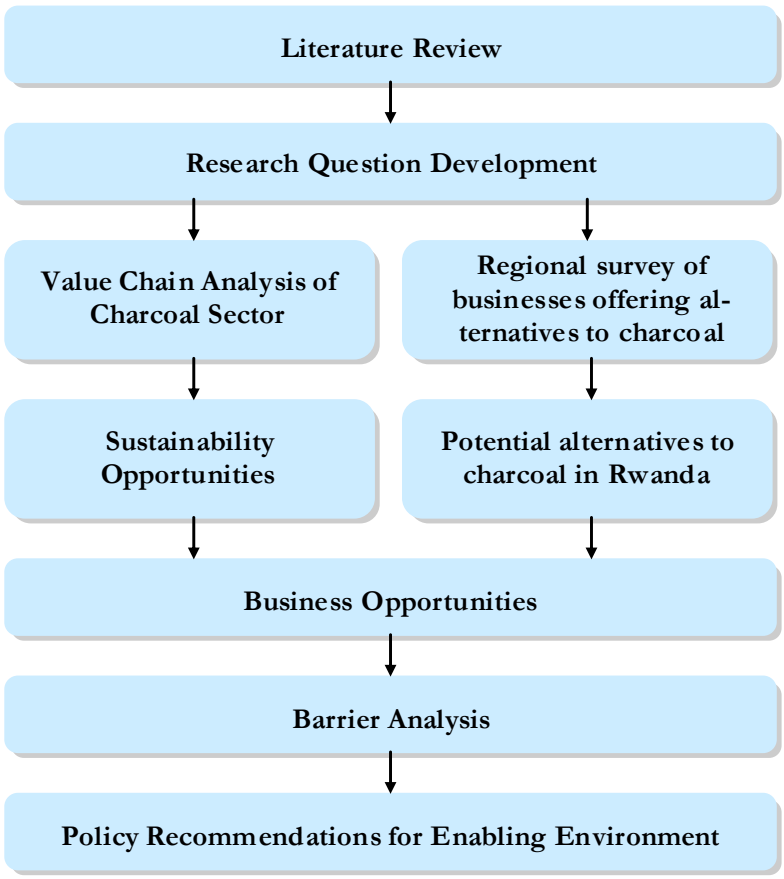

Figure 5 – Methodology outline

4. Results

4.1. Charcoal value chain

The concept of the value chain analysis, developed by Porter (1985), is a tool used to describe the value adding activities involved in providing a particular product or service (Porter, 1985). The value chain analysis is popular as a strategic management tool as it provides a holistic perspective facilitating identification of opportunities for optimisation or new business models. A value chain analysis can be performed at the firm or market level.

Attempting to analyse an individual value adding activity in isolation neglects the influence that upstream and downstream activities may have. Experience in development projects related to the charcoal industry has shown that such attempts have had mixed results (Sepp, 2008). It was thus decided to undertake a value chain analysis of the Rwandan charcoal chain as a starting point for the analysis.

The methodology outlined by Sepp (2008) specifically for charcoal value chains was extended with the *Valuelinks* methodology (GTZ, 2007). The result of this value chain analysis for charcoal supplied to Kigali is shown in Figure 6. Several secondary sources form the basis of the data for the chain, with gaps being filled with primary research. The value chain analysis was limited to the Kigali supply, given that this was the scope of the analysis.

Value Adding Activities	Wood Production	Carbonization	Transport	Retailing & Distribution	Consumption
					
Actor/s:	- Wood producer	- Charcoal labourer - Wood producer	- Transporter - Charcoal businessman	- Dealers - Loading labourers	- Households - Hotels / restaurants
Activities:	Manages/owns plantation. Obtains a tree cutting permit from local authorities, contributes to forest fund. Can use land as credit guarantee with financial services provider.	Labourers hired by wood producer or charcoal businessmen to perform carbonization job. Alternatively, performed by wood owners.	Charcoal businessmen operate with a profit motive and purchase and transport charcoal from production sites to Kigali. May organize certain upstream and downstream activities.	Charcoal arrives directly to dealers from production sites. Big dealers located at market sites, smaller dealers scattered around the city. There exists a door to door delivery service.	Final charcoal price for consumers is highly fluctuating and manipulated by businessmen. 45.5 kg bag: Rwf 5,500—6000.
Supporting actors:	- Local Authorities - Financial services provider	- Local Authorities - Financial services provider	- Local Authorities - Financial services provider	- Local Authorities - Financial services provider - Landlords	- NGO's (Stoves) - Stove businesses - Financial services providers
Persons Involved:	~300,000 (Not sole income)	~8,000 Charcoal producers ~7,000 Wood cutters	200-300 motorised	~2000	**Charcoal used for cooking:** 72.4% of HH
Volumes:	1,211,538 t / ~ US $8.7 million	157,500 t / ~ US $17.5 million	157,500 t / ~US $19.7 million	150,000 t (~5-20% losses) / ~US $6.5 million	**Volumes:** 150,000 t / ~US $52.5 million
Energy Content (% of original):	100%	24%	24%	19.2 - 22.8%	**Improved stoves penetration:** 50%
Value Share Distribution:	17%	33%	38%	13%	**Annual household use:** ~700kg

Figure 6 - Value Chain Analysis for Kigali Charcoal Supply

Compiled by the author based on several sources (Munyehirwe, 2009; GTZ/MARGE, 2009; GTZ/MARGE, 2008) and field research

The value chain provides a holistic perspective of the value adding activities in the Rwandan charcoal industry. Several interesting observations can be directly deduced from the value chain.

Energy Access
It is clear that charcoal is an important fuel for urban dwellers, with up to 72.4% of households in Kigali using charcoal as their primary fuel (GTZ/MARGE, 2009). Alternatives are not affordable and/or readily available. This fuel is thus important for maintaining basic energy access.

Employment
Charcoal provides employment for many thousands of Rwandans, particularly in rural areas. This is typical of the charcoal industry in many East African countries (Bailis, 2005). Looking at only the carbonization activity, this provides income to 15,000 predominantly rural workers. Assuming 5 dependents per individual (World Bank, 2010), up to 75,000 Rwandans are either partly or wholly dependent on revenue from this activity. If all the other actors and dependents were included along the chain, then this figure would be much larger.

Contribution to the overall and rural economy
Economically, the charcoal industry is a significant contributor, with charcoal related activities contributing approximately between 1.1% and 5% to GDP.[6] More importantly, it constitutes an important revenue stream for the rural economy, transferring wealth up the chain from urban to rural actors.

Chain losses
According to field research, up to 20% of the charcoal is lost as dust and non-carbonised pieces (Munyehirwe, 2009). This is substantial, especially given that the losses are of a high added value.

4.2. Extending the value chain: additional insights

Although not included explicitly in the value chain, additional insights from field research, direct observation and literature review that contribute to the understanding of the value chain functionality are expanded upon here.

Production Conversion Technology & Performance
As indicated in the VC analysis, charcoalers generally employ the traditional earth mound kiln. For example, in the largest producing region of Nyaruguru, 99% of charcoalers use this type of kiln (GTZ/MARGE, 2008).

Charcoal is produced in the traditional earth mound kiln through the process of carbonisation. Carbonisation occurs when wood is subjected to elevated temperatures in the order of 450 - 600°C in the absence of oxygen (Siedel, 2008). This process is also known as pyrolysis. Important factors affecting carbonisation include moisture content, carbonisation equipment and the care with which process is carried out.

[6] The lower limit was calculated by the author using the 2008 value of US $52.5 million annual turnover (GTZ/MARGE, 2009) and a 2008 GDP of US $4.5 billion (World Bank, 2009). The upper limit is taken directly from a field report (GTZ/MARGE, 2008), however the author cannot replicate this calculation.

The traditional earth mound kiln is constructed using locally available materials, thus there is little to no associated investment costs in terms of materials. Constructing the kiln does require a certain amount of skill, and the efficiency of conversion is affected by the know-how of the kiln constructors and operators. The recovery rate of charcoal is typically in the range of 8-15% by weight, and 20-40% in energy terms, quite low compared to more advanced kiln types[7]. The carbonisation process typically takes between 3-15 days, depending on the size of the kiln (Siedel, 2008).

Figure 7 - Typical Traditional Earth Mound Kiln used in the region
(Virunga NP, 2008)

When selecting a particular carbonisation technology, several factors affecting this selection process. The main factors include the availability of raw materials, the cost of installation, the scale of operation and the available time.

A reason given for fixed kilns not being successful in Rwanda (apart from prohibitively high investment costs) is that due to the small size of plantation lots, rarely is carbonisation carried out in the same place regularly. If a fixed kiln was introduced, the wood would then need to be transported, introducing an additional production cost.

Demand side conversion technology & performance

As indicated in the VC, improved charcoal stoves have already penetrated the market quite considerably in Kigali. The distribution of improved stoves has been the focus of many donor programs and is part of a current long term program from the Ministry of Infrastructure (MININFRA, 2010). These improved stoves can reduce by up to 50% the fuel consumption compared to traditional stoves. The adoption of improved stoves has been effective in Rwanda largely due to the relatively high price of charcoal, which incentivised the use of this energy-efficient technology.

[7] Efficiency is referring to 'oven dry weight'. Casamance kilns (an improved earth mound kiln) and brick kilns can have efficiencies up to 30% by weight. Steel kilns can achieve between 27- 35% (Siedel, 2008), and industrial size twin- retort kilns (such as those used in the Netherlands) typically achieve 33% efficiency by weight. It is difficult to achieve higher efficiencies than those in the modern kilns because lots of energy is required to heat the wood and drive off water vapour that is produced when the wood is broken down (FAO, 1987).

Charcoal as a fuel

Charcoal, despite certain negative connotations as a 'dirty', primitive fuel, burns cleaner than woodfuels, can be stored for large amounts of time, and has a higher energy density compared to wood meaning it can be transported at a lower per unit cost. Figure 8 shows a comparison of the higher calorific value for a variety of cooking fuels.

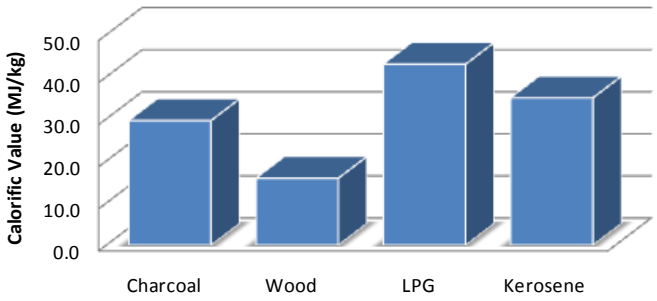

Figure 8 - Comparison of Higher Calorific Value for a variety of cooking fuels
Source data taken from ETB (2010)

Cutting & transportation regulatory requirements

In Rwanda, it is a legal requirement to obtain a permit from the local authorities to cut trees, even if the trees are ones own property. It is also necessary to obtain a permit to transport charcoal. The specific requirements for four southern districts can be found in Appendix C. The permit system was introduced in 2005.

In several interviews the issue of permits, especially cutting permits, was highlighted as *the* key regulatory factor in the value chain. Described by one person as "a good national policy being poorly interpreted at the local level", the permit system has led to several inadvertent negative effects. Most of these negative effects arise due to the difficulty encountered when trying to obtain a permit.

- As it is difficult to know when a cutting permit will be granted, ability to forward plan is greatly reduced.
- Due to the difficult procedures, illegal practices have increased, reducing overall carbonization efficiency (no waiting for drying of wood, etc).
- Also as a consequence of illegal production, prices are inflated because bribes are often paid, and these are transmitted downstream to the consumer in the final price.
- A lack of transparency in the process leads to corruption amongst those with the ability to expedite the process for obtaining a cutting permit.

A general lack of faith in the permit system from chain actors has led to poor relations between producers and authorities.

Actors

In the Rwandan charcoal industry, as with many other East African countries, many different actors are involved along the chain. The charcoal industry is largely informal, and according to charcoal experts in

Rwanda, actors are almost exclusively individuals or small informal enterprises (rather than companies or formalised associations). There has been recently an impetus for charcoalers to form associations through the CASE Project implemented by CARE Rwanda.

It is important to distinguish the different types of producers. There are those that produce charcoal legally with the required permits from their own wood, those that produce charcoal with their own wood however illegally as they do not have the necessary permit, and those that produce charcoal illegally, without permits with wood from protected reserves. This distinction is important because there is a tendency to group together all of these different producers, thus charcoal production gains the reputation as being an illegal activity, even though the majority of producers are operating completely within the law (Munyehirwe, 2009).

In several of the interviews, the 'charcoal businessman' was identified as an important actor in the chain. The charcoal businessman acts as a broker between upstream and downstream activities. This puts much power in the hands of this particular actor, allowing him/her to manipulate prices. Upstream actors have expressed their dissatisfaction with this power imbalance. Charcoal businessmen usually have large amounts of working capital as they have access to credit. This could contribute to the perceived power imbalance.

Chain linkages

Linkages between actors in the chain are largely informal. Chain actors, apart from the charcoal businessmen, do not see past the activities that take place beyond their immediate place along the chain. This lack of awareness of the whole value chain potentially results in sub-optimal performance. There are several NGOs promoting the use of ICTs for upstream actors that will facilitate communication along the value chain.

Environmental impacts

Charcoal is often associated with an array of negative environmental impacts, however large-scale deforestation (and associated consequences) is the primary effect often cited as an important reason for shifting away from charcoal. Although this may be true in other contexts, Rwanda is a particular case when compared to other East-African nations. In Rwanda, the majority (at least 90%) of wood sourced for charcoal comes from plantations (GTZ/MARGE, 2009). This means that the assumed large-scale deforestation effects of charcoal production are not occuring in Rwanda[8]. It should be noted that locally around production sites some environmental degradation may occur due to poor forest management practices.

In terms of GHG emissions along the value chain, whether or not charcoal is a net source or sink depends largely on the forestry management practices employed (see Appendix A). The GHG emissions from the carbonisation stage are the largest contributor amongst other downstream sections of the value chain. For 1 kiloton of charcoal production, a shift from a traditional kiln to a modern twin-retort kiln can save between 2 and 10 kilotons of CO_2eq GHG emissions according to a practitioner.

[8] There do exist issues of illegal felling of trees in national parks and reserves, such as in the Virunga national park and Nyungwe national park, however these are reported to be small, isolated cases rather than large scale deforestation.

The effects of black carbon, despite not being readily quantifiable along the chain, also have a significant GHG warming effect (Ramanathan & Carmichael, 2008). The charcoal value chain would undoubtedly contribute to a significant portion of Rwanda's black carbon emissions.[9]

Evolution in price

The price for charcoal has increased significantly in recent years. The following figure illustrates this evolution in price. It can be seen that between 2002 and 2006, a large price increase is observed. One interviewee believed that this was partly due to the introduction of the permit system.

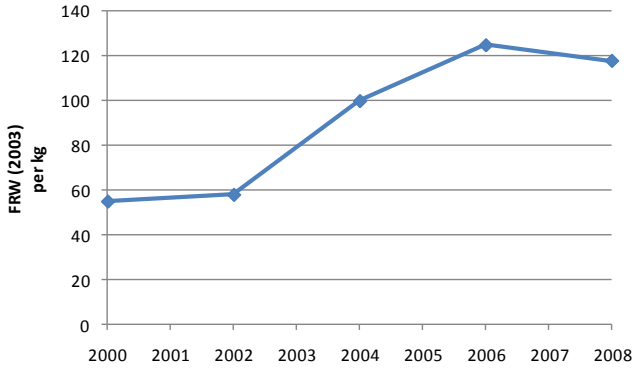

Figure 9 - Evolution in price of charcoal
(GTZ/MARGE, 2009)

Private tenure laws and effect on plantations

According to GTZ/MARGE (2009), an important factor in the chain are the strong private tenure laws that exist in Rwanda. Rwanda is an exception compared to most other African countries, in that it applies private land ownership on a large scale. This provides an incentive to plant trees, as they have some guarantee that the trees will remain theirs when the trees mature. Trees can be a form of 'security' for farmers, requiring little inputs, that can be converted into cash in case of need. This ability to quickly liquidate woodlot assets has been compromised in recent years, with the introduction of the permit system.

Transboundary issues

Several surveys have confirmed that the flow of charcoal into Rwanda is small relative to the total charcoal produced internally (GTZ/MARGE, 2009). It was suggested by one of the interviewees that in fact due to steep increases in charcoal prices in the neighbouring DRC, there is a flow of charcoal from Rwanda to the DRC.

[9] It should be noted that Rwanda's relative contribution to global GHG emissions is extremely small, and as such the primary driver for reducing GHG emissions should be to generate a revenue stream that otherwise would not have been available that can be channeled into improving the environmental performance and sustainability of the chain. In other words, charcoal production should not be stopped because of GHG emissions: rural income generation and affordable cooking energy should be higher priorities.

Energy security
Given that the charcoal chain is almost entirely confined within national boundaries and is a renewable source of energy, this type of fuel provides Rwanda with a certain degree of energy security. If Rwanda were completely reliant on costly fossil imports for cooking purposes, an increase in the oil price would have a marked impact on households.

Health impacts
As a solid fuel, charcoal represents a greater health risk than liquid and gaseous fuels such as LPG. However, as many of the volatile compounds have been driven off during the production stage, charcoal is a much cleaner burning fuel than wood fuel. According to one study, with a shift from wood to charcoal use, PM_{10} concentrations are reduced by a factor of 4-6, and the time spent with acute respiratory illness reduces by 44-65% (Ezzati & Kammen, 2002).

There are likely to be health impacts for those producing the charcoal in traditional earth mound kilns, due to exposure to the products from the pyrolysis of the wood into charcoal.

Kigali vs. other cities value chain
There is a slight difference between the value chain for charcoal supplied to Kigali and those for other urban centres. In other urban centres, given the closer proximity of producers, often the producers carry their produce directly to the urban centre and sell directly to the consumer, effectively cutting out the middle-man.

4.3. Sustainability opportunities

The sustainability opportunities can be grouped into two categories: those that improve the sustainability of the existing charcoal value chain, and those that relieve pressure on the chain by providing suitable alternatives.

Sustainability improvements
Inspection of the charcoal value chain reveals that there are many opportunities for improvement of the chain itself. Some of the obvious areas where sustainability can be improved are in improved plantation management, and carbonisation and end-use efficiency improvements. A less obvious area is reduced wastage from charcoal dust.

Alternatives to traditional charcoal
There are several alternatives that have made some inroads into the charcoal market in other East African countries, reducing some of the pressure on the charcoal chain. Briquettes made from other energy sources such as agricultural residues and household waste have been successful. Biogas from domestic food waste may also be able to partly displace charcoal consumption.

LPG & kerosene should also be considered an alternative option in this context, as they reduce pressure on the charcoal chain, and are cleaner burning, more flexible fuels. Despite not being a renewable energy source, they could be considered sustainable in the short-medium term. This is based on the ethical

dimension of sustainable development. In many definitions, such as that of the Brundtland commission[10], there is an intra-generational aspect that deals with equity and needs. If LPG and kerosene improve Rwandans access to energy and provides many co-benefits, then the use of these fuels can be deemed to be part of a sustainable development path in this particular context. It is not implied here that LPG & kerosene should be the primary cooking energy carrier, only that they be included as a 'sustainable' option to be explored further.

4.4. Analysis of business opportunities

In order to identify which sustainability opportunities can be translated into business opportunities, interviews and observational research was performed with participants from Rwanda, Kenya, Tanzania & the Netherlands. When performing the research and short-listing the business opportunities, an entrepreneurial perspective was adopted. As such, interventions including supporting the value chain are not discussed in this section. However, as these interventions are potentially important for enabling some of the business opportunities, they will be discussed in a later section.

Ten potentially feasible short-medium term business opportunities were identified that enact either an improvement to the chain or provide a suitable alternative to charcoal. The first group focuses on improving the existing chain, whilst the second group provides a potentially suitable alternative.

4.5. Improving the existing chain

The existing charcoal chain provides an energy service that is vitally important for maintaining basic energy access in Kigali and is an important source of rural income generation. If there is a supply shortage, cooking energy prices will increase for the majority of households, reducing their disposable income. Alternatively, households will revert to (cheaper) woodfuels, with negative health consequences due to indoor air pollution. As such it is important to anticipate increased demand and improve the existing chain in order that this energy service can continue to be provided at an affordable amount. If the price of charcoal was more affordable, lower income households may shift to charcoal use, with resulting health benefits.

This section details five business opportunities that improve the sustainability of the existing charcoal chain.

Investment in plantations and improved plantation management

According to several interviewees, investing in land and growing trees over longer periods is able to provide large positive returns if able to wait a sufficient amount of time to recoup on investment. Several entrepreneurs have begun investing in plantations with a longer term perspective; however this practice is not widespread. Improved plantation management means greater profits can be obtained from the same woodlot; however improved plantation practices are not implemented.

[10] Sustainable development is defined in this report as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UN, 1983)

There are several reasons explaining limited investment in plantations for charcoal and the lack of improved plantation management practices. Firstly, given the fairly uncertain legal status of charcoal, it is difficult for an investor to be confident that they will be able to recoup their investment in 7-10 years time. Secondly, the permit system is a regulatory hurdle given that the investor is uncertain on whether or not they will be able to cut down their own trees, and with what difficulty. Improved plantation management practices are not common due to a lack of technical know-how, and that many existing wood-lot owners are not aware of the business benefits of longer term management practices.

Sustainability impacts:
As highlighted in the energy access map, the manner that the plantation is managed can greatly affect the life-cycle GHG emissions of charcoal. Also greater investment in plantations will improve the resource base, securing the primary fuel necessary in the charcoal chain. Income from plantations may also increase, as the value of a specific woodlot will increase.

Improved kilns to existing producers
CARE Rwanda is currently implementing a project[11] in southern districts that trains charcoal producers in improved carbonisation techniques using an improved kiln. These improved kilns have 35% better performance which greatly improves the use of the limited resource base.

In order to introduce these improved kilns in a sustainable manner, CARE Rwanda have implemented an innovative business model. On the production side, people are organized into groups. These groups can then finance the purchase of chimneys necessary for an improved kiln and they are then trained on how to prepare the new kiln. A 1 week training period is required. On the chimney manufacturer side, they train local manufacturers to produce the chimneys. Charcoal producers can pay in money, but also by other means, given that they have limited capital. Iron sheets (required for the chimney) can be brought to the manufacturer, that way they only pay for the labour. Negotiations for chimneys occur directly between producer groups and manufacturers.

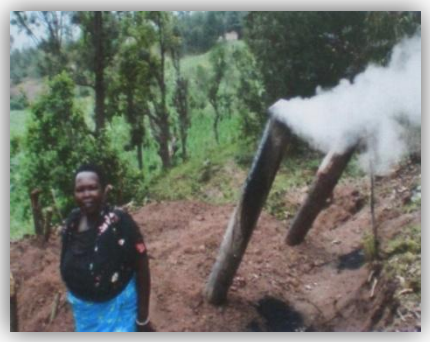

Figure 10 - Charcoal producer with improved kiln

[11] 1800 producers have been trained to date.

This model has proven to be very successful, and producers have embraced the new production methods. CARE Rwanda recognized that in order that the model becomes sustainable, there is a need for the training to be financed by another party. As such, CARE Rwanda has engaged with local investors (who own the woodlots) to provide such training. The benefit for the investor is a greater return on investment.

However, for reasons similar to those explained in the previous section, investment is discouraged because of the permit system and the long term legal status of charcoal.

Sustainability impacts:
Improving conversion efficiency greatly increases the resource base for charcoal. Also, greater income can be obtained by producers. Income is also generated for the manufacturers of the chimneys. If investors rather than an NGO were to be the source of funding for training, the business model would be sustainable and scalable.

Charcoal dust recovery
According to field research, up to 20% of charcoal is wasted as dust or fines (Munyehirwe, 2009). This is a very large loss of a high value added product. As such, recovery of this wastage is a very real business opportunity.

In Kenya, one successful business has been running for 11 years that uses charcoal dust as a primary feedstock for their energy briquettes. The business model involves salvaging charcoal dust and fines from vendors around the city in Nairobi at a low price (possible because vendors have no other use for this waste, and thus are happy to receive something for it). Cash is paid on collection, and collection is performed using the companies own lorries, as close as possible to the factory so that transport costs are kept to a minimum. The company turns a 10-15% annual profit, and employs approximately 80 people on a casual basis, depending on demand.

Briquettes from charcoal dust are not a perfect substitute for lumpwood charcoal as they contain higher ash content, thereby emitting less heat over a longer period of time. However there exists a market for this type of fuel, including space heating, water heating and meat roasting (BBQs or restaurants). These products are marketed to institutional customers such as poultry farms, hotels, lodges and restaurants, but also to charcoal dealers and individuals for direct sales into the domestic market. The company also produces premium quality products that are marketed in supermarkets for barbecuing. These products (produced in Kenya) were also found in Rwandan supermarkets (See Figure 11).

Figure 11 – BBQ products being sold in an upmarket supermarket in Rwanda

Sustainability impacts:
Salvaging the wasted dust from the charcoal chain improves the performance of the chain, and thus the overall efficiency. Jobs are also created from such an enterprise.

Improved stoves
Improved charcoal stoves can greatly reduce the amount of fuel required for cooking. By reducing the fuel requirements, the amount that households need to spend on fuel is greatly reduced and thus money can be spent for other purposes. The benefits of improved stoves are clear, and thus has been the focus of many government, multilateral institution, international donor and NGO programs.

Rwanda has one of the highest proportions of improved stove penetration in East-Africa. This is in part due to the high cost of fuel which accentuated the cost savings of this energy efficient technology. The market for improved stoves is already well developed in Kigali.

As fuel costs increase, or households look for more convenient cooking methods, the demand for improved stoves is likely to increase. Apart from stoves produced by local artisans, many MNCs have started producing and marketing improved cooking stoves in other countries.

Improved cooking stoves are an important demand side conversion technology. Access to this technology is an important part of a sustainable charcoal chain. Given that in Kigali a market has already been established, one of the major barriers for closing the market gap would be the lack of awareness of the economical benefits of an improved stove.

Sustainability impacts:
Due to the large fuel savings from an improved stove, the demand for charcoal is reduced, and pressure is relieved on the chain. The health benefits from an improved stove are also clear, as fewer emissions are released during cooking.

Pressure cookers

Although very specific, including this business opportunity is intended to reflect that extending the conventional chain beyond the conversion technologies is also important and could yield sustainability improvements. Pressure cookers greatly reduce the time required to cook a Rwandan staple dish – beans – from 3-4 hours to just 15-20mins, saving enormous amounts of time, energy and consequently money.

Figure 12 – Rwandan beans & pressure cookers in an upmarket supermarket

There is little penetration of this technology in Rwandan households, despite its benefits. Many people interviewed were not even aware of this type of cooker, nor its benefits. The starting price for a 5lt, 49kPa cooker was 33,500 RWf (47.50€). A smaller 3lt, rated at 98kPa, sold for 30,930 RWf (43.90€). These prices were found in an upmarket supermarket, and according to an employee, they sell little of these products. People usually become aware of this product when they travel abroad and see its utility. As far as the author could deduce, the low penetration was mainly due to lack of awareness, rather than affordability. A strong marketing campaign highlighting the benefits of the cooker and economies of scale could create a viable, profitable market.

Sustainability impacts:

The pressure cookers would pay themselves off in a very short period and would greatly reduce household fuel expenditure. There may also be a reduction of time spent in the kitchen, having gender implications, given that cooking is traditionally performed by women.

4.6. Alternatives to charcoal

With increasing prosperity and development, people tend to use cleaner, more efficient and more convenient fuels. This is described by the 'energy ladder' concept, illustrated in Figure 13. As such, alternatives to charcoal will be in demand for higher income households, which will reduce pressure on the existing chain. However, as urbanisation increases, people using wood will shift to charcoal, partially offsetting this reduced pressure. Thus alternatives to charcoal that provide the same quality of energy service need to also be provided to lower income households in order to further reduce pressure on the charcoal chain.

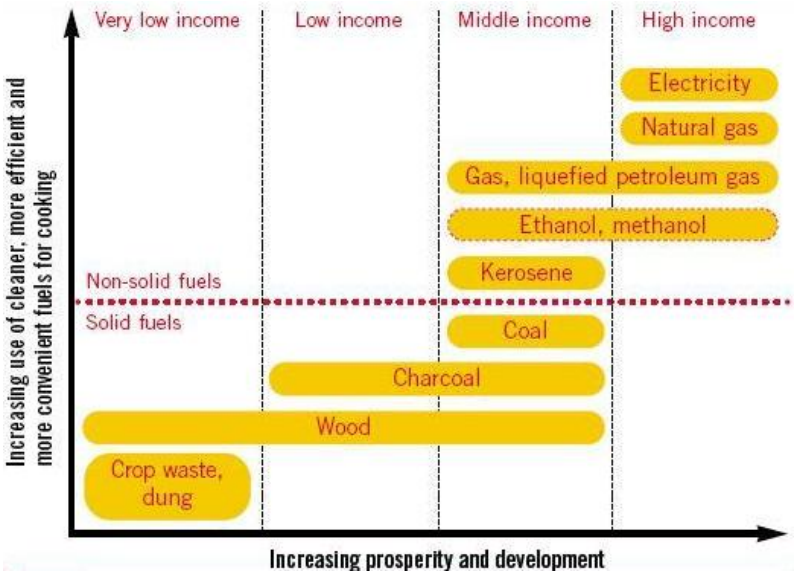

Figure 13 - Energy ladder
(WHO, 2006)

Green Charcoal

'Green' charcoal refers to charcoal produced outside the existing chain, being produced with highly efficient modern kiln technology and sustainably sourced wood. Depending on the price point of the green charcoal, anecdotal research indicates that there may be a market for such a product in higher income households. There is however a need to test this particular market. According to one interviewee, this is going to be undertaken in western provinces in the coming year by a project developer[12].

Performing basic cost-benefit analyses on various modern technologies with a vertically integrated business model (production, transport, distribution and sales) shows that these businesses are financially viable.

For example, using a mobile kiln readily available on the market, with a sales price equivalent to traditional charcoal, the simple payback time is 3.7 years and the IRR after 10 years is 23%. For details of the calculation, see Appendix C. These kilns could attract carbon finance, given that they greatly reduce the amount of emissions compared to a traditional kiln. Carbon finance would lower the price of the final product, making 'green' charcoal more competitive. However the transaction costs associated with certification and monitoring may be prohibitive.

[12] The author could not locate any detailed descriptions of the exact nature of this market trial.

Figure 14 - Mobile kiln
(Proininso, 2009)

Given the apparently lucrative investment potential of this business opportunity, the question needs to be asked why it has not been exploited yet. The simple answer is that it is difficult and risky to compete with the existing chain, particularly when a formalised business attracts an 18% VAT. The existing chain provides a similar product[13], without the associated investment risk. Most foreign investors in modern kiln technology in Africa do so to export to European markets, where wood needs to be FSC certified and emissions requirements are stricter. One investor in modern kilns in Africa was even offered a grant to cover half of the investment costs to set up a modern kiln in Rwanda (greatly increasing the profitability), however refused because he did not believe they could compete on the local market, and export opportunities are limited in Rwanda.

Apart from this very important barrier, several other barriers exist. The permit system is seen as problematic as it may limit the ability for the operator to obtain a constant feedstock. Also, if 'green' charcoal were to be introduced into the market, it would be important to differentiate between 'green' and 'non-green' charcoal, thus necessitating some kind of certification process, which at present does not exist in Rwanda. Also, in order to establish a market for 'green' charcoal, general awareness raising among the target market would be necessary in order to create demand.

Sustainability impacts:
The improved efficiency of a modern kiln (33% compared to 10%) means a much smaller amount of feedstock is necessary for the same amount of charcoal. Also, GHG emissions are greatly reduced with a modern kiln. From a rural employment perspective, if foreign enterprises were to invest heavily in charcoal production in Rwanda and take up a sizeable portion of the market share in a short amount of time, this may have negative consequences for rural employment in the traditional charcoal chain.

[13] According to a modern kiln operator, charcoal produced with modern kilns produce a superior product, however not significantly different

Waste to Energy (W2E) – Briquettes & Urban Domestic Biogas

Waste to energy involves upgrading Municipal Solid Waste (MSW) that would otherwise be disposed of into a useable fuel. Two major options exist in this respect. The first involves creating fuel briquettes, the second utilises organic food waste to fuel a biogas digester.

A detailed feasibility study into the production of W2E briquettes in Kigali was performed by Young & Khennas (2003). At the time, this study indicated that out of a 73,000 tonnes per year of waste, 16,000 tonnes was economically viable for production of energy briquettes. The market was assessed, and it was determined that there was a 'huge sales potential' for these products, and that there would be many environmental and social co-benefits. Some of the barriers identified in the study included a lack of technical capability, lack of business acumen and a lack of medium and long-term finance (Young & Khennas, 2003).

Despite this feasibility study indicating a large potential, and the later increase in operations of this particular facility, W2E briquettes have made a limited impact on the household cooking energy market. This is partly due to the fact that institutions were targeted in the first phases of the upscaling. However, a briquetting competitor that recently entered the market indicated that the lack of quality standards meant that briquettes produced in the aforementioned facility produce low-quality briquettes and consumer confidence was damaged as a result. This interviewee indicated that in order that the W2E briquette market grow, minimum standards need to be put in place and enforced, otherwise consumers will not adopt the briquettes.

Figure 15 - Waste to Energy Briquettes
(ARD, 2004)

Organic food waste can also be used in small-scale digesters at a household level to produce biogas. These types of systems have been succesful in India and Mali. The digesters do not produce enough biogas to completely replace normal cooking needs, however is able to offset a significant portion (up to 50%, depending on usage). These units are usually marketed towards middle-upper income households as lower income households cannot afford the upfront costs (~US$350). They are marketed partly as an energy source, but also as a waste management device and a source of fertiliser. One of the companies interviewed is exploring this business opportunity. The price point of the units is a major barrier for wide spread acceptance.

Figure 16 - Household organic waste digester in India
(PracticalAction, 2010)

Sustainability impacts:
W2E briquettes and biogas digesters can potentially save consumers money on fuel expenses. Expanded W2E briquetting facilities will also create jobs. By turning waste into a product with value, waste will be utilised instead of being left to rot or being washed into rivers and streams polluting water sources. Leachate (a toxic pollutant generated at landfills) and landfill gas (predominantly methane, a strong GHG) will be reduced if MSW volumes are reduced. As such, W2E can be part of a broader waste-management strategy.

There are also some negative impacts of W2E. In the actual collection of waste, the health and safety of the workers could be affected if mitigation measures were not put into place. The emissions from briquettes made from waste may have greater health impacts than charcoal, due to increased PM_{10} emissions. As with green charcoal, displacing traditional charcoal may impact income generation for rural actors involved in the charcoal chain.

Briquette Manufacture
Briquettes from agricultural residues, peat or papyrus have been shown to be feasible business options in other contexts. Rwanda has extensive peat reserves, and an ample supply of agricultural residues. Given that the briquetting operation is similar compared with W2E briquetting operations, the barriers are similar for these kinds of operations. In particular, acceptance of the fuel is an important barrier, especially when inferior products ruin consumer confidence.

Sustainability impacts:
The GHG impacts of utilising peat reserves are quite high. Many of the impacts are similar for the W2E enterprise, such as health impacts from emissions and rural employment impacts.

LPG
LPG as a cooking fuel has several benefits. It is a more convenient fuel, and due to the lower emissions compared with solid fuels, the health impacts are much lower. For these reasons it is near the 'top' of the energy ladder. As a fossil fuel, the GHG impacts are potentially higher, however this is uncertain and

depends greatly on the fuel (and more specifically the production method employed for the fuel) being displaced.

LPG already makes up a small share of the market in Rwanda. Two years ago the total market was approximately 45 tonnes/month, and currently the market is 75 tonnes/month, highlighting the large growth in this sector. The goal from the GoR is 125 tonnes/month, and according to an LPG supplier, this is achievable with current infrastructure. The GoR recently lifted the import duty, allowing for a large growth in the sector. The 18% VAT still remains.

Interestingly the sector has been able to grow on an even playing field with other energy sources, as no subsidy exists for LPG. This is partly due to the fact that charcoal can be more expensive than LPG, depending on how it is used. For a family of 5, 4 bags of charcoal per month at a total price 32,000 Rwf is equivalent to a 31,000 Rwf 20kg LPG bottle.

Figure 17 - LPG filling station in Gatsata, Kigali (left) and stock of LPG cylinders (right)

Despite this cost competitiveness, the initial outlay for equipment and the recurring cost for the cylinder remain a major barrier for lower-middle income households due to cash flow problems. In addition to this, higher income households have safety concerns about their staff utilising LPG cylinders, and thus prefer that they use charcoal as the apparent dangers are far less. Many people interviewed indicated that there were cultural aspects to charcoal use, meaning that even if LPG is adopted by a household charcoal will still be used for the preparation of many meals, as the charcoal imparts a certain taste, particularly to meats.

Sustainability impacts:

The health benefits are clear for a switch to LPG. Continued growth in the LPG sector will reduce pressure on the charcoal chain, however if LPG were to replace charcoal entirely, the effects on rural income generation would be devastating. Increased imports will also contribute to an increased trade imbalance. Despite current cost competitiveness, LPG prices may increase to a point where it becomes unaffordable, and people may revert to charcoal. Given budgetary constraints, it is unlikely that the GoR can afford to subsidize this fuel. In the short-medium term however, LPG is an affordable option for many households.

Second Generation Kerosene Stoves

Kerosene stoves are a cheaper option than gas stoves. Kerosene can be purchased in small quantities, thus is more suited to lower-middle income households cash flow. A switch to kerosene also entails similar health benefits as a switch to LPG.

The commercialisation of second generation kerosene stoves to lower-middle income households is stated as a priority for the Ministry of Infrastructure (MININFRA, 2009). They are claimed to be safer, cleaner and more efficient. If this priority is supported with concrete government incentives, this could represent a business opportunity for entrepreneurs. As was the case in South Africa, it would be important for the government to set minimum standards for safety purposes (GTZ/MARGE, 2009), as inferior quality leaking kerosene stoves have been known to be responsible for many house fires.

Figure 18 - Second generation kerosene stove

Sustainability impact:

Kerosene is a fuel that is subject to price hikes, which can have a big impact on household budgets. Also, kerosene is one of the fuels important for providing lighting. If demand for kerosene products were to raise the price of this fuel domestically, this may reduce the ability of households to purchase kerosene for lighting purposes. The long term sustainability of this fuel is questionable, however requires a more detailed investigation.

4.7. Energy Access Map with Business Opportunities

The Energy Access Map is a useful tool for visualising these business opportunities. Figure 19 highlights the different options that are available.

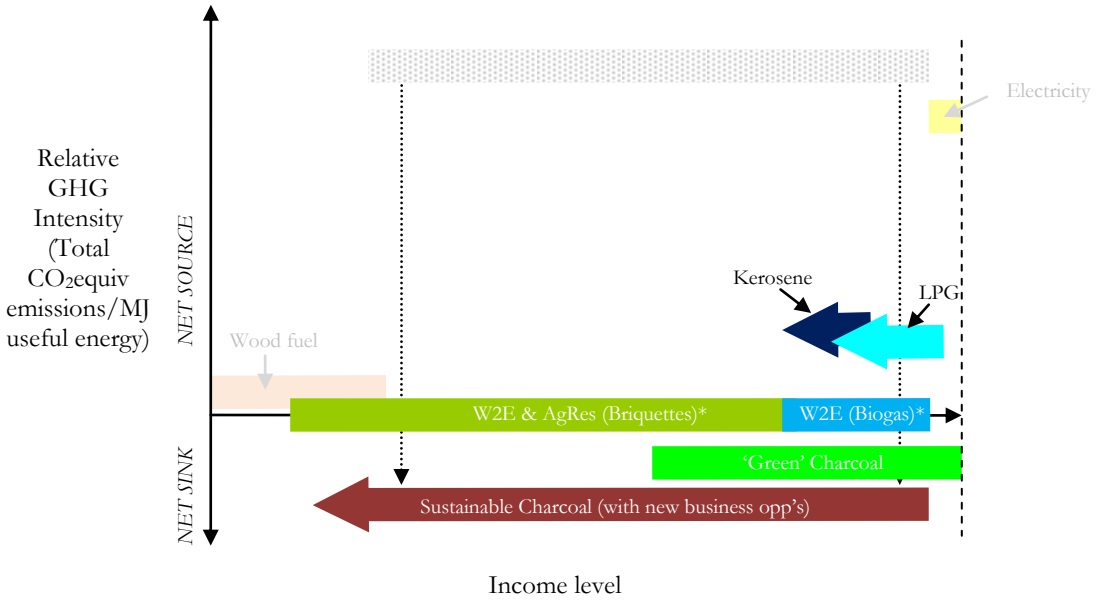

Figure 19 – Cooking energy access map highlighting business opportunities[14]

Drawn by the author. Vertical axis not to scale. (* - reliable net emissions factors were not found, see appendix for a discussion)

The business opportunities described above are by no means a final, complete list. If the demand is there, entrepreneurs will always find new & innovative business models to serve the demand, given a conducive external environment.

Three seemingly obvious exceptions that warrant explanation were electric stoves, solar cookers and biogas digesters (human waste). Electric stoves were not considered because the electric grid in Rwanda is small and further pressure on the grid for cooking purposes may increase prices, reducing the ability for other lower income households to use electricity for other purposes. Several interviewees indicated that there is no market for solar cookers in Kigali. There may be a market in rural areas, however this was outside the scope for this study. Finally, although there may be a potential for institutional biogas from human waste, there does not appear to be a market for these units in urban households in Kigali.

[14] Counter-intuitively, if a 10 year coppice cycle is employed and plantations act as a carbon sink, improved kilns (in the production of green charcoal for example) will increase the carbon intensity of the charcoal, because less wood use per kg of charcoal means a smaller amount of carbon sequestration per kg of charcoal. However, from an energy perspective, utilisation of improved kilns greatly reduces energy losses, thereby expanding the limited resource base. Also up to this point black carbon has not been included, which if included may change the effect of an improved kiln on the greenhouse warming effect of the produced charcoal.

5. Barrier analysis

Specific barriers to these business opportunities were identified in interviews with a variety of stakeholders, including entrepreneurs, civil servants, NGOs, development organisations, financial institutions and consumers. The barriers were qualitatively obtained, and as such individual bias may reduce the accuracy of the results. The barriers are presented here, and then potential mechanisms for overcoming these barriers will be presented.

5.1. Barriers

The following barriers were identified in the course of the interviews with practitioners. Each barrier is put into a category according to the nature of the barrier. The categories include regulatory, entrepreneurial, technical, financial, social and marketing barriers.

Business opportunity	Barrier	Category
Plantation investment & Improved kiln investment	Permit system deters investors	**Regulatory**
	Not seen as a business opportunity	**Entrepreneurial**
	Lack of business acumen	**Entrepreneurial**
	Uncertainty on long term legal status of charcoal	**Regulatory**
	Lack of know-how	**Technical**
Charcoal dust recovery	Investors required	**Finance**
	Lack of affordable finance (18% SME loans)	**Finance**
	Lack of know-how	**Technological**
	Not a 'get-rich quick' business	**Entrepreneurial**
Pressure cookers & Improved stoves	Lack of market awareness	**Marketing**
	Up-front costs (price-point)	**Entrepreneurial**
Green charcoal	Difficult to compete with existing chain	**Finance**
	Permit system deters investments	**Regulatory**
	No certification system for 'green' charcoal	**Regulatory**
	No general environmental awareness for 'green' products	**Social**
	Transaction costs for climate finance	**Financial**
Briquette enterprises (W2E, Alternative fuels) & W2E biogas	Lack of affordable finance (18% SME loans)	**Finance**
	Difficult to compete with existing chain	**Social / Marketing**
	No quality standards which means inferior products ruin consumer confidence	**Regulatory**
	No general environmental awareness for 'green' products	**Social**
	No sorting of waste	**Social / regulatory**
	Lack of business acumen	**Entrepreneurial**
	Lack of technicians	**Technological**
	Lack of competition among equipment suppliers	**Technological**
	Difficulty to scale operations	**Entrepreneurial**
	Capital costs prohibitive (biogas units)	**Entrepreneurial / Financial**
LPG & Kerosene	More expensive	**Financial / Regulatory**
	Safety fears	**Social / marketing / regulatory**
	People prefer charcoal	**Social / marketing**

Table 3 – Barriers to business opportunities

5.2. Removing barriers: fostering an enabling environment

Having identified the barriers to the business opportunities, strategies for removing barriers were identified from interviews and available literature (IFC & HKS, 2010; Justice, 2009; Opijnen, 2008). Although some of the barrier removal strategies are very specific to the cooking sector, many are not sector specific and contribute to the development of a general enabling environment for renewable energy and energy efficient enterprises in Rwanda. The strategies are grouped according to the categories identified in the previous section.

Regulatory

Permit system

The permit system was identified by many of the interviewees as a key issue that needs to be resolved in order to promote investment in the charcoal chain. Many different permit system designs exist in other African countries and could provide lessons for reforms in Rwanda. Reforming the permit system should be undertaken in a participatory fashion, in order that all stakeholders are engaged and the system is fair and equitable. A detailed study should be undertaken in order to develop an optimal permit system for this context.

Quality standards

In order for sustainable fuels to gain consumer confidence, quality needs to be consistent and of a certain minimum standard. This is particularly true for fuel briquettes. Creating minimum standards that are enforced would improve the reputation of briquettes as an acceptable substitute, important for growing this industry.

Governmental statement of support

Finally, from a regulatory perspective, a clear position on the legality of particular fuels, especially charcoal, needs to be taken so that long term investments can be made that improve the sustainability of the fuel.

Financial

A detailed assessment of Rwanda's financial sector was undertaken by the World Bank / International Monetary Fund (IMF) in 2005, highlighting a generally weak financial sector with many shortcomings (WB/IMF, 2005). In response, the GoR launched the Financial Sector Development Program (FSDP) in 2006 with the following priorities (Murgatroyd et al, 2007):

- Expanding access to credit and financial services;
- Enhancing savings mobilization, especially long term savings; and
- Mobilizing long-term capital for investment.

International donors are also targeting the financing issue. For example, DFID recently launched a £10m "Access to Finance" program (DFID, 2010) with the goal of improving access to finance to over 500,000 through micro, meso and macro level interventions.

Having recognised that there is momentum from the GoR and international donors in improving access to finance through general financial sector reforms, more specific interventions related to the cooking energy sector will be discussed in this section, including microfinance, growth finance, taxes & levies, sensitisation to the energy sector, climate finance, advanced market commitments, leveraging existing infrastructure and grants.

Microfinance

Microfinance, the asset class targeting small scale loans, provides loans of relatively small amounts with high interest rates over a short period of time. This type of asset class may be useful for charcoal producers who may be searching for more modest loans to purchase the chimneys for their improved kilns. In order to allow access to microfinance, aggregating producers into associations would give them an enhanced capability to access microfinance.

However, even with such aggregation, it may still be difficult to access credit. The microfinance sector in Rwanda is comparatively weak, partly due to a 'bad credit culture', largely stemming from a large influx of aid money after 1994 that mixed grants and loans, thereby distorting the market (Curtis, 2008). Access to microfinance is currently very low, and building a strong microfinance sector is important to provide credit to those seeking to develop their micro-enterprises. Innovative microfinance initiatives such as internet funds (MYC4.com & KIVA.org) can also play a role, however without a strong microfinance infrastructure and culture of borrowing, they will have a limited impact. A strong microfinance sector is an important enabler for many of the micro scale business opportunities.

Growth finance

Access to affordable capital finance was identified as a major barrier for many small to medium size enterprises[15] (SMEs) trying to grow their businesses. Access to capital was cited as more of an issue than profitability. This barrier is not isolated to the cooking sector – access to affordable capital finance is a major barrier for many SMEs trying to grow RE businesses in Rwanda.

This lack of affordable finance for SMEs has been largely responsible for creating a 'missing middle' (UNCTAD, 2001) of mid-range enterprises widely recognised as important for job creation and economic growth. The type of finance typically required for SME's is in the order of 50k – 1000k USD. These loans are too large for microfinance, and too small to attract traditional equity investments. How to cater to this 'missing middle' is a key issue.

SME loans are available through financial institutions in Rwanda, however very high premiums are charged (~18-20%) over a short payback period (normally 3 years). Loans, despite being available, are thus not affordable. Venture capital can sometimes fill in the gap, investing in start ups & new technologies. It is unlikely however that venture capital funds will be interested in these businesses because they usually search for a very high return (~50% IRR) to cover the risk associated with the investment, which is not possible for many of these cooking energy businesses, as they are dealing with high volume, low margin products.

[15] The number of employees often is the variable that defines the size of a business. The following classification was taken from the World bank (Opijnen, 2008):

Micro business:	0-4 employees
Small business:	5-49 employees
Medium business:	50-250 employees

A new form of financing is emerging, termed g*rowth finance*. This is comparable to microfinance as an asset class, however targeted to SMEs. Growth finance adopts the viability based approach, which means the lender is engaged with the SME loan recipient to improve the viability of their business, thereby reducing risk and improving the attractiveness of the investment. This in turn lowers the rate charged. An example of an active growth finance lender in Rwanda is Grofin. Innovative financing models that target the missing middle should be supported by the government, international donors and NGO's, as they could potentially provide an important financial service to many SMEs.

Taxies & levies

Taxes & levies can also play a large role in creating an enabling environment for certain business opportunities. Depending on GoR priorities, favourable tax regimes for providers of sustainable fuels would promote the growth of particular businesses. For example, a tax reduction for 'green' charcoal would make this much more competitive.

Sensitisation to the energy sector for financial providers

Sensitisation and capacity building in the financial sector towards energy investments would be a longer term intervention that would reduce the perceived risk that may be present towards these types of investments due to unfamiliarity with the sector.

Climate finance

Another source of financing that could be accessed is climate finance and could provide an extra revenue stream for several businesses. Green charcoal businesses would be eligible for such climate finance[16], given that financial additionality requirements are met. The transaction costs of accessing these revenue streams could be a barrier for entrepreneurs, who often see carbon finance as a risky investment, as carbon revenue is not guaranteed. In order to encourage greater access to carbon finance, sensitisation campaigns and capacity building could be implemented by the government[17], donors & NGOs.

Advanced market commitments

Advanced Market Commitments, or AMCs, are a new mechanism being explored by international donors to leverage private capital. AMCs provide a financial benefit based on performance. Popularised in the pharmaceuticals industry, an international donor or multi-lateral institution guarantees a price for the delivery of a certain product, creating market pull. For example, food waste biogas digesters, if made eligible for an AMC, would generate revenue for the provider once a system is installed and is producing energy. This could reduce risk given that a guaranteed income stream is provided. No examples of this to date have been undertaken in the energy sector, and the suitability of this mechanism for the cooking energy sector would need to be studied.

Leveraging existing infrastructure

A successful strategy employed by several businesses was to form a joint-venture with larger companies and utilise their existing infrastructure to minimise required capital investments. One of the enterprises interviewed adopted such a strategy. They pay the parent company realistic rates for land, electricity,

[16] For example, the small-scale CDM methodology titled "*III.K. Avoidance of methane release from charcoal production by shifting from traditional open-ended methods to mechanized charcoaling process"* could potentially be applied (UNFCCC, 2008).

[17] Such a sensitization campaign is already being implemented by the Rwandan Environmental Management Authority.

staff, etc. According to the enterprise, it would not have been viable to start the business as a lone enterprise. Despite the advantage of this, flexibility may be reduced which could be problematic in the start-up phase. These kinds of business strategies could be developed in entrepreneurs through the provision of Business Development Services (see the 'entrepreneurial' section below).

Grants

It is also important to note the importance that grants play in catalysing certain businesses. Grants from donor agencies, the World Bank and the Shell Foundation, to name a few, have permitted several businesses to significantly scale their operations. Despite this success, grants are not a sustainable or scalable financing mechanism, given that amount of financing available for grants is dependent upon the capacity of these international and multi-lateral institutions. They also have the potential to be misused or have little impact, as the grant is given upfront, and there is no real incentive other than the personal motivation of the entrepreneur to sustain and grow the business.

Entrepreneurial

Value chain management

Although presented as a contiguous chain, links across value adding activities are weak. There exists a large body of management literature looking specifically at value chain management. A large improvement in the overall performance of the chain could be achieved through a holistic approach to management of the value chain. This is being undertaken by IFDC and to a certain degree CARE Rwanda. Persons interviewed believed that such chain support mechanisms will lead to an increase in entrepreneurial activity and will engender a more business-like approach allowing business opportunities to be capitalised upon. Some of the chain support mechanisms being implemented include encouraging the formation of associations and the deployment of ICTs.

Business development services

Another entrepreneurial mechanism that has allowed businesses to improve price competitiveness, popular in the BoP literature, is the development of innovative business models. The development of innovative business models requires a certain level of capacity and business acumen that may be lacking in Rwanda. The provision of Business Development Services (BDS), through such institutes as business incubators, could potentially help develop local entrepreneurial capability. The Technology and Business Incubation Facility (TBIF) provides business development services to recent graduates of KIST. Providing these services to a wider range of entrepreneurs could help drive business model innovation and development.

Technological

Technological barriers involve the lack of technical capacity required to capitalise on certain businesses. A lack of awareness of available technologies and practices, a lack of trained technicians, and the general (un)availability of suitable suppliers were all identified as technological barriers.

Technology transfer and capacity building

Bringing technology innovations to the market and linking technology suppliers to entrepreneurs could be facilitated through a technology innovation hub. This type of facility would fall under BDS provision.

Such an innovation hub should be market driven and provide a focal point for local entrepreneurs and foreign technology providers.

A particularly important lack of technical capacity relates to plantation management. In addition to the lack of incentives for improved plantation management practices, there is a clear lack of capacity for transferring these practices to farmers. Several NGOs are active in this area, such as the IFDC. It is important this capacity is transferred in a sustainable manner, and that the departure of the NGO does not spell the end of continued improvement. In addition to continued support for these NGOs, it is important to understand how to scale the transfer of such skills, and to embed it into the common practices of farmers.

Technical training
Growing the pool of trained technicians requires further development of educational and training facilities. Specific sectoral knowledge, such as for the waste to energy field, could be integrated into existing courses. In order to understand the cooking energy sector requirements in terms of technicians (and energy businesses in general), a detailed study should be performed.

Social / Marketing
Social / marketing barriers are potentially the least and most difficult of barriers to address. Certain barriers may only require awareness raising and education to change behaviour, whereas other social barriers are nearly impossible to change due to deeply ingrained cultural practices. Some of the proactive actions that could be undertaken to try and influence behaviour and decision making could include:

- Awareness campaign on the environmental & health benefits of improved cooking fuels
- Awareness campaign for energy efficient cooking appliances
- Safety awareness campaigns for LPG and kerosene (this is already being undertaken for LPG)

PPPs
Public-private partnerships, where the GoR provides awareness raising and creates market pull, and the private sector services the market, could be constructive in order to distribute energy-efficient technologies such as pressure cookers.

Market analysis capacity building
The availability of market information was also identified as a barrier in taking advantage of business opportunities. Rather than contracting expensive foreign consultants, a more transformative and long term solution would be to develop the local capacity to collect market information. This could be undertaken through educational institutes such as KIST.

Institutional fuel switching
Another means for creating market pull and developing consumer confidence would be the adoption by state institutions of sustainable fuels, such as green charcoal. These may include schools, universities, hospitals, governmental buildings, etc. These could be sourced through a competitive tendering process.

6. Policy recommendations

In order to formulate effective policy, it is important to align new policy with existing overarching government priorities and strategies. It is also important to take into account the capacity of the different stakeholders to implement, monitor and enforce the proposed policy. In this way, the policy measures will be congruent and realizable.

Accordingly, a brief analysis of relevant government priorities and strategies is performed with relation to some of the policy intervention mechanisms described earlier in order to contextualise the policy recommendations in a broader policy environment. Following this, a set of policy recommendations contributing to an enabling environment for sustainable cooking energy businesses is presented.

6.1. Relevant government priorities and strategies

At present, according to one source, pressure is being placed on ministries to move away from charcoal and diversify to other fuel sources. Although diversification will help reduce pressure on the chain and improve health, abandoning the chain completely may be misguided, as a pro-charcoal policy would contribute to many stated development objectives of the GoR. This is summarised in the following points:

- Charcoal is the backbone of the cooking energy sector in Kigali, as such it is key to maintaining energy access
- The charcoal value chain is a key driver for rural economic growth, contributing to poverty reduction
- It is possible to improve the sustainability of the charcoal chain, thus from an environmental perspective the long term impacts are not as devastating as widely believed
- If charcoal becomes a net sink of GHG emissions, this could be part of low carbon development scenario, allowing the GoR to channel climate finance into rural development
- Rather than importing energy, supporting this sector would build on local values and strengths
- If a major shift to externally supplied fuels were to eventuate, this would increase the countries trade imbalance

Some of the support mechanisms outlined in the previous section require a small amount of financial commitment, and thus a pro-charcoal set of policies would be cost-effective in the long term.

One stated policy goal from the GoR is diversify fuel sources. Supporting sustainable alternative cooking energy enterprises would support this goal. Most of the enterprises attempting to bring other forms of sustainable cooking fuels to the market are SMEs. Many of the barriers limiting these enterprises are cross-cutting issues that are general barriers faced by all SME RE entrepreneurs. This is particularly true of the financial barrier for SMEs. SMEs will drive much of the growth in small-scale distributed generation, and the co-benefits of supporting SMEs are large, including enhanced competition and entrepreneurship, increased employment and improved allocation of capital (Levine, 2005). Such effects contribute to overarching GoR goals, outlined in such documents such as the Vision 2020.

6.2. Recommended policy actions for an enabling environment

Based on the analysis, in order to create an enabling environment for the business opportunities identified in the previous sections the following policy actions are recommended. It should be noted that before implementing these policy actions, a more detailed impact assessment should be performed, as this was not performed in a thorough manner in this study. Different policy recommendations are given for different stakeholders.

Government of Rwanda (to be implemented through relevant ministries and local governments)

- Official statement of support for charcoal highlighting the co-benefits that the value chain provides and a commitment to the long term legality of charcoal
- At the local rural level, revise the permit system through a participatory approach to encourage investment and improve transparency
- Strengthen the patrolling of forests to prevent illegal production (whilst acknowledging legality of current producers)
- Create and enforce minimum performance standards for energy briquettes
- Investigate a certification scheme for 'green' charcoal products
- Initiate environmental & energy efficient awareness raising programmes
- Continue and extend safety awareness campaigns for LPG & Kerosene use
- Create minimum standards for kerosene stoves
- Programs to sensitise the financial sector to energy related investments
- Targeted support for technicians in relevant fields
    - Technical training in waste to energy field
    - Capacity development for market data gathering

GoR & Private Sector Partnerships

- Investigate PPPs for dissemination of energy efficient cooking utensils, such as pressure cookers and cooking stoves, where the GoR raises awareness creating market pull, and private sector provides merchandise
- Support pilot projects for green charcoal
- Source sustainable cooking fuels in institutions (schools, hospitals, government buildings) through a competitive tendering process

International Donors/NGO's

- Continued support for the finance sector, particularly microfinance and innovative financing models for SME's (growth finance)
- Facilitate access to climate funds for 'green' charcoal & briquettes with capacity building
- Investigate the appropriateness of 'Advanced Market Commitments' for the cooking energy sector
- Investigate the establishment of a centre providing Business Development Services (BDS) to a wider range of entrepreneurs. The centre could facilitate:
    - Identification and connection of potential partners (local & international) through a centralised scheme
    - Training in general business skills

- Continue and strengthen programs supporting the professionalisation of the charcoal value chain, in particular the transfer of skills and management practices to plantation owners

7. Conclusions

Sustainable cooking energy is an integral aspect for continued energy access. Several business opportunities can provide such energy services, however several concrete barriers exist. Removing these barriers can create an enabling environment in which the business opportunities can be capitalised upon.

In this report, the barriers to several sustainable cooking energy business opportunities were articulated. The identification of these barriers will contribute to the knowledge base by giving specific and concrete examples of challenges faced by entrepreneurs in a Bottom of the Pyramid market.

Policy actions were detailed that may remove these barriers and create an enabling environment that will foster these businesses. Many of the policy actions are cross-cutting, in that they create an enabling environment for RE entrepreneurs in general, not just those in the cooking energy sector.

However, the onus is not entirely on policy makers to catalyse these businesses. There is always risk involved in private enterprise, and this is fundamental to entrepreneurship. Buying out risk has proven many times to distort the market and is not sustainable from a business perspective. As such, the policy recommendations outlined in this report avoid firm-level interventions and focus on creating an enabling environment. Developing such an enabling environment is a longer term solution, and brings many broader societal co-benefits.

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Appendices

Appendix A – Calculations for cooking energy access map

In order to develop the cooking energy access map, a detailed study from Bailis (2005) was the basis for the Rwanda case. Bailis calculated the life cycle GHG emissions for a variety of household fuels in Kenya. Only some small changes were required in order to translate the results into the Rwandan case.

The following summary table gives the life cycle GHG emissions from Bailis' study:

Fuel	Calorific value (Q) [b]	Heat transfer eff (η) [b]	$EF_{TOT\text{-}MASS}$ (tC/ton_{fuel})	$EF_{TOT\text{-}ENERGY}$ (gC per *useful* MJ) [c]
Wood	16	15%	0.06	25
Charcoal – *Tarch grain*	31	25%	2.72	351
Charcoal – *Tarch regrowth*	31	25%	(0.26)	(34)
Charcoal – *Tarch coppice* (5-15)	31	25%	0.08 – 0.29	10-37
Charcoal – *Euc coppice*	31	25%	(0.82) – (0.50)	(106) – (65)
LPG	43	50%	1.03	48
Kerosene	46	54%	1.04	42

Table 4 - Lifecycle GHG emissions for HH fuels in Kenya
(Bailis, 2005)

The alterations to these values (if any) are described here:

Wood

No change, as consumption & behavior similar in Kenya & Rwanda

Charcoal

Several examples are given for charcoal. In Rwanda, the most common source of wood for charcoal is from Eucalyptus plantations. However, it is unclear whether or not the same coppice management technique is utilized. The other extreme is wood for charcoal taken from clearing of native forests. These two values form the range of values for charcoal in the energy access map.

LPG & Kerosene

LPG & kerosene in the calculations from Bailis assume the fuel needs to be transported from Mombasa to Nairobi (~500km). In the Rwandan case, the emissions for transport are increased approximately 3.5 times, as the fuel needs to be transported from Dar es Salaam to Kigali (~1750km). The following table illustrates the lifecycle calculation performed by Bailis for these fuels:

	Raw materials extraction and production	Transport	End-use	Total GWI
	$EF_{LUC} + EF_{PROD}$	EF_{TRANS}	EF_{CONS}	EF_{TOTAL}
LPG	0.12	0.025	0.89	1.03
Kerosene	0.16	0.025	0.85	1.04

Table 5 - LPG and Kerosene GWI coefficients
(Bailis, 2005)

Multiplying the EF_{TRANS} coefficient by a factor of 3.5, and carrying the results through gives a EF_{TOTAL} of approximately 1.1 for LPG and 1.11 for kerosene. This has only a minor impact on the life cycle GHG impact per unit of useful energy.

There are other values that do not appear in Bailis' work that were estimated by the author. These are only rough estimates, which is sufficient for this work.

Electricity

Rwanda has an approximate electricity mix of 54% hydroelectricity, 46% from heavy fuel and diesl generators.

For 1MJ of electricity to arrive to the electric cook top:

Assume 1 $kgCO_2$/kWh from a diesel generator

1 MJ = 0.2778 kWh

But:

1MJ delivered needs more due to losses

Assuming a 55% effectiveness at the stove

Assuming 15% T&D losses

Energy required from generator = $\frac{1\ MJ}{0.55 \times 0.85}$ = 2.14 MJ

But:

Hydropower contributes 54% of the energy required (assume no emissions from this source)

So,

Energy required from generator (for 1 MJ delivery) = $\frac{0.46 \times 1\ MJ}{0.55 \times 0.85}$ = 0.984 MJ

Calculating the CO_2 emissions:

CO_2 emissions = $0.984\ MJ \times \frac{0.2778\ kWh}{MJ} \times 1\ \frac{kgCO2}{kWh} = 0.273\ \text{kg}CO_2$

Waste to Energy (W2E) and agricultural residue briquettes and biogas

No reliable information could be found that could accurately determine the net emission factors for these fuels. Some studies were found for larger scale applications where waste is used in developed countries for electricity generation (Kaplan et al, 2009). These studies indicate that despite emissions in the combustion phase, they are smaller than letting the waste decompose into methane, thus combusting waste acts as a net sink of GHG emissions. As the author does not have reliable information, it is assumed that that the emissions intensity for these fuels is zero (neither a source nor a sink), however this would need to be verified with further research.

Appendix B – List of persons consulted

The following is a list of persons consulted during the research. Please note that although the author has attempted to accurately retransmit the content of the exchanges, the work has not been reviewed by these persons, thus the opinions expressed in this report are those of the author.

Person	Position	Organization	Location
Fred Smiet	First secretary of regional affairs	Dutch Embassy	Kigali, Rwanda
Hayo Brandt	Engineer	Carbo Group	Almelo, The Netherlands
Frank van der Vleuten	Senior Consultant	ETC Energy	Leusden, The Netherlands
Dave Smit	Manager, Structured Finance Energy	FMO	The Hague, The Netherlands
Matthew Owen	Director	Chardust	Nairobi, Kenya
Veronica Echavarria	Coordinator briquette program	ACF	Virunga NP, DRC
Rajeev Aggarwal	Director TBIF	Technology Business Incubation Facility	Kigali, Rwanda
Dr. Anastase Rwigema	Renewable Energy Expert	CITT/KIST	Kigali, Rwanda
Naila Umuhyeyi	HoD	Technology Transfer / CITT	Kigali, Rwanda
Jean Bosco Rwiyamirira	Chairman	Association Rwandaise de l'Energie Durable	Kigali, Rwanda
Evariste Shangala Gatete	Vice-chairman	Association Rwandaise de l'Energie Durable	Kigali, Rwanda
Robert van der Plas	Consultant	MARGE	Kigali, Rwanda
Gerard Hendriksen	Senior adviser	GTZ/MININFRA	Kigali, Rwanda
Gaspard Nkurikiyumukiza	Biomass	MININFRA	Kigali, Rwanda
Prof. Longin Minani	Head of Mechanical Engineering	Kigali Institute of Science & Technology	Kigali, Rwanda
Robert Nyamvumba	Engineer (Thermal Power Plants)	Rwanda Electricity Corporation	Kigali, Rwanda
Paulin Buregeya	Director General	COPED - Ecomake	Kigali, Rwanda
Kenneth Tumusiime	MD & Waste Prevention Expert	Ecomake	Kigali, Rwanda
Prudence Ndolimana	Project Manager	CARE Rwanda	Kigali, Rwanda
Guy Dekelver	Renewable Energy Senior Advisor	SNV	Kigali, Rwanda
Francois Sihimbiro	Senior Adviser Agriculture	SNV	Kigali, Rwanda
Lina Mukashyaka	Head of SME Banking	Finabank	Kigali, Rwanda
Gerard Mpyisi	Managing Director	Finabank	Kigali, Rwanda
Siôn McGeever	Growth & Infrastructure Advisor	DFID	Kigali, Rwanda
Craig Feinberg	Resident advisor	Finabank	Kigali, Rwanda
Sehmi Lakhbir Singh	Head Marketing & Operations	KOBIL Rwanda	Kigali, Rwanda
Fabien Kayitare	National value chain expert	IFDC – International Center for Soil Fertility and Agricultural Development	Kigali, Rwanda

Appendix C - Cutting & transport regulatory requirements

The following table highlights the different requirements for cutting trees in several southern districts:

		Plantation size	
Type of requirement		**Less than 1 hectare**	**More than 1 hectare**
Administrative requirements in all districts		• The approval of the village representative that witnesses and confirms that the tree plantation is somebody's property. • The Approval of the cell coordinator. • Visit of sector by agronomist who gives advice and delivers tree cutting permit.	• The approval of the village representative that witnesses and confirms that the tree plantation is somebody's property. • The Approval of the cell coordinator. • Visit of sector agronomist who gives a go ahead to the District for authorizing tree cutting permit. • Visit of District Environment officer who then delivers tree cutting permit.
Cost of tree cutting permit	Gisagara	15,000 Rwfr	15,000 Rwfr
	Huye	5,000 Rwfr	5,000 Rwfr
	Nyamagabe	20,000 Rwfr	Not yet defined
	Nyaruguru	10,000 Rwft	12,000 Rwfr
Number of permits offered per month	Gisagara	Currently banned	
	Huye	Seldom	Intermittently
	Nyamagabe	2 per cell (34 on average per month)	
	Nyaruguru	1 per cell (35 on average per month)	
Contribution to the National Forest Fund	Gisagara	-	1% of the value of the forest or Rwfr 2,000
	Huye	-	
	Nyamagabe	-	
	Nyaruguru	-	

Table 6 - Regulatory requirements for tree cutting in 4 southern districts
Adapted from Munyehirwe (2009)

Similarly, in order to obtain a transport permit, several requirements need to be fulfilled:

	Administrative requirements	Cost of Charcoal transportation permit	Tax per bag	Contribution to the National Forest Fund
Gisagara	• Report from the sector* • Presentation of Tree cutting permit of the charcoal to be transported • Presentation of receipts from the bank attesting the payment of all administrative costs. • Tree Transportation permit is signed by the mayor, director of infrastructure and the officer in charge of environment.	30,000 Rwfr	100 Rwfr	1% of the value transported charcoal or 2000 Rfwr **
Huye	• Report from the sector* • Presentation of Tree cutting permit of the charcoal to be transported • Presentation of receipts from the bank attesting the payment of all administrative costs. • The tree Transportation permit is signed both by the Director and the officer in charge of environment.	5,000 Rwfr	-	2,000 Rwfr
Nyamagabe	• Report from the sector*** • Presentation of Tree cutting permit of the charcoal to be transported • Presentation of receipts of payment of all administrative cost; • Tree cutting permit is signed by the mayor, director of infrastructure and the officer in charge of environment.	40,000 Rwfr	150 Rwfr	2,000 Rwfr
Nyaruguru	• Report from the sector*** • Presentation of Tree cutting permit of the charcoal to be transported • Presentation of receipts of payment of all administrative cost; • The tree cutting permit is signed by the mayor, director of infrastructure and the officer in charge of environment.	50,000 Rwfr	100 Rwfr	2,000 Rwfr

Table 7 - Regulatory requirements for charcoal transport in 4 southern districts
Adapted from Munyehirwe (2009)

***** Report shows the number of harvested trees and number of produced charcoal. It also confirms that trees were cut according to the standards recommended.

****** All those payments are done on a bank account of the district and if 1% represents a small amount which is less than accepted minimum deposit for the bank, then a fixed amount of Rwfr 2,000 are paid as a contribution to the National Forest Account.

*** This report includes the identity of the businessman, the charcoal production and destination place, the name of the driver and the plaque of the vehicle.

Appendix D – Cost-benefit analysis for ‘green’ charcoal

Email from equipment supplier:

From: ANTONIO Q.A. [mailto:antonio@proininso.com]

Sent: woensdag 24 maart 2010 20:41

To: Falzon, J.P. (James)

Subject: Re: Interested in product: Kilns For Making Charcoal.

Dear James, thanks for your inquiry.

James, we manufacture mobile and static furnaces/kilns for biomass carbonization applying a ecopyrolysis system, they are mono-retort design.

The standard capacities are 2-4m3 for the mobiles and up to 10m3 for the statics, when need to produce quantity of charcoal we can install lines of several retorts to fit any required capacity.

The average efficiency are 30-40% of the anhydrous biomass at 10-15 hours process.

They don't use any external energy to operate, only biomass. The big retorts, off course, need crane operated by electric motors to hoisting the inner ovens.

We delivery and install at any country.

The prices (CIF at any container's port) fluctuate from 12,000 to 16,000 EUR/m3 of capacity.

If any question, please contact freely.

With kind regards,

Antonio

Information provided on website (http://proininso.com/pageID_7968213.html):

RENTABILIDAD ECONÓMICA Y MEDIOAMBIENTAL

COMPARATIVAS DE RENTABILIDAD

20 m3 de leña de Eucaliptus	Hornos tradicionales	Hornos PIROECO
Rendimiento de carbón:	1.800 kg	3.800 kg
Tiempo de carbonización:	12-16 días	15-18 horas
Mano de obra (Hombre/Día):	15 H/D	4 H/D
Consumo energético:	leña carbonizable	resíduos leñosos

La tecnología de los hornos de carbonización ecológica Piroeco permite incrementar el rendimiento de las biomasas leñosas (o resíduos densificados) un 100-120% y la productividad por trabajador un 300-500%. La amortización (a 5 años) de la inversión para la adquisición de los hornos representa solamente un 30% del incremento del rendimiento.

COMPARATIVA MEDIOAMBIENTAL

Sin lugar a dudas, la mayor ventaja de los HCEP está en su aspecto medioambiental que permite el máximo de reducciones de emisiones de gases de efecto invernadero considerados por el Protocolo de Kioto y por tanto poderse acoger al Mecanismo de Desarrollo Limpio (MDL).

EMISIONES EVITADAS, EN KILOGRAMOS POR TONELADA DE CARBÓN PRODUCIDO:
CO2 (dióxido de carbono): 8.000-10.000 kg.
CH4 (metano): 300-375 kg.
N2O (óxido nitroso): 4-5 kg.
COVNM (compuestos orgánicos volátiles no metano): 500-625 kg.

Simplified cost-benefit analysis:

Number of units		1
Capacity	m3s wood / vessel	4
Specific weight wood (dry)	tonne / m3s	0.5
Moisture content wood	prop, wet basis	0.5
Efficiency	prop, dry basis	0.4
Efficiency	tonne wood (dry) / tonne of charcoal	2.50
Actual efficency	tonne wood (wet) / tonne of charcoal	5.00
Average production time for one vessel	days	0.5
Working days	days/year	300
Capacity	tonne / year	300
Capacity factor	prod. hrs / total hrs.	1
Annual input	tonne wood (wet) / year	1500
Annual output	tonne charcoal / year	300
Wood (moisture content 50%, wet basis) costs	Eur / m3s	2.64
Charcoal sales price (excl 18% VAT - counter price 6500 Rwf / 42.5kg)	Eur / tonne	165
Project time	years	10
Investment	Eur	80000
O&M costs	prop'n of investment	0.3
Discount rate		0.18
IRR		0.222630608
Annual costs	Eur / year	27960.00
Annual revenues	Eur / year	49500.00
Annual cashflow	Eur / year	21540.00
Simple payback	year	3.71
Net Present Value (NPV)	Eur	16802.62
Internal Rate of Return (IRR)		23%

Table 8 - Cost-benefit analysis for 'green' charcoal