Ethanol as a Household Fuel in Madagascar:

Health Benefits, Economic Assessment and Review of African Lessons for Scaling up




Component B

FINAL REPORT

Economic Assessment of the Ethanol Household Fuel Program

3rd December 2010

PRACTICAL ACTION Consulting

Acknowledgements

This report was produced by a number of individuals and organisations including Project Gaia, Inc. including Harry Stokes, Fiona Lambe (Stockholm Environment Institute), Liz Bates, Brady Luceno, Regina Couto, Joe Obueh, James Murren, Chidochashe Munangagwa, Megan Graham, Hilawe Lakew (Ethio Resource Group) and Getnet Tesfaye (Ethio Resource Group); Gaia Association including Firehiwot Mengesha Tachea & Wubshet Tadele Tsehayu; Practical Action Consulting including Dr Smail Khennas, Dr Ewan Bloomfield, Steven Hunt and Courtney Cabot Venton; Eco Consult including Dr Frank Richter and the University of Liverpool including Dr Nigel Bruce & Kirstie Jagoe.

We would also like to give special thanks to Dometic AB for their donation of stoves.

Table of Contents

List of Figures

List of Tables

List of annexes

Abbreviations

HH	Household
FAA	Foyer amélioré en argile; improved mud stove
FSA	Foyer semi-amélioré (en métallique); semi-improved (metal) stove
Yr	Year
NPV	Net Present Value
CBA	Cost Benefit Analysis
T	Tons

Executive Summary

Ethanol Production

Due to a number of issues, including high oil prices, international awareness of global warming and concerns about energy security world production of ethanol is rising. For producer countries ethanol offers a range of opportunities, both for domestic energy supply and for export, such as the example of Brazil, the only developing country to have so far gone to scale with ethanol production. Although Africa's ethanol base is less developed than those in Latin and North America, several countries are increasing production and there is significant potential for the African biofuels industry to expand. Despite recent growth however, the global market for biofuels is still in its relative infancy.

The dominant current consumption of ethanol is for transport fuel-blending, but there is also significant demand and use of ethanol in the industrial sector. However, in developing country contexts where household energy accounts for 75-90%,[1] ethanol has also been shown to have potential as a cleaner and healthier household fuel. Developing a stable domestic ethanol household fuel market is considered to have potential to offer substantial economic, health and environmental multiplier benefits at local, national and international levels. This potential has been partially demonstrated in Africa (e.g. Ethiopia), but also setbacks have been observed linked to poor stove technologies (e.g. Malawi), fuel forms (e.g. South Africa) and policy inconsistency (e.g. Ethiopia). If ethanol to achieve it's potential as a household fuel then these lessons must be learned in developing new sectors in countries such as Madagascar.

Ethanol can be produced from any biomass containing significant amounts of starch or sugar. Production scales can be categorised as: large scale, micro-distilleries and artisanal scale. Artisanal production is very accessible to poor rural producers due to low capital costs enabling local level benefit distribution, however low ethanol quality and strength at poor conversion efficiencies (implying more fuelwood use per litre of ethanol), creating a higher cost product make it non-viable for a widespread household ethanol programme. The close association of this type of production with drinking, the higher market price per litre for this application, and the difficulties of policing production at this scale appear to preclude its serious consideration for household ethanol market creation.

Large scale production is relatively well known internationally and is the typical scale of production in Brazil and other large ethanol producing economies, offering good efficiencies, quality, strength and low cost per litre. However centralised plants will not necessarily promote maximum benefit distribution along the supply chain and high capital barriers exclude local people from direct participation, other than as waged labour or raw material suppliers. As such, the structuring of agreements with out-grower sugarcane suppliers for example, can have a strong influence on inclusivity and development impacts. Micro-distillation is a relatively new scale of production but it appears from international experience to offer many of the energy efficiency and ethanol quality benefits of large-scale production, but with increased levels of decentralisation of production and corresponding dispersal of opportunities

[1] WHO, 2006. Stockholm Environment Institute Policy Brief, June 2009.

and benefits. Although a detailed analysis of costs of production is needed for each new installation, available micro-distillation technologies internationally appear to also be capital cost competitive per litre of ethanol produced compared with large scale installations. The lower total cost per installation also allows production to be dispersed closer to cane production and household ethanol consumers, and lowers the capital barriers to market entry.

International experience however shows ethanol markets to be strongly dependent on government policy. Particularly given the volatility of international fuel markets and the multiple potential applications of ethanol at different price points – stable and progressive government policies will be important if the ethanol household fuel market is to develop sustainably. In initial stages it may be necessary to ring-fence and prioritise sufficient ethanol fuel for the household energy market to ensure that a failure in the supply chain for ethanol (perhaps linked to international price fluctuations or a fuel blending mandate) does not destroy the burgeoning market for stoves which would also be created. Ethanol fuel pricing is very vulnerable to commodity prices of existing fuels, for example charcoal, fuelwood and fossil fuels, particularly kerosene - and if multiplier benefits of ethanol to health, the environment, rural incomes and balance of payments are to be realised – then government policy must mediate price fluctuation to some extent, especially in initial stages.

In order to succeed, the Malagasy household ethanol programme must learn from the international experiences described in this chapter, and put in place measures to overcome challenges encountered elsewhere, and replicate successes.

Ethanol Supply in Madagascar

Approximately one-half of Madagascar is potentially cultivable, but little more than 5% of the land is currently under crops Taken together cropland and crop/natural vegetation mosaic accounts for 13% of land cover, with approximately 21% of the total land area is covered by forests and 63% by shrub-land, grassland and savanna. However the demand for cultivatable land is on the increase, and is not being matched with an increase in land allocated for agricultural use. Any expansion of sugarcane production needs to ensure it does not encroach on sensitive ecosystems and land required for agriculture and food production, and that sugar cane production does not result in food price rises and decrease food security. Madagascar has problems of land ownership, land tenuring and land taxation, all of which are unlikely to stimulate farmers to invest in small-scale sugar cane production.

Madagascar also has a recent history of land degradation and any increase in sugar cane production must be sure to not result in forest clearance or increased land degradation. In general the agriculture system in Madagascar is underperforming, and requires significant investment in improved techniques and technologies to improve soil quality and production. The use of land for sugar cane to produce sugar and ethanol has the great potential to reduce poverty if managed effectively, but requires a strategic and large scale investment to ensure high yields can be achieved sustainably. Producer cooperatives and associations might be an avenue for increasing productivity and ensuring the local farmers derive the most benefits. The extent to which foreign investment is sought to increase sugar cane production needs to be carefully assessed to ensure that benefits to local farmers are maximised and the household ethanol fuel market is not ignored. To ensure that the potential benefits of sugar cane production to increase ethanol supply, it needs to be fully integrated into the national agricultural planning.

Madagascar is very susceptible to increases in oil price rises and so local production of fuels such as ethanol would be of great benefit to the country. The use of ethanol as a household fuel would create a large sustainable market local that would result in a number of significant benefits to the country. Currently Madagascar's sugar cane production is quite low and there is significant potential to increase its production through just efficiencies and technology. Small-scale sugar cane production is also widespread, but generally with very low yields, and almost exclusively used to produce toaka gasy, the locally manufacturer rum for human consumption. The supply of ethanol in Madagascar is set to increase steadily over the next 5 years, which could be directed towards use as a household cooking fuel. It has been suggested that artisanal toaka gasy production could be improved, to be used as a fuel instead, but it is unlikely that ethanol of a high enough grade can be produced efficiently, sustainably and competitively from such scale of production, and it is recommended that the installation of micro-distilleries be promoted instead of artisanal scale production.

Both wood and charcoal use in Madagascar has been growing steadily, and has directly led to increased deforestation. Electricity is generally not used for cooking, and Kerosene and LPG only accounts for a relatively small sector of the market, compared to both charcoal and wood, particularly in rural areas. Madagascar's forests are some of the most diverse and fragile in the world and increased efforts need to be made to reduce their destruction. This can be carried out through investment in sustainable forest management and more efficient charcoal production, but serious consideration needs to be given to how ethanol production for household fuel can contribute to protecting Madagascar's forests. The transport of household cooking fuels is a big issue in Madagascar, particularly due to the relatively poor road network, which is another reason why micro-distilleries located throughout Madagascar could make a lot of sense for developing a more decentralised sustainable energy production.

Ethanol Demand in Madagascar

It is estimated that 95% of households in Madagascar depend on woody biomass, primarily fuelwood and charcoal, for their household energy (annual consumptions of 9.026 million m^3 of wood as firewood and 8.575 million m^3 as charcoal (IRG Jariala, 2005)). Fuelwood is the predominant fuel for poorest, poorer and middle income quintiles, whilst charcoal predominates for the richer and richest quintiles. Electricity, natural gas and kerosene capture very little of the market even for the richest quintile. Most city households use charcoal rather than wood fuel, while the use of natural gas is recorded as almost 11% of the main cities, but negligible in the small cities.

The household sector in Madagascar is expected to be heavily dependent on wood fuels for some time to come, with the FAO predicting an increase in household wood fuel consumption, with little substitution with electricity or kerosene due to the high costs of the fuels and appliances. Fuelwood may be extracted free of charge provided that it is not commercially traded, but an official permit must be obtained in order to sell wood, however illegal cutting is commonplace, particularly in areas where fuelwood is in short supply.

User preferences for household fuels were investigated, and the major concerns were the speed of cooking, followed by convenience, cleanliness, and costliness of the fuel. Smoke, dirt, suffocation and bad health, were some of the factors that made fuels unfavoured by the surveyed households. Within the project area, spending on fuel was widely distributed in both the wet and dry seasons, with the majority of households spending around MGA 2,500 with more affluent households spending up to MGA 10,000 to MGA 15,000 per week. Ethanol compares favourably in cooking cost comparisons amongst domestic cooking fuels in Madagascar, being significantly cheaper than LPG and kerosene and only marginally costlier than cooking with wood fuel on an open fire. If non-financial measures of fuel-stove combinations are introduced, ethanol cooking with a good quality ethanol stove will be preferable to currently available fuels.

An initial estimation of the potential market of ethanol for household cooking (based on relative cost of fuels and the purchasing capacity of households) indicates that there are at least 180,000 households who might substitute their primary cooking fuels with ethanol (LPG, kerosene and charcoal users). The rate of market penetration for a new technology usually follows a logistic curve, with slow initial take-up, fast growth in the middle and saturation at the end, and it is believed that the market penetration of ethanol stoves will follow such a route over a period of 20-25 years. Following this scenario the associated requirements for household ethanol fuel would be 0.7 million litres in 2011, reaching 105 million litres by 2030.

Cook Stoves

A number of stoves were tested to address issues of stove safety, usability, performance, design, efficiency, preferences of cooks/households and initial indoor air pollution. The study can act as an indicator of likely acceptability, and any corresponding stove development needs, but it cannot be presented as a full assessment of the viability of the stoves in the long term and as part of a commercial scale up. Feedback from the three CCT cooks stating that of all the stoves, the ones they liked best were the modified wood and the modified charcoal should act as a warning to promoters of ethanol stoves in Madagascar. In order to enter the household cooking market, ethanol and ethanol stoves will have a substantial challenge in order to overcome existing patterns of preference, low cost and familiarity.

Positive feedback on ethanol was noted for all ethanol stoves in the Focus Group Discussion feedback on their cleanliness and perceived environmental benefits. It should be noted from the reactions to ethanol from the Usability survey that the stove in which the ethanol is used has an impact on the perception of the fuel, particularly in terms of safety, usability and smell. The success of ethanol introduction will therefore be a function of both the fuel and stove, as well as linked fuel issues of price, local availability, quality, purchase volume options and bottle/tank options as well as ethanol specific requirements like denaturing.

The Proimpex stove in its current form does not appear to represent a viable alternative to charcoal or compare favourably with other ethanol stoves available in Madagascar, due to safety concerns. The stove also generated IAP levels higher than the competing ethanol stoves in the testing. In terms of convenience, responses from CCTs and Usability tests revealed long cooking times, difficulties in lighting and difficulties/attention required in fuel regulation. Two out of three of the users of the smaller Proimpex stove considered it too small for cooking typical meals and with an average cooking time of over 65 minutes for a standard meal it took more than twice the time taken by the other ethanol stoves and the traditional and modified wood stoves.

The ISPM stove performed consistently better than the Proimpex stove (large and small) on most measures. With scores on a par with the other stoves in consideration the ISPM stove deserves further consideration for possible introduction and commercialisation. It shares many of the potential advantages cited for the Proimpex in the previous section in terms of local ownership and initiation, but without several of its drawbacks. It is recommended that the ISPM undergoes further development and testing where budget additions to accommodate it may be made.

In general the CleanCook stove delivered the best performance of the four ethanol stoves in evaluation screening, CCTs, CCT Cooks feedback, Usability tests and IAP testing. It would be considered therefore as a stove which, if fuel of appropriate quality was made available at a price which people could afford, would be safe, accepted and offer substantial IAP improvements over existing wood and charcoal stoves. However, key challenges from a wider perspective with the CleanCook include its imported origin, its up-front cost, and the need for 95% pure ethanol, which may not be as easy to produce in the current local distilleries. The Cooksafe stove was not available for field testing and seems to no longer be in production at the present time.

Financial and Economic Analysis

Financial Analysis

The financial assessment of the three scales of ethanol plants show that the net present value (NPV) is positive for all the 3 types which is an indicator of the financial profitability of the ethanol schemes with however sharp differences according to the scale. Over the 15 year time horizon, the NPV of the large scale distillery plant is estimated at 62.69 million US$, while the NPV of the community and artisanal plants is US$67,459 and US$12,674 respectively, much lower than the large scale ethanol scheme.

A sensitivity analysis carried out with the 2 key parameters of ethanol prices and sugar cane yields, shows that the NPV of the large scale plant becomes negative if the production of the sugar plant is reduced by 35%. For the two other plants, the NPV will become negative if there is a further reduction of the 2 parameters; for the community scheme, the NPV will become negative if there is a 40% decrease of the productivity, while in the case of the artisanal plant the NPV will become negative if there is a decrease of 43% of the productivity with an ethanol price of just US$0.11 per litre.

With respect to the financial analysis of household cooking stoves, the NPV over a 10 year period is negative for the three ethanol stoves. On the other hand, the NPV for the improved and semi improved charcoal stoves is positive with overall savings (energy savings and investment costs) of US$260 and US$202 per stove respectively compared with the traditional charcoal stove. The sensitivity analysis indicates that ethanol stoves are only more profitable than traditional charcoal stoves if ethanol retail prices drop down to between 63 and 84%. Changes with regard to the price of charcoal also have a strong effect on the viability of the ethanol stoves.

Nevertheless, even with an increase of 200% the NPV of an improved charcoal stove will still be higher than the NPV of the first ethanol stove.

Economic Analysis

The economic analysis of household cooking stoves demonstrates that from the society's point of view ethanol stoves are more preferable than improved charcoal stoves in the case of non-managed forests. However, the results indicate that improved charcoal stoves also have a high positive impact on the national economy if the charcoal production is based on sustainable forest management system.

The analysis of the entire ethanol programme (including sugar cane production, ethanol distilleries and ethanol stoves), compared with the costs and benefits of traditional charcoal stove and non-sustainable forest management, demonstrates that an ethanol programme based on artisanal scale ethanol production with a subsidised ethanol stove will bring the greatest economic return.

Considering the impact of ethanol stove dissemination on household's income, resulting from fuel and investment savings, there will be a negative impact even in the best scenario. Improved charcoal stoves have the most positive impact on household's income. As far the impact on forest cover is concerned, a penetration rate of 10% over 15 years will allow a substitution of 892,139 tons, saving 187,424 ha assuming the charcoal is produced from non-managed forests combined with traditional charcoal stoves. However the combination of managed forests and improved charcoal stoves can save over 243,000 ha over 15 years, just above the savings of an ethanol programme.

With respect to greenhouse gas emissions, over a period of 15 years, the ethanol programme will allow the avoidance of 7.5 million tons CO_2 equivalent, equating to more than US$27.5 million based on a market price of US$3.5/t of CO2. The dissemination of improved charcoal stove will avoid only 33% of these emissions compared with the base line scenario. However, the impact on greenhouse gas emissions of the sustainable forest management option coupled with the diffusion of improved charcoal stoves will be close to the impact of the ethanol programme (7.2 million tons CO2 equivalent). With regard to the health monetary impact, the ethanol programme will save about US$12million resulting from avoided non-working days due to illness, whereas the introduction of improved charcoal stoves will avoid about US$9million.

From the society's point of view ethanol programs are highly profitable. Compared to traditional household energy production and supply systems - non sustainable wood production in combination with the use of traditional charcoal stoves - ethanol programs at different scales will have a positive impact on forest cover, greenhouse gas emissions and public health. However, the burden of each ethanol program will be the consumer acceptance; in comparison to actual charcoal prices the costs ethanol is still too high.

	LPG (US$)	Ethanol (US$)	Charcoal (US$)
Annual Total Cost	302.82	107.61	63.76

Currently about 2.7% of the urban households (167,000 habitants) are using LPG as a primary type of cooking fuel. Compared to other energy sources, non-subsidised LPG is the most expensive source of household energy and both. Based on a financial analysis, ethanol is more profitable than the utilisation of LPG as a cooking fool; stove and fuel are less expensive for ethanol as shown in the table above, and these LPG users could provide a potential market for next years. A higher share in the market can only be obtained if ethanol retail prices fall and the price of charcoal increases.

1. Introduction and Overview of the Economic Assessment

The purpose of this report, Component B of the Ethanol as a Household Fuel in Madagascar project, is to evaluate the potential role of ethanol as a transformational sub-sector within the Malagasy household energy sector. This report has been prepared for the World Bank by a consortium, led by Practical Action Consulting (PAC), to provide a broad-based cost-benefit analysis of possible household ethanol development scenarios drawing on both international sector experience and primary data and contextual factors in Madagascar.

Through consultations with local stakeholders, partners and relevant experts during the kick-off meeting in Madagascar in December 2008, the Component B team started to build an understanding of the local situation in the project target towns of Vatomandry and Ambositra, as well as make the necessary connections to develop an overview of the national picture regarding future plans for ethanol production and utilisation. Based on the overall work plan requirements and the local conditions, the team drafted an outline for the Component B report and made progress towards local and international data collection as well as selecting specific scenarios and sensitivities for the modelling work. The steering committee provided additional insights into the most relevant scenarios and sensitivities to be applied in the modelling.

The team drafted a master list of data needed and set up channels of communication with the World Bank Country Office in Antananarivo and with local partners Tany Meva and local sector experts to pull together the diverse and dispersed information required to feed into the modelling. Specific tasks under Component B were divided among the team and the work was structured into various sections which form the chapters of this report.

Chapter 2 provides a comprehensive review of the experiences internationally with large scale ethanol production versus small-scale production, giving specific country experiences as examples, as well as a review of available technologies and their application.

Chapter 3 provides a detailed review of the possible production scenarios for Madagascar given the national situation and trends in terms of land use, agriculture, energy, forestry, regulatory frameworks, and industrial sector capacity for production at varying scales. In order to provide an adequate picture of the economic factors affecting the production of ethanol from sugar cane in Madagascar, the analysis addresses large-scale commercial production, small scale community production and artisanal scale production, over a ten-year time horizon. The data collected and analysis presented encompasses the entire ethanol production system including plant design, construction, operation, maintenance, feedstock/fuel procurement, transportation, and distribution.

At the large industrial scale, the analysis considers current and projected domestic ethanol production capacity, projected domestic and international demand, and likely market prices. The study also examines international demand for alternative sugar cane products and its implications for domestic ethanol production in the future. Based on likely demand and production capacity, the analysis considers the availability of land for ethanol production, and its competing uses for food and other products, as well as the environmental impact and disposal of residues from ethanol distilleries. Furthermore, the analysis considers co-generation opportunities, such as the sale of power to the national grid as additional income for large distilleries.

At the small-scale, the analysis considers the capital investment needs and production costs of ethanol using Ethanol Micro Distilleries (EMD) in Madagascar, including their technical and financial feasibility, to supply the household fuel market, under different distillery sizes and operational configurations (sole ethanol producers versus sugar cane multiple products). The study reviews the existing technical and industrial capacity to manufacture EMDs in Madagascar, with a list of domestic and international manufacturers and their prices, the existing and required regulatory framework in Madagascar for EMDs, and the environmental and social impacts of EMD for small farmers and communities, including competing use of land for food and other needs.

Chapter 4 provides an analysis of the actual and projected ethanol demand side in Madagascar, including a detailed overview of future demand scenarios incorporating also fuel blending with gasoline for the transport sector and export. The international market for ethanol with reference to supply and demand trends and the likely impacts on household fuel price has also been included.

Chapter 5 provides an examination of available ethanol cook-stoves, through examining energy efficiency, capital and operating costs compared with existing improved charcoal and fuelwood stoves, kerosene, LPG, and electricity. Information was gathered on ethanol stoves' maintenance, durability, value, safety, acceptability, emissions and overall performance, based both on user trials, and controlled cooking tests conducted in Madagascar and through independent testing by an internationally recognised stoves laboratory (Aprovecho), assessing both ethanol cook stoves available in Madagascar as well as on the international market. Estimates were made of the economic value of the emission reductions and improved health outcomes (based on the data collected in Component A), as well as the environmental benefits of ethanol stoves compared with alternatives. When data and information was not available in Madagascar, proxy data was used from other relevant experiences worldwide.

Chapter 6 provides an outline of the modelling approach and results, respectively, against a range of scenarios based on the scale of ethanol production in Madagascar, to understand the impact of a number of sensitivities on the development of a future household ethanol market, as well as a risk analysis to identify potential pitfalls. The sensitivities include oil price, national regulation and policy and international climate change agreements. The three scenarios modelled include: large-scale distillation using out grower sugarcane production; community scale distillation of community farmer sugarcane production; and artisanal distillation at sugarcane farmer level. The methodology for estimating the economic impact of ethanol production in Madagascar includes a computer-based spreadsheet that combines the direct, indirect and induced impacts, with the indirect and induced effects being assessed using input-output model-derived multipliers. The analytical method covers the entire ethanol production system including plant design, construction, operation, maintenance and feedstock/fuel procurement, transportation and distribution, including the price of sugarcane, and the cost of capital, labour, energy and distribution. The competing uses of land for ethanol production versus food production (and other uses) are also analysed, in order to establish the opportunity costs of land use changes. The analysis includes the potential cost advantages of large-scale ethanol production against the livelihood and fuel security benefits of micro-distilleries. An analysis of the existing legal framework is also included, including restrictions on ethanol production at both large and small scale, ethanol consumption by households, stove manufacturing and related intellectual property rights.

Based on the assessment of the economics of ethanol production at small and large scales, and the assessment of the comparative advantage of ethanol cook-stoves, the analysis examines the economics of a household ethanol programme, including cost structure, seasonal price variation, ethanol fuel distribution and logistics, quality control of the fuel, marketing, local manufacture versus import of stoves, user training, level of taxation, opportunities and needs for micro-finance, and the potential for exploiting Clean Development Mechanism (CDM) revenues. Finally the analysis considers the risks of diverting ethanol cooking fuel to other uses, such as drinking and transportation, and incorporates an energy-cycle analysis focusing on the energy inputs versus energy outputs of the production of ethanol as a cooking fuel, and the renewable energy share of the total cycle, from both large and small scale production units.

The results of the modelling are interpreted using the Rural Livelihoods Framework and are presented according to the expected impacts on Natural, Economic, Human, Social and Physical capitals in Madagascar. The analysis concludes with an assessment of the environmental, health, economic and social costs and benefits of a widespread shift to ethanol as a household cooking fuel.

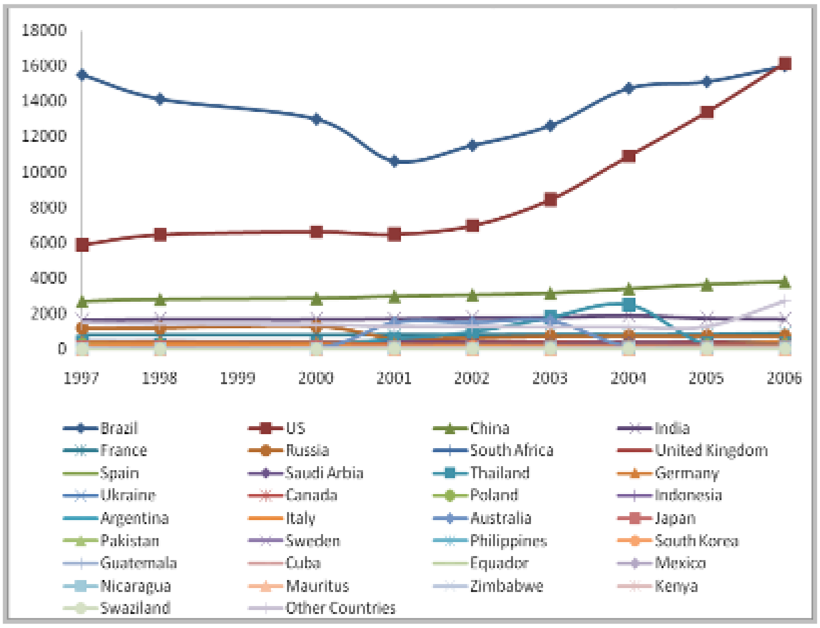
Chapter 8 presents the overall conclusions and recommendations based on the proceeding research and analyses.

2. International Experience: Large and Small Scale Ethanol Production

2.1. Global Overview

World ethanol production has seen a rapid increase over the past decade in particular in terms of expansion and diversification (Figure 2.1). Between 2000 and 2007 international production increased by a factor of three to over 52 billion litres.[2] In recent years the United States has become the leader in global production, with an output of 16.14 billion litres of corn-based ethanol in 2006[3], increasing to 20 billion litres in 2007[4], while Brazil produced 16 billion litres in 2006. The main ethanol producers in Asia are China and India, which produced 3.7 billion and 2.3 billion litres in 2007, respectively[5]. Production for all Asian countries reached 7.4 billion litres in 2007 and was anticipated to surpass 8.1 billion litres in 2009.[6]

Figure 2.1: World Ethanol Production (million litres)



During this time, the production of ethanol in Madagascar showed a steady decline because of neglect of the state-owned sugar factories, their distilleries and the farms supplying them. However, there is now a private-sector-led effort to rehabilitate the sugar factories and associated distilleries and among three plants, Ambilobe,

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2 Towards Sustainable Production and Use of Resources: Assessing Biofuels, United Nations Environment Programme, 2009
[3]3 Brazil Ministry of Agriculture, Livestock and Supply
[4]4 REN 21, 2008
[5]5 Sugarcane Based Bioethanol Energy for sustainable development, November 2008
[6] FO Licht World Ethanol and Biofuels Report, Vol. 7, No. 4, 23-10-08. FO Licht production figures are similar but show higher values. U.S. production is reported as 24.5 billion litres in 2007 and 34 billion in 2008. Brazilian production is reported as 20 billion litres in 2007 and 24.5 billion in 2008. China shows 5.25 billion in 2007 and 5.38 in 2008. India shows 2.62 billion in 2007 and 2.48 (a decline) in 2008.

Namakia and Morondava, some 8.5 million litres of ethanol were produced in 2009.[7] This is expected to increase 20% by 2011.

There is renewed investor interest in the Malagasy sugar holdings. Tany Meva reported that 11 investor groups are known to be looking at properties in Madagascar. These are in three areas—the north, west and eastern sugar cane areas. Of the 11 investors, two groups have completed feasibility studies. These are JWE Ltd. in Katsepy-Boeny Region and SAIM in the Ambilobe-Diana Region. However, the unsettled political climate continues to slow the progress of international investors, and most projects are on hold[8].

2.2. The Ethanol Outlook

High oil prices, international awareness of global warming, and the decline in energy security have all lead to an increase in global interest in biofuels; however, despite its recent growth, the global market for biofuels is still in its infancy. The future global potential for biofuel production is also difficult to estimate, due to a number of factors including the limits of natural resources and the need for food security above biofuel use. However, early studies of biomass availability have concluded that by 2050, the possible contribution of biomass to global energy supply could vary from 100 EJ/year to 400 EJ/year, which represents 21% to 85% of the world's current total energy consumption, estimated at 470 EJ[9]. Although biofuels are only a fraction of total biomass, biofuels still have the potential to play a significant role in meeting future global energy demand, if developed through appropriate channels.

With most biofuels, including ethanol, production is consumed through domestic markets; however, as the interest in biofuels production continues to increase, international trade is expected to increase, creating new implications for developed and developing countries. Many European biofuels companies have already invested in Africa and Latin America, ensuring the global status of the biofuels industry. Of particular note is that investment in the biofuels industry directly impacts rural development, which is a key priority of global policies such as the Millennium Development Goals (MDG). The current biofuels production trend has mainly focused on large-scale industrial plants, but as more countries turn to biofuels, this trend must include medium and small-scale biofuels enterprises which are targeted more towards impacts on poverty reduction through community and local farmer involvement.

Latin American and Caribbean countries have moved into the ethanol market most quickly, based on strong economic interests in exporting to other countries, mainly the United States. The major global ethanol market player is Brazil, being the largest biofuels exporter, currently supplying 50% of the international demand for ethanol[10]. Due to Brazil's early inclusion of biofuels into their energy portfolio and aggressive government-supported expansion through PROALCOOL, Brazil has led the international biofuels movement. The Brazilian climate is well suited for sugarcane production, labour costs are relatively low, and much biofuels research and

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[7] Email correspondence with Mr. Henri Tsimisanda, former general manager of Sirama Sugar Factory and later Secretary General of Industry and Commerce, dated 23 Aug. 2009. U.N. Data shows that less than 50,000 litres of ethanol were produced in 2006, while FO Licht shows that some 12.3 million litres were imported.

[8] Email correspondence with Ravaka Ranaivosan, Tany Meva, dated 2-9-10.

[9] Bioethanol, Sugarcane based Bio-ethanol. Energy for Sustainable Development

[10] http://www.iied.org/pubs/pdfs/G02587.pdf

development has already taken place. For these reasons and others, Brazil is promoting their experience as biofuels diplomacy around the world. Brazil is also the country which exports ethanol to the greatest number of countries, thus promoting technology transfer, and many Brazilian organizations advise and support other countries' bioethanol industries. The country is estimated to have saved an estimated US$43.5 billion between 1976 and 2000 and the Brazilian bioethanol industry directly employs half a million people. In only the last five years, biofuels have been recognized as a potential means of achieving multiple policy goals, and many countries are starting to use the Brazilian experience to design their own energy portfolios.

The dominant current consumption of ethanol is for fuel-blending, but there is also significant demand and use of ethanol in the industrial sector. Around 60% of industrial ethanol is used as a solvent in the manufacture of pharmaceuticals, paints and lacquers. However this use of ethanol is now subject to environmental restrictions because it is classified as a volatile organic compound (VOC), and this may well play into the hands of ethanol production for use as a household fuel.

2.3. Ethanol as a Household Fuel

The household energy sector accounts for 15-25% of primary energy use in developed countries[11] and 75-90%, or more, in developing countries.[12] Developing countries are looking for more efficient and affordable household energy, which implies a combination of both a fuel and the appliance technology in which the fuel operates, and only when an efficient combination is produced, does household energy improve. In many developing countries, particularly in rural areas, traditional fuels such as fuel wood, charcoal, dung, and agricultural waste, constitute a major proportion of total household energy consumption. Although varying between different settings, the efficiency of a traditional fuel wood cooking stove is as low as 30 to 35% of a liquefied petroleum gas (LPG) stove.

For developing countries, the key determinants of household energy demand are:

- Prices and availability of fuels and appliances
- Disposable income of households
- Stove and fuel emissions
- Cultural preferences
- Fuel and stove efficiency
- Inconvenience of fuel transportation and storage

Within a country, great disparities are often seen between the household energy use of rural and urban populations and high and low income groups. The major factors contributing to these differences are levels of urbanization, economic development, and living standards.

In most developing countries when income increases and changes in lifestyles occur, households tend to move from the cheapest and least convenient fuels (biomass) to

[11] Dzioubinski, O., and Chipman, R., Trends in Consumption and Production: Household Energy Consumption, United Nations Department of Economic and Social Affairs, April 1999.
[12] WHO, 2006. Stockholm Environment Institute Policy Brief, June 2009.

more convenient and more expensive fuels. Eventually households will switch to the most convenient and most expensive types of household energies, in the same way the developed world made its transition. There is also a significant correlation between the choice of cooking fuels and urbanization; urbanization tends to lead to higher levels of household energy consumption, although it is difficult to separate these effects from the increases in income levels that generally accompany such urbanisation.

Most countries are looking for more efficient, long-lasting and sustainable fuels to replace unreliable, polluting and inefficient household fuels. The household fuel market is enormous and research is required to determine exactly which types of fuel and stoves are required for particular regions of the world.

Ethanol as a household fuel is considered to have enormous potential as a clean and healthy fuel for the user as well as offering substantial economic, health and environmental benefits at local, national and international levels. This report seeks to determine the extent to which this is true in Madagascar. However, in order to gain a greater understanding of the potential future growth paths of ethanol as a household fuel market in Madagascar, it is useful to look at other countries which currently host ethanol household fuel markets.

2.4. The Manufacturing Process

2.4.1. Raw materials

Ethanol can be produced from any biomass containing significant amounts of starch or sugar. In the case of Brazil, it is predominantly sugarcane, mainly due to the high fuel yield per hectare of planted sugarcane. Through various centres of research, about 6 new varieties of sugarcane are released each year, so that, in actuality, close to 500 varieties are grown. Each variety is adapted to different conditions of culture and climate, increasing a crop's productivity.[13]

Crops containing starch, such as cassava, are processed in a similar way to the sugar-to-ethanol process but require additional steps to convert the starch to sugar, including reducing the size of the tubers, and exposing the starch to enzymes that convert the starch to sugar in a chemical reaction called hydrolysis.

Sucrose extracted from sugar-cane accounts for just over 30% of the chemical energy stored in the mature plant; 35% is left in the leaves and stem tips in the fields during harvest, and 35% is in the fibrous material (bagasse) left over from pressing.

This bagasse is an important by-product of the process, and can be burnt in a processing plant to produce electricity. Alternatively the wet residues from fermentation and distillation can be used as an animal feed or, with further digestion by bacteria, to create biogas which can be used to power the process itself.

Although the vast majority of ethanol comes from plant-based feedstocks, this is not always the case, as in South Africa, ethanol is synthetically produced from coal and gas using technologies developed by SASOL, the chemical conglomerate world leader in coal and gas to liquid technologies, which produces 400 million litres of

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[13] CTC and Canavialis

synthetic ethanol per annum. Mossgas, a gas to liquid plant produces a further 160 million litres per year[14].

An number of potential alternative bio-feedstocks have also been identified for ethanol production which might become good investment opportunities once the ethanol industry in a country becomes more mature.

The basic conversion of a sugar crop to ethanol begins with processing the feedstock. In the case of sugar-cane and sweet sorghum, this consists of washing, crushing and filtering to separate the bagasse from the sugar. The sugar is sterilized, concentrated and then fermented, using yeast, to produce alcohol solution, which is subsequently distilled to concentrate the alcohol to about 95%. Carbon dioxide is a by-product of the fermentation process. If the resultant alcohol is to be used as a fuel, a denaturant is added to the mixture to make it unpalatable, and unsuitable for consumption.

2.4.2. Ethanol Quality – Impurities in distillation that affect ethanol as a fuel

Water

Alcohol at 75% ABV is the minimum required to fire a boiler. Alcohol at 85% ABV is generally the minimum required to run a generator or an internal combustion engine (Blume, 2007)[15]. A fuel injection system requires at least 92.5% and preferably 96% ethanol (Blume, 2007)[16].

The Aprovecho Research Laboratory tests on the ethanol stoves performed for this study, detailed in Chapter 5, suggest that while ethanol at 50% ABV will ignite, ethanol at 60% to 65% is the minimum necessary to support a stable flame, and ethanol at 80% is necessary to obtain a robust flame.

Aldehydes and Ketones

The presence of these more volatile compounds in ethanol, while usually very low, can be significant if a distillery has not been operated properly or if the concentration of these compounds in the starting material was high. Aldehydes and ketones are generally concentrated in the head or foreshot in batch distillation and come off in the first 15% of the run (Blume, 2007). If possible, these lighter compounds should be separated, if the distillery equipment is adequate to allow this to be done easily.

Acetic Acid

In bad fermentation batches, undesirable bacteria may produce high amounts of acetic acid, which has a low enough boiling point to be distilled with the last part of a run in batch distillation. High acetic acid together with low proof creates a corrosive fuel. If the alcohol falls below a pH of 6.0 this has been known to be acidic enough to cause problems in auto engines. For this reason, it is standard procedure to neutralize mash to pH 7.0, before distillation, by adding lime.

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[14] 14 (Castro JFM, 2007 – Biofuels Overview, Final Report, May 2007)
[15] David Blume, pp. 196-197.
[16] David Blume, pp. 377.

Fusel Oil

Figure 2.2: Ethanol laden with fusel oil. The top of the canister was removed for this photo (Gaia Association).

Fusel oil is a mixture of higher alcohols such as amyl, isoamyl, propyl, isopropyl, butyl and isobutyl alcohols and acetic and lactic acids. The term fusel is German for "bad liquor". During distillation, fusel alcohols are concentrated in the "tails" at the end of the distillation run. They have an oily consistency, which is noticeable to the distiller, hence the term fusel oil (Blume, 2007). While acetic acid can be corrosive, the various esters that comprise fusel oil are known to deposit gum or carbon on valves in automobile engines.

In the CleanCook stove pilot studies in Ethiopia, fusel oil led to an oily crust of unburned carbon on the top of the exposed fibre at the mouth of the canister, which became progressively worse over several months of use of the contaminated fuel. This was because of a serious failure of the distillery's fusel oil collection system, and provides a useful lesson on the negative impact of fusel oil. In continuous distillation, fusel oil is extracted from the distillation column and is harvested for sale as its own product. Fusel oil may be separated from alcohol by use of a soft-wood charcoal filter. Another method for removing fusel oil from beverage alcohol is to induce phase separation and to decant it (Guymon, 1958[17]).

2.4.3. Continuous versus Batch Distillation

Unlike simple pot stills or artisanal stills, modern batch distilleries use a distillation column, somewhat like a continuous distillation process. However, these distillation columns are generally not as tall and are not as difficult to operate, and thus may not need an automated system to control temperature and pressure.

In continuous distillation, the fermented mash is pumped into the lower part of the distillation column, called the stripper, where it meets an upward flow of steam. In contrast, in batch distillation, the mash is boiled and alcohol and water vapour enter the base of the column and move up the column. In batch as in continuous distillation, the column works on the principle of enrichment and counter-current flow (steam and alcohol vapour move up the column while water or mash move down the column). In batch distillation, when almost all of the alcohol has been removed from the mash, the distillery is shut down and a new batch of mash is prepared. In contrast, continuous distillation involves the distillation column running for months at a time, with a steady stream of mash being prepared and pumped into the stripper section of the column to be distilled.

[17] Guymon, James F., Principles of Fusel Oil Separation and Decantation, American Society for Enology and Viticulture, 9:2:64-73 (1958)

Continuous distillation has a number of advantages and it can be run on a micro-scale, although Blume states that below 35 to 50 gal/hour (130 to 190 litres per hour) it may not be as cost-effective as batch distillation (Blume, 2007), the primary issue being the original capital cost of the plant. Other advantages include tighter control over the production of alcohol, both with regard to quantity and quality and the efficiency and the ability to recycle and reuse the heat generated in the system more effectively. A third factor may be that less labour is required due to a more automated process, so that the system essentially runs itself. Disadvantages include a higher capital cost for the plant, a taller distillation column (1:42 diameter to height for a continuous column versus 1:24 for a batch column), which is harder to build, using perforated plates rather than simple packing. There is also a greater need for automation, achieved through the use of electronic controls and even computerization, as well as it being less convenient to shut down and restart. Therefore, if the plant is to be run on a batch basis, is should be designed as a batch plant.

For fuel production, the tail of the distillation run can be added to the next batch for re-distillation. This is also referred to as the recycling of the “low wines” (Blume, 2007), and reduces the loss of the alcohol.

Table 2.1: Volume and alcohol content distribution in batch distillation

Fraction	Total volume (L)	Alcoholic strength (°GL)	Ethanol volume (L)	Fraction of the volume of alcohol in wine (%)
Original Wine	1000	8.5	85.0	100
Distillate head	7	67	4.7	5.5
Distillate heart	160	46	73.6	86.6
Distillate tail	20	21.5	4.3	5.1
Vinasse	813	0.3	2.4	2.8

Table 2.1 shows the amount of the ethanol in the mash that is distilled off in the head, the middle cut (or the “heart”) and the tail, with most of the ethanol coming from the middle cut (86.6%) and smaller amounts coming from the head (5.5%) and the tail (5.1%). Thus, if this ethanol is redistilled, more of it is separated successfully from the impurities and less is wasted.

Batch plants can exhibit many of the advantages of a continuous process and can even be run for extended periods using two or more fermentation lines on the front end. So while batch processing may not be quite as efficient as continuous distillation, it can come close. The choice between selecting a continuous or batch plant should depend upon the particular project for which the plant is to be designed.

2.4.4. Scale of Ethanol Production

The effects of scale of manufacture can be seen in the quantities of ethanol produced relative to unit input and capital cost, the raw feedstock costs, manpower, and uses of markets for the manufactured fuel. Typical large scale plants may have an output of many million litres per annum. For example, the Illovo Sugar, Merebank plant in South Africa, produces 40 million litres per year. By comparison artisanal producers may output only 200-300 litres per day, and only for part of the year, depending on the particular country and feedstock. Between these two extremes, micro-distilleries are of growing interest, as initial capital costs for each distillery are low, and as recent distilleries have produced ethanol efficiently, using the wastes from the process to provide energy for running the distillery and co-products for sale or beneficial reuse, they have become more competitive.

One of the main concerns about ethanol production is the energy balance[18], the total amount of energy input into the process compared to the energy released by burning the resulting ethanol fuel. This balance considers the full cycle of producing the fuel: cultivation, transportation and production, including the use of oil and fertilizers. A comprehensive life cycle assessment[19] commissioned by the State of São Paulo found that Brazilian sugar-cane-based ethanol has a favourable energy balance, varying from 8.3 for average conditions to 10.2 for best practice production[20] (for average conditions one unit of fossil-fuel equivalent is required to create 8.3 energy units from the resulting ethanol). The USI distillery produces a similar output with the same feedstock.

In must be noted that a distinction is made in this report between pot or "artisanal" stills and micro-scale distilleries with modern stripper units. Crude, traditional, handcrafted stills should not be grouped together with engineered micro-distilleries that take advantage of the latest advances in distillery science. Micro-distilleries are generally considered to range in capacities from 100 to 5,000 litres per day, after which they start to be referred to as small scale (Horta, 2006). This distinction is based largely on regulation that was put in place in Brazil in the 1970s governing the use of financial incentives for distilleries. Larger plants were favoured over smaller plants, many feel incorrectly.[21]

2.5. Manufacturing processes for different sizes of distillery

2.5.1. Artisanal (or Batch) stills

Artisanal stills are typically very small, up to a few hundred litres of production per day, and they rely on batch processing. They are generally not efficient and their energy inputs are large compared with the output of distilled product.

The traditional method for producing ethanol in Madagascar is from sugar, in the form of rum, or toaka gasy. It comprises a number of stages beginning with the cutting of cane stalks by the farmer, which are then transported by foot (about 15-20 stalks at a time) to the distillation point, often several kilometres from farms. At the distillation point the stalks are cut into smaller pieces in preparation for crushing, which is carried out manually, usually by two men using 'rammers', which can take several hours. Extracts of local plants are added to the cane stalks during crushing to add flavour to the cane juice. The mixture is then placed in a traditional metal barrel, protected from wind and rain, and left to ferment for up to one week (Figure 2.3). Fermentation can take less than one week if the producers are in a hurry to get the toaka gasy to market.

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[18] http://en.wikipedia.org/wiki/Energy_balance
[19] http://en.wikipedia.org/wiki/Life_cycle_assessment
[20] J. Azevedo Ramos da Silva, 2004
[21] Horta Nogueira, Luiz, ed., Sugarcane-based Bioethanol: Energy for Sustainable Development, BNDES-CGEE, 2008, Chapter 6, pp. 148-150.

The distillation process involves bringing the mixture to the boil by lighting fuelwood under the container, evaporating the water, to produce a concentrated toaka gasy which is then mixed with less concentrated alcohol to make it safe to drink. The producer tastes the alcohol a number of times during the process to check if the concentration level is appropriate for drinking. Once he is happy with the product, the alcohol is 'bottled' in jerry cans and transported to market. Often the distillation takes place on the same day as the market so that the toaka gasy is still 'sparkling', an attribute which is appreciated by the consumer.

Artisanal stills range in size from 10's to 100's of litres per day, to more developed pot stills built for high-end commercial beverage making, producing several hundreds of litres of 45-55% alcohol per day. While more sophisticated pot stills can be quite efficient, artisanal stills are generally not very efficient and their energy inputs are large compared with the distilled product output. Basically they are suited for making beverage alcohol not fuel-grade ethanol.

Artisanal distilleries, despite equipment limitations, can be well designed and operated to produce good quality drinking alcohol. To distil alcohol to 80-90%, or up to hydrous grade at 95%, the beverage distiller, with the same equipment, would have to redistill the alcohol several times to remove enough water, using more time and energy, making the product more costly, and possibly using more energy to produce the can be derived from the fuel.

Basic stills will differ from well-engineered micro-distilleries in five key ways:

- Heat is provided to the process by burning wood, not in a boiler or even a firebox but with an open fire which is very inefficient
- Fermentation is by batch and is controlled by the skill of the "cook" or operator
- The alcohol content of the fermented beer or wine produced is often lower, not reaching higher than 40-50%, due to inefficiencies such as requiring more heat than necessary to distil the alcohol
- The batch can more easily spoil, producing no alcohol produced, causing great wastage
- Impurities may be produced, which may find their way into the distilled product (acetic acid, ester and higher alcohols - although not methanol which is produced only in trace amounts)

Figure 2.3: Artisanal and Batch Stills

Clockwise from left to right – An artisanal Toaka Gasy still near Toliara in SW Madagascar; The Proimpex batch still outside of Antananarivo; The Vale Verde cachaça distillery in MG, Brazil showing traditional alembics; The distillery designed by Prof. Juarez de Sousa e Silva at the Federal University of Viçosa. The stills on the left are pot stills; the stills on the right use distillery columns.

2.5.2. Small and micro-scale ethanol manufacture

Micro-distilleries typically range from 75 up to 5,000 litres per day, after which they are referred to as small scale (Hulett, 1981; Horta, 2006). There are currently no clear definitions of micro and small scale, although this size threshold may have been set by regulations in the Brazilian Programa Nacional do Álcool (1975) or the subsequent Conselho Nacional do Álcool (1979) that provided subsidies for the construction of large distilleries and discouraged or excluded smaller and "micro" distilleries (Hulett, 1981; Ortega, 2006). This size distinction is only used today as a matter of convenience.

As an approximation, a small-scale or micro-distillery can process a truck supplying about 12 tonnes of cane per day, and permitting a daily production volume of 780 litres of ethanol, requiring a cultivated area of approximately 24 hectares. Usually the distillation process is based on the extraction of sugars by milling or diffusion, before the fermentation stage. After fermentation, the "wine" is distilled [22].

As previously discussed artisanal methods of ethanol manufacture cannot provide fuel-quality ethanol at an affordable price, so this section provides details on the smallest type of distillery that can effectively produce ethanol for the fuel market, referred to as micro-scale production. Annex 1 describes in detail the manufacturing equipment for the USI small-scale distillery, highlighting the advanced systems which are now available.

Historically, small-scale distillation was not cost-effective due to the use of cruder technology, providing lower efficiencies than large distilleries possessing more modern equipment and operating systems. Small systems often suffer from uneven quality control and the logistical and regulatory difficulties of reaching large, profitable markets. Recently, however, small-scale distilleries with capacities of 400 to 5000 litres per day have been designed, which address these problems (see Annex 2 for more details of an ethanol micro distillery in Nigeria). These distilleries are decentralized, increasing the flexibility and security of fuel access through local distribution and capacity to use multiple feedstocks and alternative feedstocks, available in small quantities (Blume, 2007).

Small-scale ethanol production units generally require more manpower than larger plants for similar outputs, which can be viewed as providing decentralized employment opportunities and thus the opportunity for jobs in rural areas, but will increase the manufacturing costs. According to estimates carried out in Minas Gerais, Brazil, during the 1980s, manpower requirements are typically 42.4 workers / day / hectare. For units using less modern technology, twice this number of workers may be needed, as was noted in north-eastern Brazil (SEME, 1985). However, with small and micro-distillery operations, the operation can be integrated into other operations, such as farms, where they are part of the overall management of the farm structure.[23] This is due to their reduced complexity, and because of their size and the context into which they fit – allowing the by-products to be used on farm, and have value. Feedstocks may be produced on the farm itself, using bio-residues (such as bagasse) to reduce costs.

As a result, engineered micro-scale distilleries can achieve efficiencies and economies comparable with industrial distilleries, and their competitiveness enhanced by managed use and sale of by-products - now frequently referred to as the *biorefinery concept* (Horta et al, 2008). With reference to Madagascar, realistically, Brazilian ethanol can be delivered with current pricing for around US $0.45. The opportunity for Malagasy ethanol to compete could be securely placed between $0.45 and $1.00 for the cost of a litre of ethanol. The manufactured cost in a modern distillery is $0.15 to $0.30. This is the same cost range that an efficient micro-distillery can achieve, especially where co-products can earn revenue. So if locally produced ethanol can be manufactured for about $0.30 to $0.50 cost, it can be competitive. One of the advantages of small distilleries over large distilleries is the

[22] Bioethanol from Sugarcane
[23] Blume, David, Alcohol Can Be a Gas! Fueling an Ethanol Revolution for the 21st Century, 2007. (See Chapter 26, pp458-9, Economics of Alcohol Fuel Production.)

considerable economy in transport for both cane and alcohol, as such distilleries can be located close to their raw feedstock source and in the midst of their market.[24]

Figure 2.4 shows the micro-distillery portion of a farm operation in the boxes enclosed in the dotted red line.[25] Additional value added products include hot water and steam for milk pasteurization and stillage from the pre-distill step for animal feed.

Figure 2.4: Added value from micro-distilleries

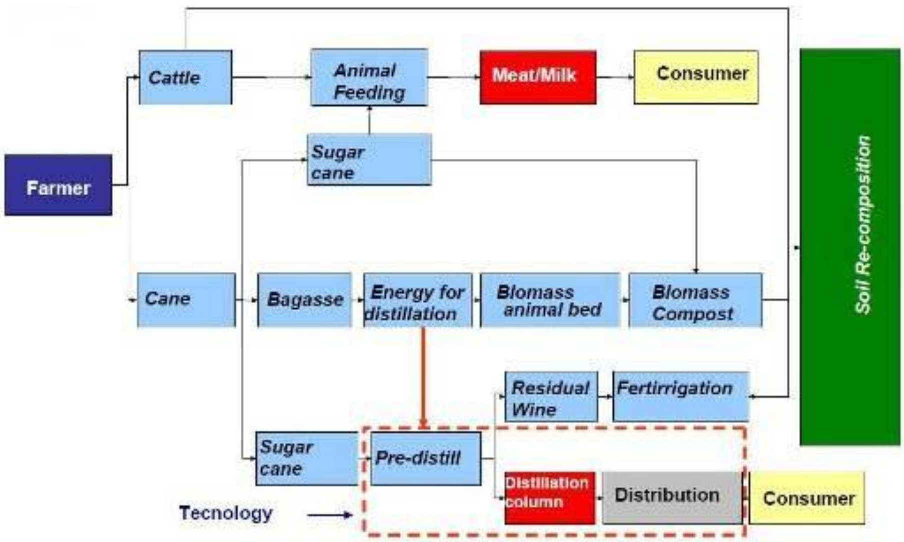

Figure 2.5 compares ethanol production on a small and large scale. In large scale production, best practice today is to process and use stillage and other liquid wastes. Bagasse is used as boiler fuel to generate steam with excess to electricity. In small scale and artisanal production stillage may or may not be used, and woodfuel is used for direct firing, rather than for the production of steam.

Large-scale plants will produce de-watered stillage that can be sold for cattle-feed or fertilizer, as shown in Figure 2.5, as well as chemical by-products such as fusel oil, as described earlier. Consequently, the differences between micro/small and large/industrial distilleries should be viewed as having *different* advantages and disadvantages, because of the differences in management, operations, end-products and transport costs.

Products from the micro-distillery may also be marketed differently than products for an industrial distillery because there is less in quantity to sell and products that may be of agricultural use (eg fertilizer). The market is much closer to the production, possibly right at its door. Therefore, there is more opportunity for marketing retail rather than wholesale.

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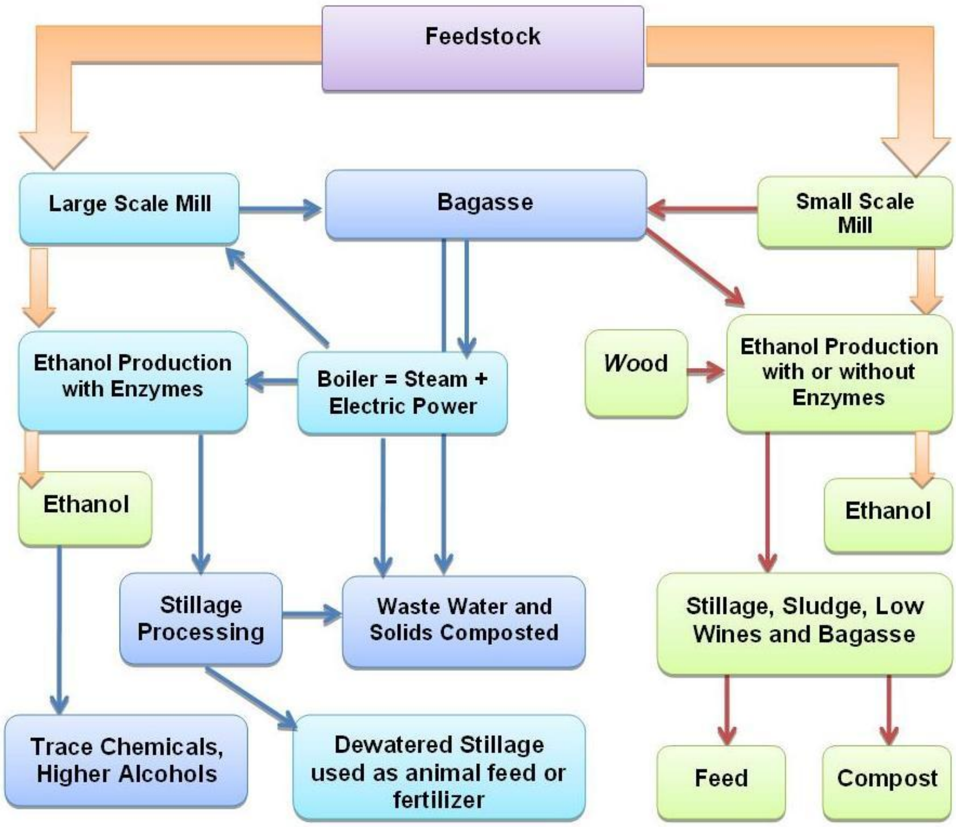
[24] Scholtes, Fabian, Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction, Center for Development Research (ZEF), Bonn University, July 2010.

[25] Silva, Juarez de Sousa (2007) Department of Agricultural Engineering, Universidade Federal de Viçosa, Braz *Produção de Álcool Combustível na Fazenda e em Sistema Cooperativo*. Universidade Federal de Viçosa, Brasil. Graphic is from a report originally prepared for Winrock International and Project Gaia, Shell Foundation Project # 21316, July 2006.

Less product to market means that it can be absorbed into a smaller geographical area and costs less to get to market. A micro-distillery selling fuel alcohol for cooking or for tractor or generator fuel may be able to sell all of its ethanol at its door, in a pump dispenser.

2.5.3. Physical and technical differences in technology and process

Figure 2.5: Processes of Small and Large Scale Production



Today, engineered micro-distillery equipment that optimizes the efficiency of each step in the ethanol production process, from processing the feedstock to dehydrating the alcohol, is available for sale (see Annex 4 for a list of suppliers). Technical simplicity, without a loss of technical sophistication, has been achieved through engineered processes. This is possible because the process of distillation, unlike many physical and chemical processes, lends itself well to scalability. With modern cooler-temperature enzymes and tighter controlled cooking and fermenting, the chemistry of ethanol production has been improved, with the result that fully optimized micro-scale distilleries can now achieve efficient production systems, similar to those of large scale distilleries (Ortega, 2007[26]; Hulet 1961[27], Júnior,

[26] Ortega, Enrique, Marcos Watanabe and Otavio Cavalett, 2007, Production of Ethanol in Micro and Mini-Distilleries, Laboratory of Ecological Engineering FEA, Unicamp, Campinas, SP, Brazil. Accessed January 20, 2010 at: http://www.unicamp.br/fea/ortega/MarcelloMello/MicroDistillery-Ecounit.pdfJúnior, Adriano Garcia Rosado, Hilton Machado Coelho, Norton Ferreira Feil, Análise da viabilidade econômica da produção de bio-etanol em

2008[28]). Each step of the production process can be operated efficiently and tightly controlled.

This ability to efficiently manage the entire process has reduced the technological advantages of large-scale industrial production, which used to be overwhelming. Now a micro-scale distillery can operate efficiently, through controlled processes, and take advantage of the factors in its favour that bring a range of opportunities, including economic and financial ones.

2.5.4. Capital costs and return on investment

With regard to return on investment, Hulett claimed, writing at the time of the creation of the National Alcohol Council (CNAL) in Brazil, when ProÁlcool began to be implemented (Horta, 2008), that the investment cost per litre of alcohol from his 2,400 litre/day micro-distillery was approximately one-third that of a conventional 120,000 litre/day distillery, and that 'for the same initial investment as that of one 120,000 litre/day conventional distillery, one hundred and forty seven (147) Micro-distilleries, producing a total of 352,000 litre/day, can be installed' (Hulett, 1981). The apparent unit cost of production of Hulett's distillery was low, at $0.44 per annual gallon in 1981, which today would possibly be about $1.10 per annual gallon.

It is useful to conduct a feasibility analysis for each micro-distillery before it is built, especially since the aspects or business opportunities of a particular micro-distillery project might be quite unique. Annex 1 outlines an example of a micro-distillery feasibility study, and Júnior, et al., 2009, outlines a feasibility study using the Usinas Sociais Inteligentes 1,000-litre/day micro-distillery case study[29].)

From these studies it can be seen that Return on Investment (ROI) can be competitive for advanced small and micro-distilleries. Operating costs can be low where, for example, labour costs can be absorbed, to some extent, by staff having other farm duties, and where feedstock production is internal to the business and valued low.

For all distilleries, factors that will affect the ROI will need to be determined on a plant-by-plant basis: fuel costs, use of process heat, maintenance costs, power generation, transport costs. For small-scale production, the two factors that will most impact profitability are feedstock cost and co-product use or sales (Blume 2007), and managing these two key factors will be critical to the profitability and repayment of capital costs.

Perhaps the most recent new ethanol plant in Africa is the Metahara Sugar Factory Distillery just completed in Ethiopia, at the southern end of Lake Awasa. The Metahara distillery was engineered by KBK Chem-Engineering Company, Pvt. Ltd., an Indian company. It has a nameplate capacity of 12.5 million litres/year and was

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microdestilarias, Universidade Federal do Rio Grande do Sul (UFRGS), 2008. Available at: http://www.slideshare.net/guest5b121/microdistillery-feasibility-study-brazil.

[27] Hulett, Deon, The Development of a Micro Distillery for Fuel Alcohol in Brazil, Proceedings of the South Africa Sugar Technologists' Association, June 1981, pp. 64-66.

[28] Júnior, Adriano Garcia Rosado, Hilton Machado Coelho, Norton Ferreira Feil, Análise da viabilidade econômica da produção de bio-etanol em microdestilarias, Universidade Federal do Rio Grande do Sul (UFRGS), 2008. Available at: http://www.slideshare.net/guest5b121/microdistillery-feasibility-study-brazil.

[29] Júnior, Adriano Garcia Rosado, Coelho, Hilton Machado and Feil, Norton Ferreira, Análise da viabilidade econômica da produção de bio-etanol em microdestilarias. Universidade Federal do Rio Grande do Sul (UFRGS). Brazil, 2009.

built at a cost of $8.5 million.[30] It includes many of the latest advances in process and environmental controls, including a completely computerized operating system.

The unit cost of production for this plant would be the plant cost, at $8.5 million, divided by capacity, at 12.5 million annual litres, equaling $0.68/annual litre or $2.58/annual gallon. During the first year of operation, this plant is actually anticipated to produce 10 million litres. It falls into the category of a small plant, yet it is large for Ethiopia.

The 1,000 litre per day USI distillery, which is the subject of the study attached in Annex 8, is estimated to cost just under $150,000[31]. The cost of production of this plant is estimated at $0.50/annual litre or $1.90 per annual gallon. Therefore, it actually results in a lower production cost per litre than the 12.5 million litre Metahara Distillery.

From Gallagher we learn that the unit cost of production of a 15 million gallon-per-year (MGY) dry mill corn-to-ethanol plant in 1988 dollars was $1.40 per annual gallon, which would be $2.63 per annual gallon in 2010 dollars. The Gallagher study determined that the range of values for similar plants fell between $2.36 to $3.23 annual gallons per year, expressed in current dollars (Gallagher, 2005).

David Blume, of Blume Distillation, LLC, provides a prospective cost on a 400 gallon per day (1,500 litre per day) Blume distillery of $135,000. Expressed as unit cost of production, this is only $1.13 per annual gallon (Blume Distillation, 2010)[32].

Although a detailed analysis of costs of production is needed for each new installation, current international micro-distillation technologies appear to be capital cost competitive per litre of ethanol produced compared with large scale installations. The lower total cost per installation also allows production to be dispersed closer to cane production and ethanol consumers, and lowers the capital barriers to market entry.

2.5.5. Case studies for micro- and small-scale distillation

Case Study 1: USI Modern Micro-distillery, Brazil

The Usinas Sociais Inteligentes (USI) micro distillery is designed to work with efficient agricultural technologies for sugar-cane cultivation. It uses modern equipment and processes low cost sugar-cane as feedstock, with the residual cane-waste (bagasse) being used to produce process heat and power. The reduction in these costs keeps the production costs low, and provides a favourable energy balance (output energy/input energy). A front end has been designed for the distillery to allow it to use multiple feedstocks, such as sweet sorghum or cassava.

Because of the higher production capacity, and the use of equipment that produces from 400 to 1500 litres per day, the biorefinery is suitable for a group of small farmers or growers who wish to combine their production power. An important opportunity for such groups of producers is the possibility of diversifying crop production, because

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[30] Interview on site with Engineer Andualem Bekele in charge of plant construction, July 29, 2010. Engineer Andualem is the project manager of the Metahara Distillery construction.
[31] Obueh, Joe, Bio-refinery Mini-Plant Model USI 1000 Proposal for the Okokhuo Community, Edo State, Nigeria, July, 2010.
[32] Blume Distillation LLC, Confidential Private Placement Memorandum, February 1, 2010.

the biorefinery is designed to accept multiple feedstocks. With the diversity of feedstocks, the opportunity to recover agricultural residues from carefully selected crops for animal feed is enhanced.

USI has taken advantage in the advances in biotechnology to streamline the front end and increase the production of alcohol in the fermentation step. Likewise, USI has taken advantages of optimized agronomic practices to boost production and yield. The following table shows the yield that can be expected with different feedstocks.

Table 2.2: Ethanol Production from Different Feedstocks

Crop	Crop Production (tonnes/hectare)	Ethanol (litres / tonne)	Ethanol Yield (litres / hectare)
Sugar-cane	85	83	7055
Cassava	40	200	8000
Cassava	30	200	6000
Sweet Potato	20	140	2800
Sweet Sorghum	40	55	2200
Corn	10	400	4000

Annex 3 goes into more detail about the potential of other bio-feedstocks for ethanol production. The USI distillery is able to produce ethanol for in the range of 22 cents per litre for high quality ethanol, compared with (typically) 40 cents per litre (500 to 1000 Ar/L) of rum produced in Madagascar. Industrial ethanol costs approximately 25% more in Madagascar to produce than in Brazil, extrapolating from current ex-work prices being charged by COMPLANT, presumably because of lower efficiencies system wide[33]. However, the barrier to the more efficient production of ethanol is the purchase cost of the USI distillery or any good small plant, which will come at a substantially higher price than a "home-made" distillery.

Case study 2: The Alcompac distillery

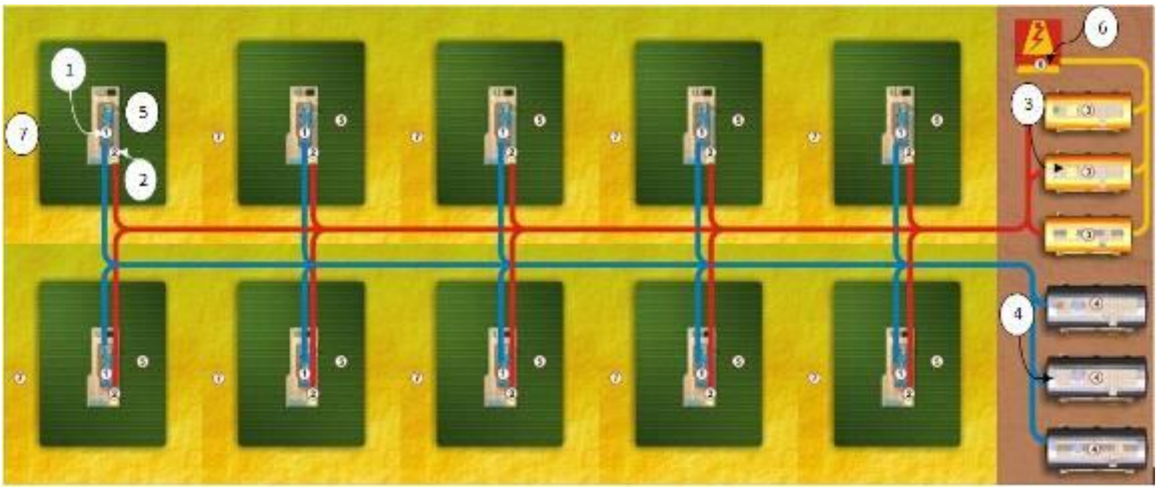
The Alcompac distillery technology envisions building ten small, compact units of 10,000 litres/day and placing these in a single complex for a total daily production of 100,000 litres or 30 to 35 million litres per year. Each distillery would be placed in the middle of its own plantation, to achieve the highest raw material efficiency, as well as its own juice extraction equipment (shredder, diffuser), fermentation tanks using continuous fermentation, distillation unit, steam boiler and turbine and drying beds for the spent stillage (vinasse) - in short each would have its own complete plant. All ten plants would be served from a central power plant and ethanol storage would be aggregated through pipelines to a central tank storage (see Figure 2.6). The intent of the design is for the equipment redundancies to be offset by advantages in raw material handling. The designers of this system, Alcompac (Destilaria Compacta de

[33] Based on data provided by Henri Michel Tsimisanda on pricing ex-works at COMPLANT Distilleries.

Álcool) claim the equipment redundancies are advantageous, as when one distillery is down, the others would take up the slack[34].

Proximity to feedstock and efficient handling, for example swift processing of cane to avoid sugar loss, are advantages that a small distillery can have over a large distillery. Avoided transport costs for cane to the plant and alcohol to market, as well as for liquid and solid wastes to disposal offsite, are other potential advantage for small plants.

Figure 2.6: Alcompac Fuel Ethanol Compact Plants



This modular approach of 10 compact ethanol plants, to build capacity, is detailed as follows: 1. distillery, 2. bio-digester, 3. natural gas tanks for power supply, 4. alcohol storage tanks, 5. sugar cane plantation, 6. power plant, 7. sanitary buffer and area for growing food crops.

Case Study 3: Small-scale ethanol production in the USA

One of the first significant steps towards creating an ethanol industry was in the late 1970's and 1980's, when the U.S. government, through the Energy Security Act, promoted small-scale production. The government provided up to $1 million in loan guarantees to small ethanol producers (with less than 1 million gallon output per year). Another measure the government took was to place a tariff on foreign-produced imported ethanol which promoted domestic production of ethanol.

According to the American Coalition for Ethanol, farmers and local investors are the largest producers of ethanol in the country, representing about 40% of national ethanol production. These famers and investors form either closed cooperatives or limited liability cooperatives to raise money necessary for operation. Backyard ethanol stills produce 180-200 proof alcohol which the federal Alcohol and Tobacco Tax and Trade Bureau (TTB) requires to be denatured to prevent entrance into the beverage trade and consumption.[35] Home-owned distilleries are quickly becoming an emerging American market capitalized on by entrepreneurs.

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[34] Alcompac Fuel Ethanol Compact Plant, Company presentation, November 2007, accessed on the web June 15, 2010 at http://www.sag.gob.hn/arch_desc/otros/Alcompac(english).pdf.

[35] Melcher, Joan. Lunar Power: Running on Moonshine. Miller-McCune, Science & Environment. May, 2008.

2.5.6. Large-scale ethanol manufacture

The manufacturing process for large-scale ethanol is widely documented, and the quality of the produce is not dependent on the precise plant. This section looks more at the scale of specific technologies, particularly in Africa, and the role of government in their promotion and commercial aims.

Ethanol production in Africa is concentrated on the Southern tip of the continent (Table 5.3), with the Republic of South Africa accounting for approximately 70% of the total[36] and leading the export market among the African nations.

Table 2.3: Ethanol Exports from African Countries (cubic metres)

	2008	2007	2006	2005	2004
South Africa	188,215	175,778	289,937	329,290	146,653
Zimbabwe	7,647	13,998	8,968	12,526	12,389
Senegal	0	0	0	0	285
Egypt	36,267	40,467	39,035	22,846	9,137
Kenya	15,000	12,370	17,766	8,239	6,637
Congo DR	2,238	0	0	2,343	449
Mauritius	6,552	11,028	5,569	3,909	4,637
Total	**255,919**	**253,641**	**361,276**	**379,152**	**180,196**

Source: F.O. Licht, 2009

South African production is on a large scale and, like Brazil, the industry has consolidated to large scale, despite having advocates for small scale (Hulett, 1981). Large projects are also coming to other African countries and in some cases have already arrived. Sudan commissioned a distillery in late 2009 with a nameplate capacity of 61 million litres per annum. Industrial plants have come to other countries, albeit at a smaller scale. A new 12 million litre plant has commenced operation in Ethiopia and a similar-sized plant has begun producing in Senegal.

Multiple and very large projects have been announced in a number of countries, as the table below, compiled from F.O. Licht intelligence, indicates. A stunning 3.7 billion litres of new capacity has been announced as being planned, with a small amount already under construction.

Table 2.4: New Planned African Ethanol Production Capacity

New Capacity Announced or Under Construction Ethanol '000 Cubic Meters			
Angola	180	Mozambique	758
Ethiopia	94	Niger	19
Ghana	156	Nigeria	952

[36]36 Berg, C (2001) World Ethanol Production 2001, July 31, 2001

Kenya	282	South Africa	142
Madagascar	39	South Africa	590
Malawi	12	Sudan	24
Mali	15	Tanzania	440
Mauritius	27	Zambia	**13**
		Total	**3743**

(F.O. Licht Intelligence on New Projects, April 25, 2009)

Even if just 10% of these announced projects are built, this would be equivalent to adding the current capacity of South Africa to Africa's total production, or 400 million litres of new capacity. If this happens over the next three years, this is a growth rate for Africa of 16% per year. African ethanol capacity is already growing at 20% per year based upon the increase of 139 million litres in 2008-2009 (F.O. Licht, 2009).

Figure 2.7 shows African ethanol production compared to imports, exports, and South Africa's share of this production. What is significant is that exports nearly equalled imports, and therefore the ethanol production was in largely used domestically, not exported. Figure 2.10 shows the production trends of Kenya, Malawi, Mauritius, Swaziland and Ethiopia. Several of these countries are positioned to show significant capacity increases in the next few years. Since 2005, the growth trends are moving upward.

Figure 2.7: African Ethanol Production – Imports and Exports

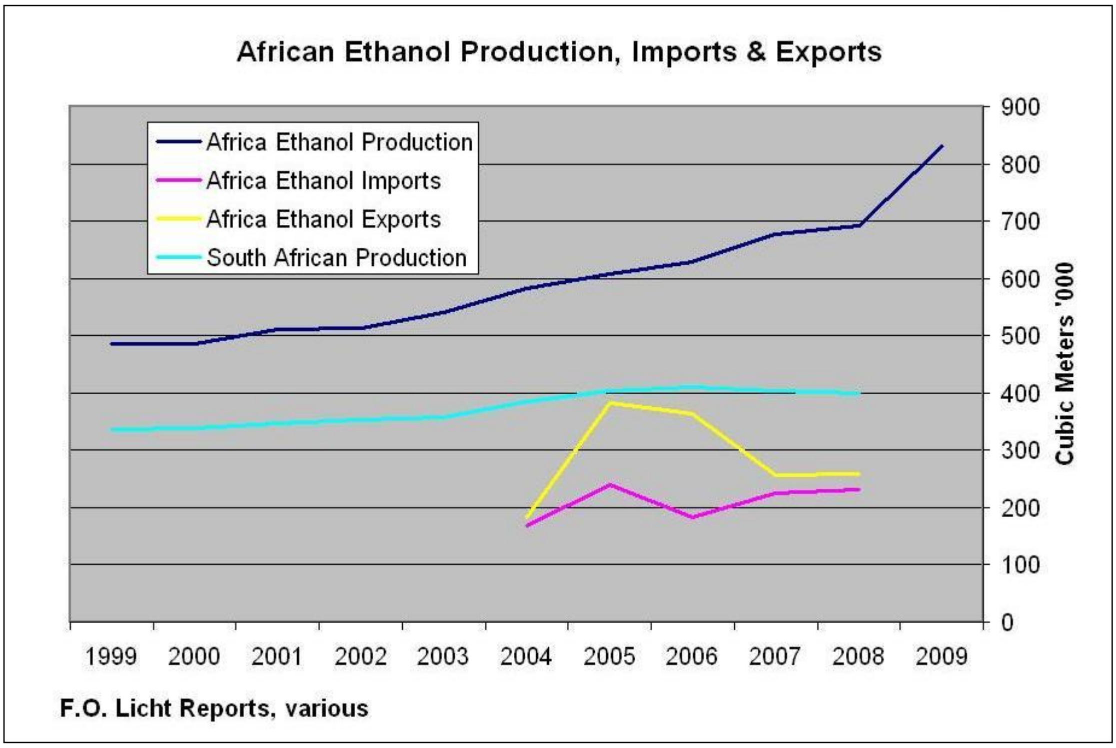
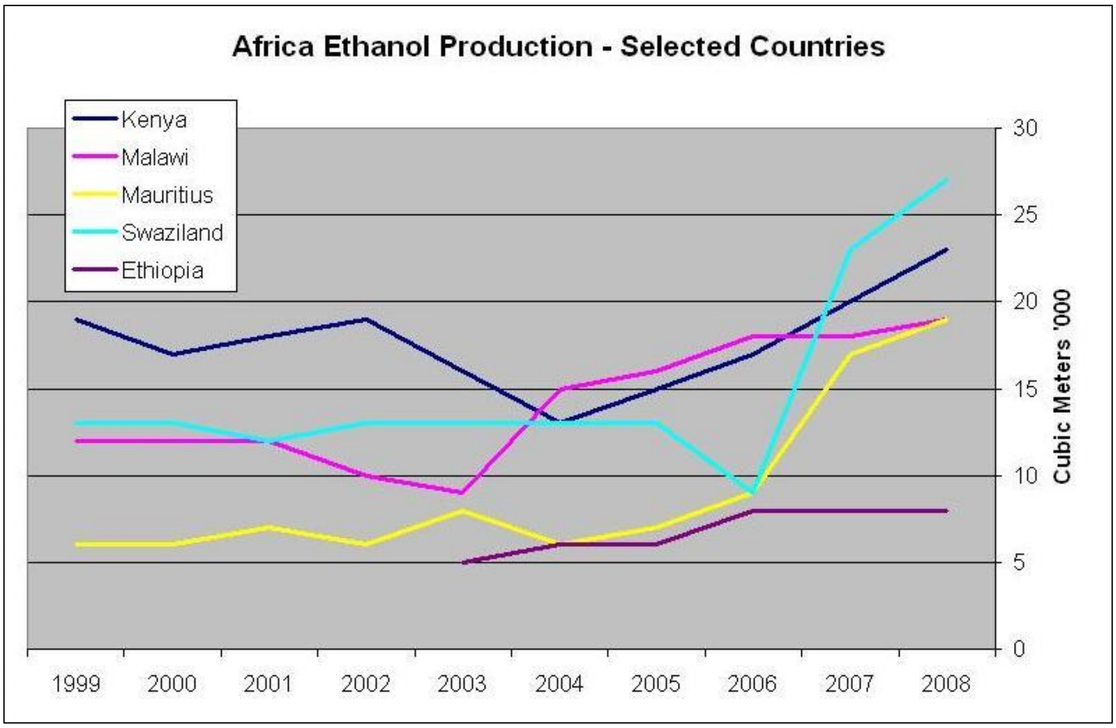


Figure 2.8: Ethanol Production in 5 African Countries



Although Africa's ethanol base is less developed than those in Latin and North America, there is significant potential for the African biofuels industry to expand, and this appears to be beginning to happen. Two pioneer initiatives have been the Ethanol Company of Malawi (ETHCO), which has been in operation since 1982, and a bioethanol fuel programme implemented in 1980 in Zimbabwe, which was halted in the early 1990s due to a serious drought, but which has recently resumed production. Many projects have recently come on board, some financed by European, Brazilian, American and Chinese businesses, and some financed within Africa. Currently, at least 11 African countries are creating rules for bioethanol production and trading, including South Africa, Angola, Mozambique and Benin.[37]

2.5.7. Government support for household energy access

The governments of many countries in Africa are much more involved in large-scale manufacture, and a positive policy environment for access to fuel by the household sector is vital. Many governments set targets for ethanol production; for example, the South African government's aim is for biofuels to account for 40% of South Africa's renewable energy in order to achieve their target of 10,000 GWh of renewable energy by 2013.[38] Besides cushioning the effects of oil prices, the large scale production of biofuels in South Africa is projected to provide several other benefits, which include job creation, rural development, and foreign exchange savings.

[37] PISCES Bioenergy Policy Brief 2010. Unpublished.

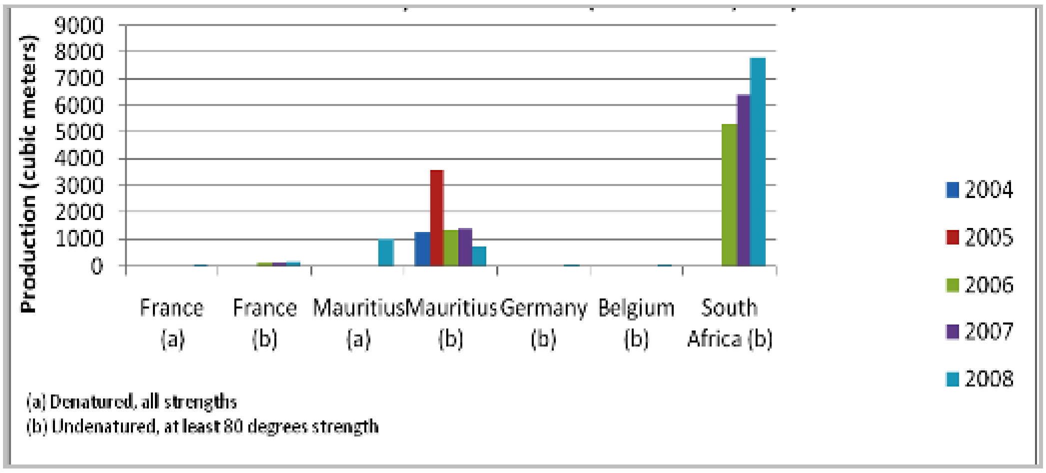
[38]38 Energy and Resources, Country Profile for South Africa http://earthtrends.wri.org/pdf_library/country_profiles/ene_cou_710.pdf

It is important that the government is actively involved in promoting the household sector, as well as the transport sector, in countries where it has control over fuel sales. For example, in Ethiopia, the fuel blending market is prioritised by the government for the transport sector due to soaring global prices of fossil fuels, and the household sector and local industries are on the waiting list to get locally produced ethanol. The government biofuels policy is aiming for massive upscaling of local production coupled with using ethanol for both the transport and household cooking sectors. It has signed an agreement with fuel companies to blend ethanol with gasoline, starting with a 5% ethanol blended gasoline for the transport sector, but this percentage is set to increase in the coming years. Reduced outputs of raw feedstock due to poor harvests that lead to a shortfall in ethanol can be very destructive of an emerging technology such as ethanol stoves. Government policies and legislation need to ring-fence and prioritise sufficient ethanol fuel for the household energy market to ensure that a failure in the supply chain for ethanol does not destroy the burgeoning market for stoves.

2.6. International experiences relevant to Madagascar

Madagascar has recently imported ethanol from France, Mauritius, Germany, Belgium and South Africa, for a range of uses, including pharmaceuticals, cosmetics, inks, and industrial-grade chemical products[39], from both sugar cane, sugar beet and rape seed feedstocks. Figure 2.11 shows the importation of both denatured and non-denatured ethanol of all strengths to Madagascar between 2004 and 2008 (FO Licht, 2008). Madagascar imported 21,000 tons of sugar from Brazil in 2008, up from 10,500 tons in 2006 (UNICA, 2009).

Figure 2.9: Madagascar – ethyl alcohol imports (cubic metres)



This section details a variety of still evolving experiences with ethanol production around the world, with the general drivers for sector development being the need to modernise the sugar industry, on the supply side, and domestic fuel blending mandates on the demand side. Often there is direct state support for the sugar

[39] Charts Compiled from FO.Lichts Vol. 7, No 17./1/05/2009, Vol. 7, No 16/28.04.2009, Vol. 7, No. 12/02.03/2009, Vol. 7, No. 4/23.10.2008

industry and/or for fuel blending, even when there is not an adopted biofuels policy. A key lesson for Madagascar is that while fuel blending may drive sector expansion and address petroleum import issues, if only blending is encouraged then the household fuel sector for ethanol may not develop. Consumers who cannot afford a clean fuel such as LPG may not be able to gain access to ethanol as a household fuel and will thus receive little benefit from such fuels unless through equitably arranged agricultural livelihoods strategies in fuel production (e.g. small scale production and distributed supply and sales). Such challenges are likely to be exacerbated through explicitly export-oriented strategies, which may be a temptation if markets like the EU continue to demand increasing amounts from international supply at higher and higher prices.

In terms of production scenarios, the focus for industrial ethanol fuel development in most other countries has been towards large scale production. However, trends in this are changing as the industry matures and development benefits are being sought more explicitly within biofuels policy in developing countries. As such smaller scale efficient production and distillation technologies are becoming available as outlined in the previous section and this offers an additional route for the Malagasy ethanol sector which may not have been available in previous years.

Experience with small and micro scale ethanol production has been especially rich in Brazil, the United States, India, South Africa and a few other countries, and there are lessons to be learned and technology to share from these countries. The micro scale experience comes from not only the beverage industry (formal or informal) in these countries but also from agriculture and the search by farmers both for cheaper fuels and value-added products.

It must be noted that while ethanol has been used on a limited basis for cooking, heating and lighting in many cultures, formal, international experience of ethanol as a commercial household fuel is limited and relatively recent, with programs in other countries struggling, usually for one or more of the following reasons:

- Inefficient or unpopular stoves being promoted which are then not taken up by households. Examples are gelfuel stoves in southern Africa (South Africa, Malawi, Zimbabwe, Mozambique), which have suffered from being under-powered and of requiring frequent refuelling.[40]
- Ethanol supply mandates to fuel blending programmes, pulling affordable domestic supply away from household markets. A recent example is Ethiopia where the government pulled ethanol from the operating ethanol stove program for a government run fuel blending program when production shortfalls caused a supply constraint. This left over 3000 stove users without ethanol.
- Quality (energy content and form) of the ethanol fuel not being suitable for widespread use. Where beverage and farm-scale stills operate, in most instances they produce only a low grade ethanol, in the range of 40 to 55% ABV. This is true for Brazil as for India and selected African countries.
- Lack of supportive policy or policy swings on biofuels, undermining sector confidence in both the fuel and stoves, requiring both to remain relevant as a

[40] UNDP-Malawi GSB for Poverty Reduction Program Report, Feasibility Study for the Use of Ethanol as a Household Cooking Fuel in Malawi, prepared by Ethio Resource Group and Gaia Association, November 2007. See also: Lloyd, P and Visagie, E., The Testing of Gel Fuels and their Comparison to Alternative Cooking Fuels, Energy Research Centre, University of Cape Town, Cape Town, South Africa, April 2007.

viable option for consumers despite supply interruptions. Fuel blending in both Kenya and Ethiopia suffered interruptions, as has the ethanol stove program in Ethiopia.

- Ethanol fuel pricing is very vulnerable to commodity prices of existing fuels, for example charcoal, fuelwood and fossil fuels, particularly kerosene. Ethanol for domestic fuel may have to compete with ethanol priced for export to developed economies. An example is Eastern Africa, which is developing a robust trade in ethanol to the E.U countries, encouraged by European businesses that are looking to diversify from Brazil. Sudan exports all of its new 60 million litres of capacity to Europe.

If the Malagasy household ethanol programme is to overcome these challenges it must learn from the experiences described here and put in place consistent and substantial measures for overcoming them. Such a programme needs to be based on a sustainable domestic supply of ethanol. If it is able to do so at scale, it will be the first country to achieve this and in so doing will achieve the multiple benefits which are foreseen from the development of ethanol as a household fuel.

2.6.1 International African Ethanol Production Experience

Annex 5 gives a detailed overview of large-scale ethanol manufacture for a number of countries worldwide, particularly in Africa, and this section provides a short overview of the future government policy from each country.

2.6.1.1 South Africa

South Africa's energy profile was changed through the introduction of ethanol gel fuel as a substitute for paraffin, supported by the Department of Minerals and Energy, due to lack of progress in finding safe paraffin appliances. Unfortunately emissions from gel appliances were high and ethanol gel stoves produced only low heat outputs. No standards were set to control ethanol gels, and products containing less than 70% ethanol reached the market, which do not burn well (Lloyd and Visagie, 2007).

Ethanol gel continues to be manufactured and sold in South Africa and several gelfuel stoves are sold. "GreenGel" is one example.[41] SAFE cooking gel is another.[42] The gel stove, however, does not seem to have received widespread acceptance. One South African stove, the Cooksafe, was tested as part of this study (Chapter 5).

In 2006, South Africa's cabinet approved a National Biofuels Industrial Strategy, which proposed that 4.5% of liquid road transport fuels[43] should be biofuels, allowing the country to produce around 40% of its own fuel supply.[44] The strategy was predominantly driven by the need to address the issues of poverty, rural development, and Black Economic Empowerment (BEE). In 2007, the South African

[41] See http://www.greengel.co.za/.
[42] See http://www.safepremier.com/.
[43] 43 Mayet, M (2006) South Africa, Bioethanol and GMOS: A Heady Mixture: African Centre for Biosafety, May 25 2006 www.biosafetyafrica.net
[44] 44 Nilles, D (2006) Biofuel Requirements Going Global: Ethanol Producers Magazine, available at: http://www.ethanolproducer.com/article.jsp?article_id=2574

cabinet announced that the country would aim for biofuels to account for 2% of its total fuel production by 2013.

2.6.1.2 Ethiopia

An important lesson for Madagascar is the effort made by Ethiopia to raise the issue of domestic needs. This persuaded the government to cease exporting ethanol and focus on developing local markets. Ethanol export was halted in 2008. Ethanol was provided to an ethanol stove pilot study in 2004-5 and to refugee camps through the UNHCR in 2006-9. An experimental fuel blending program commenced in late 2008. With increasing production, the government plans to raise the gasoline-ethanol blending ratio and supply the household cooking sector. A biofuels policy favouring fuel blending and stove fuel use over export has been adopted by the government. The government, while leaving ethanol stove and fuel market development to the private sector, has taken direct ownership of implementing fuel blending and marketing while tasking the oil companies build the costly infrastructure.

Since ethanol as a cooking fuel was new to Ethiopian households, it was essential to measure the impact of the new technology on air quality in the household, assess the safety of ethanol fuel and stoves, and understand the impact on livelihoods. Results on both stoves and fuel were very positive; however, a recent shortage of ethanol and the government's decision to prioritise fuel blending over the household sector resulted in a supply interruption to the ethanol stoves operating in the country. Policy stability in favour of the household fuel market development is required for successful and sustained uptake.

As early as 2002, the Ethiopian government experimented with marketing a fuel known as "K-50" (an ethanol and kerosene mix) in Addis Ababa as a cooking fuel for use in ordinary kerosene wick stoves. The kerosene-ethanol mixture, in these poorly suited stoves, proved to be too volatile and resulted in several house fires and serious burns.

Bioethanol is expected to create employment and opportunities for local Ethiopian agriculture and agro-industry; however, with the government's focus on large scale centralised production, benefits in the value chain may not be as widely spread as may be hoped. The World Bank is supporting a micro distillery and stoves project in Ethiopia during 2010-2012, which may result in the turn to small or micro scale production as one solution to supplying ethanol to the household sector.

Ethiopia is expanding its sugar factories to scale up sugar and ethanol production, and existing sugar factories will be expanded to 700,000-tonnes a year from the current 300,000 tonnes a year. Tendaho, a new sugar factory being built, will produce 600,000 tonnes of sugar annually when it starts to operate in 2013. The five main sugar factories will have a combined production capacity of 1.3 million tonnes of sugar per year.45 Ethanol production is expected to reach 130 million litres per year by 2013-15.46

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45 Ministry of Mines and Energy, 2008
46 Ibiddi.

2.6.1.3 Kenya

Bioethanol production is an agro-based industry which can, if structured correctly, provide on-farm and off-farm employment opportunities especially in the rural areas. Ethanol production could boost the agricultural sector which contributes up to 26% of Kenya's Gross Domestic Product (GDP) and provides employment for 80% of rural people. Ethanol plants can be expected to attract other industries and employment.

The tax base in Kenya is low, making it difficult for the government to provide social services. The Kenyan government is under pressure from international funding organisations to increase its tax base and reduce its dependence on foreign aid. Jobs and taxes (income and VAT) in a formal ethanol sector could contribute to government revenues.

Kenya's relatively inexpensive labour force makes production costs competitive in the world market, and surplus ethanol could be exported to the world market. By 2001, eight European member states had introduced carbon taxes, and Kenya has a geographical advantage with their port to export ethanol to other countries.

The export of ethanol to other countries could be favoured by free trade agreements between Kenya and other African countries especially the East African Community (EAC), Kenya, Uganda and Tanzania, and through the free trade agreement between the Common Market for Eastern and Southern African (COMESA) of which Kenya is one of 20 member states.

The Kenya Bureau of Standards (KEBS) has produced a standard for 10% ethanol fuel blending, but as there is no existing regulation on biofuels or alcohol fuels standards, it is not possible to determine whether or not it is currently permissible by law to produce or sell biofuels to the public. Prior to the creation of a biofuels standard, KEBS is required to conduct an environmental impact assessment which will analyze the effects of such regulations.[475]

The UNDP, in cooperation with the Ministry of Energy, has funded an ethanol stove commercialization pilot study to be undertaken in 2011-12, using the same stove technology that was successfully tested in Ethiopia and scaled up in refugee camps. Spectre International, Ltd., the leading ethanol producer in the country, is participating in the study, which will take place in Western Kenya. Socio-economic impact studies and indoor air monitoring, as well as the development of a commercialisation plan, will be a part of this study.[48]

2.6.1.4 Malawi

Recently the supply of molasses to produce ethanol has not been inconsistent, and Malawi has had to import molasses from neighbouring Mozambique and Zambia. The increased demand and capacity in producing ethanol by local factories has produced periods of feedstock deficit (which interrupts fermentation). Malawi has consistently exported half of its ethanol to other East African countries and smaller amounts to Mozambique, Zambia, and Botswana.

In Malawi, at the current market price of ethanol, the stove market segment in Malawi is only approximately 2% of the urban population (representing 7,000 households)

[48] UNDP-Kenya Project Identification Form, Sept. 10, 2009.

which currently rely on kerosene and LPG fuel. If the price of ethanol can be reduced, ethanol will become more competitive with charcoal. This is significant because around 4% (representing 14,000 households) of urban households might be persuaded to switch to ethanol for its positive attributes.

Two private entities BluWave and D&S Gelfuel Ltd. manufactured ethanol gel fuel for domestic cooking between 2002-2005. However, without appropriate stove technology being put in place, this production was discontinued.

2.6.1.5 Mozambique

Mozambique has a substantial amount of natural resources ranging from fossil fuels (natural gas and coal) to renewables (solar and hydro); however most of these resources remain untapped. Most of the energy demands in the country are fulfilled by biofuels. In 2008, the government of Mozambique approved a $296 million project for ethanol production. The 44,000-acres of sugarcane associated with the project are estimated to produce three million tonnes of cane, which should, in turn, produce 56.3 million gallons of ethanol yearly.

Since Mozambique is a traditional African sugarcane producer, and well positioned with good ports and trade infrastructure, it has a big potential to become a net exporter of biofuels. While Brazil leads in global exports, many low-cost African producers are expected to become biofuels exporters in the next few years, which is one reason Mozambique is drawing high profile foreign investments. Translation of this interest and investment into sustainable benefits for the poor in the country remains the key challenge.

In the last few years there has been a transition to the implementation of wide-scale biofuel development projects, which include both small and large scale initiatives. Procana, a private company has already released plans to invest US$150 million to develop 30,000 hectares of land for sugarcane feedstock and a plant producing bioethanol. These plans also encourage rural development with the use of out-grower schemes to add additional hectarage. In fact, out-grower schemes are becoming increasingly popular as the Mozambique experience shows out-grower farming, less than a hectare, can bring in more income than factory employees earning a large salary. These integrated projects are taking off in Mozambique with the companies, Mozambique Principle Energy (large and small-scale) and Elaion (small-scale jatropha), investing in the country.[49]

A private company, CleanStar Ventures, has started developing a project in Sofala Province in central Mozambique with the aim of producing ethanol as a household cooking fuel, but it is currently still in the piloting phase.

2.6.1.6 Nigeria

Even though the country is rich in fossil fuel resources it is still considered by the government and analysts to be an important country for ethanol production due to ethanol's potential for diversification of Nigeria's economy, foreign exchange savings, new economic opportunities, job creation and rural development.

[49]49 www.iied.org/pubs/display.php?o=17059IIED

As ethanol burns very cleanly, producing much less particulate matter and carbon monoxide than wood or kerosene, its use as a cooking fuel would reduce deadly indoor air pollution that afflicts millions of households in Nigeria. A 2007 WHO report attributed the total deaths to the use of solid fuels in Nigeria at 79,000 so far, the highest level in Africa.

The total market volume of ethanol in Nigeria is estimated to be around 90 million litres, the largest part of which is supplied by South Africa, Brazil, and Spain (Utria Berg 2001). Estimates from the Central Bank of Nigeria put the national annual ethanol consumption in Nigeria at 88,000 MT, while the Federal Office of Statistics estimates Nigeria's annual ethanol imports, besides the importation of fuel ethanol for fuel blending, at 42,600 MT. Based on current demand for gasoline in the country, at 10% blend ration with fuel ethanol, about 1.3 billion litres of ethanol will be required for the country, and is estimated to increase to about 2 billion litres by 2020. Policy commitment to the development of a national programme on biofuels, as well as the few planned and on-going private sector-led initiatives on bio-ethanol are centred around the use of cassava and sugar cane as feedstock. All ethanol currently used in Nigeria, particularly the industrial and pharmaceutical grade ethanol, is imported. There are companies importing either sugar cane molasses or crude ethanol for other ethanol production in Nigeria.

2.6.1.7 Tanzania

A national biofuels policy and strong government support may encourage foreign investment, bolstering the local economy. The President of Tanzania played a major role in the promotion of domestic energy by inviting potential biofuels stakeholders to invest in the country. However, this trend was seen by many to have gone too far, too fast, in favour of foreign-owned export-oriented enterprises not delivering enough benefits in Tanzania to justify the areas of land and resources they would be occupying.

Tanzania created the National Biofuels Task Force, a body responsible for drafting guidelines and ensuring safeguards are met and incorporating the full range of stakeholders. This should allow Tanzania to diversify biofuel production models; from foreign large-scale investment to the local out-grower schemes targeted at fortifying rural development

An increase in national biofuels production is considered to be a potentially cost-effective way for Tanzania to save on imports of costly oil. The international community, including major biofuels companies and governments has been promoting investment in biofuels to promote energy security. Tanzania is one of the African countries on the forefront of this trend. In fact, over 4 million hectares of land has already been requested for biofuels investment (jatropha, sugarcane, and oil palm). As of June, 2009 only 640,000 hectares had been allocated for this use, and only 100,000 of those acres have been formally granted the right of occupancy.[48] National policies which promote biofuels production, also attracts foreign investment and already some countries have proposed biofuels projects which have attracted investments of a few billion USD over the next two decades.[48] According to official government figures, about 20 companies had requested land for commercial biofuel production by March 2009 (varying from 30,000 to 2 million hectares).[48] There is considerable variation of biofuel production models in Tanzania, with some relying only on smallholder out-grower schemes while others requiring large swaths of land owned and farmed by the producer/investor.

2.6.1.8 Uganda

Uganda has taken stock of its natural resources in an attempt to use a variety of feedstocks for producing alternative energy. Although no plans have been set, Uganda wastes a huge amount of agri-wastes from sugar production. Most of these wastes are burnt in situ, while they could be used for energy generation.

Due to a lack of local facilities to refine oil, Uganda pays a higher price for fuel than neighbouring countries like Kenya and Tanzania which import crude oil and refine it locally. As such, Uganda has a high incentive to invest in infrastructure to produce domestic alternative energy. However, Uganda already distils and produces ethanol, the grand majority for the beverage industry; most of these crude beverages are locally distilled using very old inefficient distillation systems to yield a more concentrated and strong beverage called *waragi*, with an ethanol concentration of up to 40% (v/v).[50]. WHO estimates Uganda has the highest per capita ethanol consumption rate of 19.4 litres per capita per annum (adults over age 15). This suggests the technology to produce ethanol exists in Uganda, but separating fuel ethanol from beverage ethanol safely and economically will be a major challenge in policy and practice.

Alternative energy is seen as a way for Uganda to reduce is heavy dependence on charcoal as a cooking fuel. The use of charcoal is escalating dramatically, as urban migration rates increase at 6% per year, creating an unsustainable demand for charcoal90

Uganda has investigated its potential for production of ethanol from sugar molasses and cassava. In 2002, cane crushed in Uganda amounted to 1,707,000 tonnes with an estimated ethanol production potential of 119,490,000 litres. In 2003 the total production of cassava was 5,265,000 tonnes while stock residues produced 326,430 tonnes, and currently the Uganda Cassava Development Program (UCDP) is working to improve this cassava production. The government is targeting the transport sector since it is consuming fuel that is costing the country too much in terms of foreign currency. According to the plan, it is envisaged to reach 20% gasoline blending in order to reduce the rising costs of fossil fuel imports.[51]

2.6.1.9 Zimbabwe

Zimbabwe was one of the earliest African ethanol producers, commencing operations in 1980. During this initiative, an estimated 40 million litres of oil imports were displaced, providing huge earnings to the local economy. Low sugar prices allowed Zimbabwe to take advantage of investment in a secure energy supply

One success of the Zimbabwe ethanol production model was the ability to maximise the use of local materials (60% locally sourced), construction and labour. A new agricultural industry was created which provided many new jobs. Even though the programme had a clear pricing policy, the biofuel programme faltered due to the collapsing economy and the lack of management to oversee these programmes

An obstacle Zimbabwe faces is a declining water supply and susceptibility to drought. The quantity of water depends mainly on the water requirement of the feedstock related to the relative scarcity of water in a specific water basin. For example, in Zambia, Zimbabwe and Mozambique 60% of the total water supply of the Zambezi river basin is used for sugarcane production

Zimbabwe's government has established a policy to support biofuels such as biodiesel and ethanol-based fuels, to reduce fossil fuel use, thereby reducing carbon emissions and helping to curb climate change and global warming.

2.6.2 International Non-African Ethanol Production Experience

2.6.2.1 Brazil

Brazil is one of the earliest ethanol producing countries, utilising vast sugarcane resources, and basing the development of its industry on an aggressive fuel-blending programme that was heavily subsidised by the government. Brazil's interest in ethanol as a motor fuel dates back to as early as 1903 and the first blending mandate was instituted in 1931.[52] The national alcohol development program for which Brazil is well known, the *Programa Nacional do Álcool*, referred to as *Proálcool*, was enacted in 1975. Blending mandates, paired with subsidies, helped to keep the price of ethanol competitive with oil, despite great swings in pricing of fuels, and eventually led to the rapid expansion of the ethanol industry. Today, hydrous ethanol fuel in flex cars is poised to overtake gasoline use. Domestic use of ethanol is targeted to expand to 53 billion litres in 2017, which would supply 80% of the vehicle fleet.[53]

From an economic point of view, the estimated cost of implementing *Proálcool,* between the years of 1975 and 1989, was approximately $7.1 billion, of which $4 billion was paid for by the government and the rest by private investment.[54] It is estimated that during this time the Proálcool program saved Brazil $195 billion in foreign exchange, $69 billion in avoided imports, and $126 billion in avoided foreign debt interest.[55]

At a critical time in the building of Brazil's ethanol industry, incentives instituted under *Proálcool* were written to favour large plants over small ones, a source of contention and even bitterness among members of the industry, including Brazil's many small-scale sugarcane growers. The debate in Brazil about the importance and relevancy of small and micro producers, and their ability to produce for the fuel market, still carries on. In part because of the tradition of the cachaça or sugarcane rum enterprises and in part because of the interest of farmers in value-added production, a robust micro distillery movement continues, despite the government's clear preference for scale, and some micro distilleries continue to aspire to produce for the fuel market. Even though the industry has been heavily consolidated to large scale, which dominates in areas where production is high, many smaller producers continue to operate, particularly in areas where production is much lower, as shown in Figure 2.12.[56]

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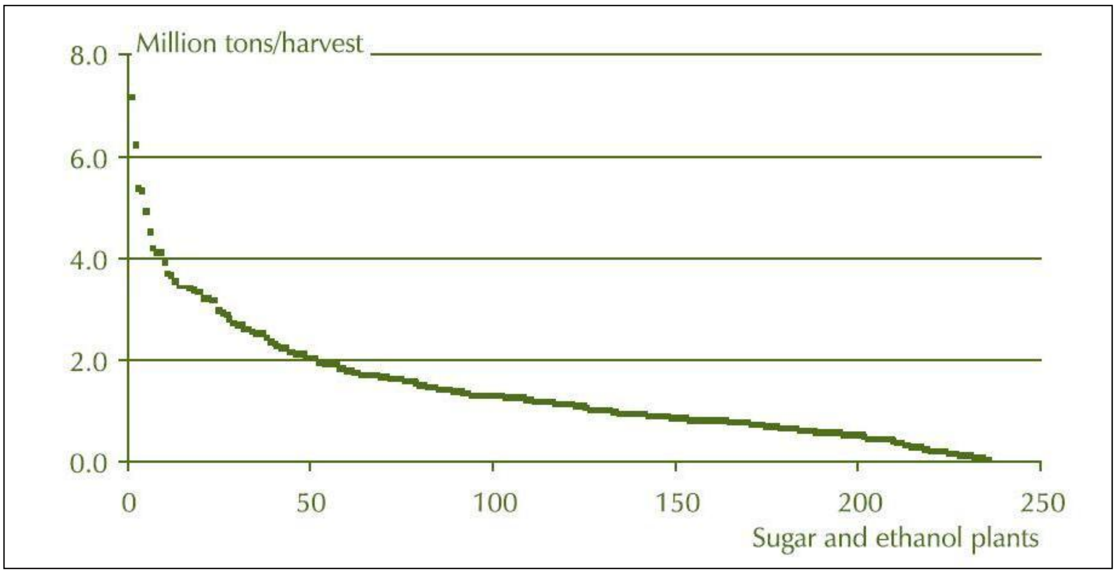
52 Horta Nogueira, Luiz, ed., Sugarcane-Based Bioethanol: energy for Sustainable Development, 2008.
53 This was Liz's addition, I think. This needs a citation but I don't have it.
54 Horta Nogueira, 2008.
55 Idem.
56 Idem.

Figure 2.10: Scale of Sugar Cane Production and Number of Sugar/Ethanol Plants



Source: Sugarcane-Based Bioethanol, 2008, p 156

Interest has grown in trying to find a role for micro distilleries in the Brazilian fuel economy as well as in determining if the particular know-how possessed by small producers and distillers could be transferred to other countries.[57]

As a result, a good deal of work has been done not only to build micro distilleries for efficient fuel production but also for easy and affordable replication. With regard to replication in other countries where small scale might make sense, one study concluded as follows:

- The extreme concentration of the bioethanol production industry that has taken place in Brazil is not inevitable.
- The concentration of bioethanol production in Brazil is due to past and current economic practices and conditions that could be subject to alternative policies.
- Small-scale ethanol is promising for remote energy supply and related value chains, for example in rural Africa, especially for uses and markets other than transportation. Separate markets for small-scale ethanol producers, such as household appliances and isolated mini-grids may provide smallholders with income opportunities from sugarcane that are more secure than the large sugarcane-for-industry/transportation market.
- The ease of integrating cane and ethanol production via small-scale distilleries creates the opportunity for cane-producing smallholders to profit.
- Regulation and other policy measures may be necessary to limit market concentration and encourage small-scale sugarcane and ethanol production.[58]

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[57] Scholtes, Fabian, Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction, Center for Development Research, University of Bonn, July 2010.

Brazilian ethanol is competitive around the globe because it is generally produced and priced more cheaply than ethanol traded from other countries. Brazil produces in adequate quantities to allow it to respond to international demand with a robust and growing export market. Ethanol exports are expected to increase quickly along with global demand for ethanol as a source of alternative energy.

Brazil has been able to address household energy needs at home through the use of its domestic reserves of natural gas, complemented with cheap, imported natural gas from neighbouring Bolivia. A small portion of this natural gas is separated as butane and propane, providing the supply of liquefied petroleum gas (LPG), which, like ethanol for fuel blending, was stimulated by incentives to promote its uptake for cooking fuel. At the height of the program, 98% of Brazil's households had access to LPG for cooking. Brazil's "LPG miracle" has not been replicated in many other countries, making Brazil a special case in this regard.[59]

Brazil has invested millions in R&D of ethanol production processes and technologies. Currently, Brazil is advising emerging markets on how to create successful ethanol industries. It does so through its Ministry of External Affairs Energy Office and through various promotional, technical and research units. The Energy Research Company (EPE) has put in place a ten-year plan for the period of 2008-2017, anticipating that demand for ethanol fuel in the domestic market will rise from 20 billion litres to 53 billion litres, a growth rate of 165%.[60] As for international demand, the expansion of Brazilian exports has been leveraged by external events, such as U.S. and European law which broadened the goals of their use of biofuels. In 2007 Brazil exported 3.5 billion litres of ethanol. In 2008, this increased to 5.1 billion litres[61], yet producers still had more to trade. Fuel blending mandates around the world are on the rise, yet blending rates remain low. Brazil's expectation is that exports will increase steadily and that its production will grow and will be able to meet this demand.[62]

2.6.2.2 India

India's ambitious biofuels policy is comprehensive in the way it included ethanol distilleries, R&D organizations, and policy planners. Government mandates for ethanol have increased India's capacity to produce ethanol substantially. Furthermore, the government provided financial incentives to produce ethanol as well as cogeneration from the bagasse.

The history of India's ethanol industry clearly shows how government policies affect the supply chain, as they can intervene during depression of sugarcane production, feedstock or molasses production and cost. India subsidized and provided tax exemptions to production facilities using molasses and sugarcane as an encouragement to produce ethanol. A focus on fuel blending in ethanol policy has not led to any impact from ethanol as a household fuel in the country in which vast

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[58] Scholtes, 2010.

[59] Lucon, O., Coehlo, S., and Goldemberg, J, LPG in Brazil: Lessons and Challenges, Energy for Sustainable Development, Volume VIII, No. 3, September 2004

[60] EPE is a government business located in the Ministry of Mines and Energy – www.epe.gov.br.

[61] Brazilian Secretariat of Foreign Trade, elaborated by UNICA, accessed on the web 9-15-10 at http://english.unica.com.br/dadosCotacao/estatistica/.

[62] "Ethanol – fuel of the future" by Marcelo Junqueira.

numbers of people are still wholly reliant on fuelwood and dung as fuels. Such fuels are strongly linked to health impacts as assessed in Component A of this project.

In May 2009, the Petroleum Ministry of India proposed to lower the import duty on denatured alcohol from the present 7.5% to 5% and that on molasses from 10% to 5%. The government's 5% petrol blending plan has been affected due to the decline in molasses production in India which arose from a decrease in sugarcane production. Currently, the Ministry's proposal is awaiting clearance from the Cabinet. Analysts are of the view that at 5% blending the requirement for ethanol is about 600 Mlt/y and there has been a shortage of about 40%. The oil marketing companies are unable to take up blending in the areas of Tamil Nadu and Kerala due the taxation policy of these State Governments. A major hindrance to the blending programme has stemmed from the erratic supply of ethanol. The original plan to make 10% blending available from October 2008 has still not been implemented. Contracts for 1,320 M litres of ethanol had been signed for by oil companies, but as of January 2009, they had only received 120M litres.

2.6.2.3 United States of America

A diversified energy portfolio can meet different markets, as seen in the U.S. example of distributed energy and small-scale approaches to making ethanol. This approach particularly engages local entrepreneurs. After receiving significant backlash from producing corn-based ethanol, the U.S. government is investing heavily in R&D of cellulosic ethanol facilities. This ethanol is expected to be produced from a variety of feedstocks and waste materials and to be close to CO2 neutral.

The U.S. case is an example of the limitations of fuel-blending. Ethanol blending is capped at 10%, and the U.S. market for ethanol will hit a "blending wall" which is estimated to be 14 billion gallons. The country has created a strong base of small-scale famers by providing loans to jumpstart productivity. The U.S. ethanol's domestic market is protected, with the government levying a 51% per gallon tax on any imported ethanol. This tax is widely debated, but protects U.S. farmers and the national ethanol industry

Due to the additional steps in biochemical conversion, the U.S. has not yet commercially produced cellulosic ethanol. In the last few years however, intensive research and government incentives have advanced the agenda for the development of cellulosic ethanol plants. At the start of 2008, the Department of Energy pledged $114 million to support the creation of cellulosic bio-refineries at a small-scale. One of the goals is to test new and various feed-stocks to create a multiplicity of biofuel and bio-products.[63] Furthermore the Department of Energy chose six projects to fund over four years, with the aim of demonstrating that bio-refineries can operate profitably and with greater net energy yields once the construction cost is paid, and this the model can be replicated. Cellulosic ethanol is enticingly desirable to U.S. production since the final fuel product contains a net energy yield which is close to CO_2 neutral.

[63] U.S. Department of Energy. *Alternative Fuels and Advanced Vehicles Data Center*. http://www.afdc.energy.gov /afdc/ethanol/production_cellulosic.html, February, 2009

2.6.2.4 European Union (EU)

Based on the EU's current ethanol targets for fuel blending, 17.7 billion litres of ethanol will be required by 2020. Local production capacity may reach 12.16 billion litres by 2015 and might remain constant thereafter based on the current trajectory of first generation and cellulosic projects entering the market. In short, as a result of the EU's mandated targets, and individual ethanol and biodiesel targets in several countries, the growth of demand in the EU will be significant and above its internal production capacity. Imports will continue to make up the difference between domestic supply and demand and are likely to play an important role in global ethanol trade.

2.7. Conclusions

World production of ethanol is rising linked with high oil prices, international awareness of global warming and concerns about energy security. For producer countries ethanol production offers a range of opportunities, both for domestic energy supply and for export. In Brazil, the only developing country to have so far gone to scale with ethanol production, ethanol appears to have delivered reduction in oil importation and improved security of energy supply. Africa's ethanol base is less developed than those in Latin and North America, but several countries are increasing production and there is significant potential for the African biofuels industry to expand. Despite recent growth however, the global market for biofuels is still in its relative infancy.

The dominant current consumption of ethanol is for transport fuel-blending, but there is also significant demand and use of ethanol in the industrial sector. However, in developing country contexts where household energy accounts for 75-90%,[64] ethanol has also been shown to have potential as a cleaner and healthier household fuel. Developing a stable domestic ethanol household fuel market is considered to have potential to offer substantial economic, health and environmental multiplier benefits at local, national and international levels. This potential has been partially demonstrated in Africa (eg. Ethiopia), but also setbacks have been observed linked to poor stove technologies (eg Malawi), fuel forms (eg. South Africa) and policy inconsistency (eg Ethiopia). If ethanol to achieve it's potential as a household fuel then these lessons must be learned in developing new sectors in countries such as Madagascar.

Ethanol can be produced from any biomass containing significant amounts of starch or sugar. Production scales can be categorised as: large scale, microdistilleries and artisanal scale. Based on the information collected from international experience, the table below summarises the relative merits of these scales in terms of key attributes relating to fuel production and impacts (XXX being "most preferable" for each attribute).

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[64] WHO, 2006. Stockholm Environment Institute Policy Brief, June 2009.

	Artisanal	Micro-distilleries	Large-Scale
Energy Efficiency	X	XXX	XXX
Low capital barriers	XXX	XX	X
Cost of litre produced	X	XXX	XXX
Distribution of benefits	XXX	XXX	X
Ethanol quality	X	XXX	XXX
Alcohol % concentration	X	XXX	XXX
Risks of leakage into drinking	X	XX	XXX

Artisanal production is very accessible to poor rural producers due to low capital costs enabling local level benefit distribution, however low ethanol quality and strength at poor conversion efficiencies (implying more fuelwood use per litre of ethanol), creating a higher cost product make it non-viable for a widespread household ethanol programme. The close association of this type of production with drinking, the higher market price per litre for this application, and the difficulties of policing production at this scale appear to preclude it's serious consideration for household ethanol market creation.

Large scale production is relatively well known internationally and is the typical scale of production in Brazil and other large ethanol producing economies, offering good efficiencies, quality, strength and low cost per litre. However centralised plants will not necessarily promote maximum benefit distribution along the supply chain and high capital barriers exclude local people from direct participation, other than as waged labour or raw material suppliers. As suchm, the structuring of agreements with outgrower sugarcane suppliers for example, can have a strong influence on inclusivity and development impacts.

Micro-distillation is a relatively new scale of production but it appears from international experience to offer many of the energy efficiency and ethanol quality benefits of large-scale production, but with increased levels of decentralisation of production and corresponding dispersal of opportunities and benefits. Although a detailed analysis of costs of production is needed for each new installation, available micro-distillation technologies internationally appear to also be capital cost competitive per litre of ethanol produced compared with large scale installations. The lower total cost per installation also allows production to be dispersed closer to cane production and household ethanol consumers, and lowers the capital barriers to market entry.

International experience however shows ethanol markets to be strongly dependent on government policy. Particularly given the volatility of international fuel markets and the multiple potential applications of ethanol at different price points – stable and progressive government policies will be important if the ethanol household fuel market is to develop sustainably. In initial stages it may be necessary to ring-fence and prioritise sufficient ethanol fuel for the household energy market to ensure that a failure in the supply chain for ethanol (perhaps linked to international price fluctuations or a fuel blending mandate) does not destroy the burgeoning market for stoves which would also be created. Ethanol fuel pricing is very vulnerable to commodity prices of existing fuels, for example charcoal, fuelwood and fossil fuels, particularly kerosene - and if multiplier benefits of ethanol to health, the environment, rural incomes and balance of payments are to be realised – then government policy must mediate price fluctuation to some extent, especially in initial stages.

In order to succeed, the Malagasy household ethanol programme must learn from the international experiences described in this chapter, and put in place measures to overcome challenges encountered elsewhere, and replicate successes.

3. Madagascar Production Scenario

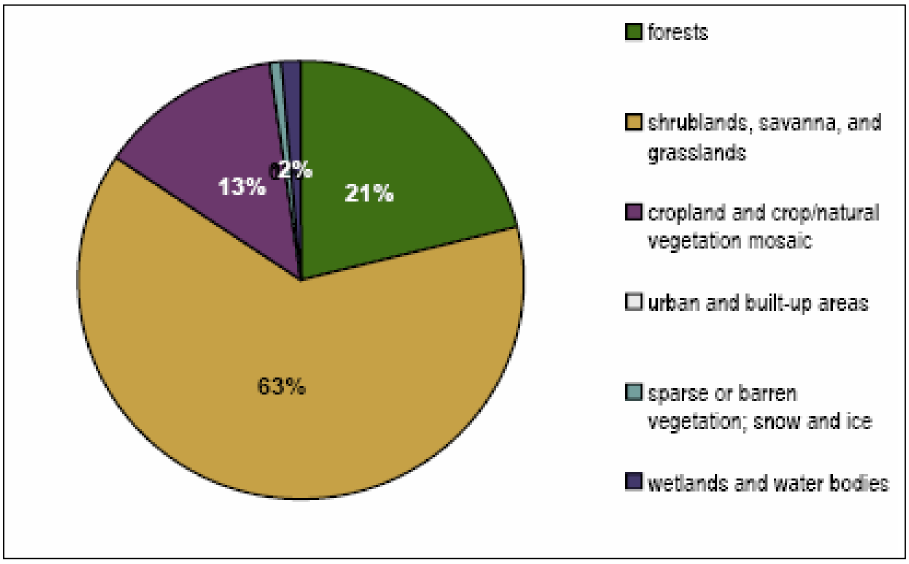
This chapter seeks to analyse the main factors affecting the proposed production of ethanol in Madagascar through a household fuel programme. The analysis starts from a consideration of the current patterns of production in evidence then goes on to consider how these might be affected by an increase in ethanol production from sugarcane.

3.1 Land

3.1.1 Land Use

The total surface area of Madagascar is 587,041 square kilometres and the population density is 33.5 persons per square kilometre (UN Data, 2007). About one-half of Madagascar's land area is cultivable, but little more than 5% of the land is currently under crops, with a large part of this cultivated area under irrigation (40%)[65]. Of this, less than 2 million hectares is permanently cultivated (World Bank, Rural Development Support Project, 2008); taken together cropland and crop/natural vegetation mosaic accounts for 13% of land cover (Earthtrends, 2009). Approximately 21% of the total land area is covered by forests and 63% by shrubland, grassland and savanna (Earthtrends, 2009). Sparse vegetation, snow and ice account for 1% of land cover and wetlands/bodies of water account for 2%. Less than 1% of land area is urban/residential (Earthtrends, 2009), as described in Figure 3.1.

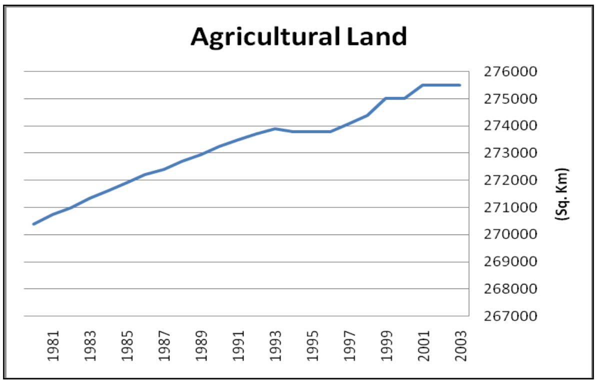
Figure 3.1: Ecosystem Areas by Type, Madagascar 1992–93



[65]Madagascar Ministry of Agriculture, http://www.maep.gov

Due to the high population growth rate in rural areas, demand for new agricultural land is high (Figure 3.2). Data from a survey by IFPRI/FOFIFA in three regions in Madagascar showed that while rice land area grew by about 5% on average for all regions over a ten year period, the area of cultivated upland where it is grown increased by about 24% (Minten and Zeller, 2000).

Figure 3.2: Madagascar Agricultural Land History[66]



The fact that the agricultural frontier can still be expanded in many Malagasy villages is evident from the survey data: 59% of villages report that there is additional land available for expanding upland cultivation, 50% for expanding irrigated land, and 35% for both types of land. Despite this, the average holding of upland per household has declined over time. Clearly, growth in population has outpaced growth of agricultural land in many communities and pressures for agricultural intensification have tended to increase over time (Minten, Cornell 2001).

Implications for the Household Ethanol Programme of Land use policy

In this context, any policy aimed at integrating the expansion of sugarcane production for the ethanol market in Madagascar would require careful zoning and planning of agricultural encroachment into new areas (at any scale), to ensure that neither food production nor the delicate ecosystem was put in jeopardy.

3.1.2 Land Ownership and Rights

Traditional and modern land rights co-exist in Madagascar. Legally, all non-titled lands belong to the State while in practice, even land in inhabited areas is often allocated through traditional rights (Minten Cornell paper, 2001). As of 2006 approximately 10% of the national territory in Madagascar was legally occupied with title or certificates. The current land tenure system dates back to the 1960s when the government of Madagascar established rules for proving traditional property rights (World Bank, 1994, discussion paper). For traditional property rights to be granted, the intended owner of the land must prove that the land has been continuously worked, and then an administrative body must verify that the working of the land is consistent with legally specified conditions (World Bank discussion paper, 1994).

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[66] Africa Agricultural Statistics
http://www.nationmaster.com/time.php?stat=agr_agr_lan_sq_km&country=ma

During the same period, the government set up procedures for granting rights to individuals claiming ownership of public, untitled lands that they have occupied. This complicated process involves making a formal request to a special land register, which is later passed over to the sub-provincial officer of the Direction of Public Land and Agrarian Reform (World Bank, 1994, discussion paper). It is a lengthy process, and the outcome does not provide the applicant with the right to occupy the land permanently. This may only be obtained if it can be proven that the land in question has been under continuous agricultural use for ten years (World Bank, 1994, discussion paper).

Problems inherent in the Land Tenure System

The requirement of continuous cultivation for ten years before ownership can be granted is problematic for a number of reasons. Most smallholder farmers in Madagascar practice a traditional shifting slash-and-burn agriculture known as *Tavy*. Typically, this involves upland cultivation of rice in areas recently burned and cleared of vegetation, a highly unsustainable practice which quickly leads to loss of soil fertility and the soil itself. The rule requiring continuous cultivation encourages farmers to slash-and-burn entire plots in order to stake a claim, rather than conserving some forest vegetation to protect against soil erosion. Moreover, since Tavy involves three years of cultivation, followed by up to five years of fallow, it is not possible for farmers to adhere to the 10 year continuous cultivation required prior to application for tenure (World Bank, 1994, discussion paper).

Research shows that in order to obtain a land title, citizens have to follow a lengthy and costly procedure. The registration process includes numerous governmental departments, who have insufficient staff to deal with the cases. Furthermore, the institutions lack material and financial resources (Falloux en Talbot 1993: 49, Teyssier 2004: 5-6). The net result of all this is that the state is still unable to grant effective title to land, or even properly register or strike rights from title deeds, which has brought the national registration campaign to a halt. The reality remains that much rural land has yet to be registered (Direction Générale des Domaines et des Services Fonciers 2000: 4-6).

Reforming the Land Policy

In 2005, the Government launched the *National Land Tenure Program* with the goal of facilitating land tenure transactions and establishing 21 land tenure offices by December 2006. The government believes that increased land tenure is a means of enhancing small holder agricultural productivity, as well as a way of attracting investment, both domestic and international, in large scale agriculture. According to the government, the current system of land titling is insufficient for stimulating private actor involvement in agriculture and does not meet the requirements of small holder peasant farming.

To address the deficiencies in the system, the government has incorporated a series of measures into the Madagascar Action Plan (MAP).

The main strategies outlined by the government for increasing small holder land tenure are as follows:

1. Modernise (including computerisation) the land property and topographic records

2. Decentralise land property management at commune (region) level
3. Reform the legal framework
4. Strengthen the capacity of the staff of land tenure services
5. Create a land bank for investments in tourism, agri-business and manufacturing
6. Harmonise the intervention of development partners in the National Land Tenure Policy

Conflicts between Traditional and State Land Ownership Systems

In practice State rules recognise neither village territories nor the local authority to manage lands which have not been titled, are not farmed continuously, and are considered part of the national domain (Muller, Evers, 2007). For the most part, state authorities have not concerned themselves with what happens on cultivated and fallow lands that the village considers its own. Tensions between state and local tenure systems are more common on forested lands.[67]

Implications for the Household Ethanol Programme of Land Ownership Schemes

Although some studies have shown that the private economic benefits of land titling would be minor and would not exceed the costs of doing so under the current system (Jakoby & Minten, 2007), it is widely held that the absence of land titles for 90% of rural households is the main reason why most farmers tend not to invest in their land and diversify their production (African Economic Outlook, 2008). Without land title it is difficult for farmers to approach banks or credit unions for investment or harvest loans, thus land tenure policy may have considerable implications for small-scale sugar-cane production. Without security of land ownership, it could be argued that it would be highly risky for households not already involved in sugar-cane production to engage in out-grower schemes. Indeed, the complicated nature of the land tenure system could prove to be a major disincentive for investment in larger scale ethanol production.

3.1.3 Land Taxation

Madagascar's land tax is applied according to the size of the holding. A total of six categories are distinguished with nominal tax amounts for the first five categories and a 1% rate for lands that fall into the last category (World Bank, 2003). The land taxation system is severely deficient in a number of ways; tax collection is almost non-existent, inflation adjustments on nominal tax amounts are not made; and land holdings are typically undervalued (World Bank, 2003). The weak land tax system is a major contributor to decreasing agricultural productivity as it does not encourage the transfer of underutilized lands to more efficient uses (World Bank, 2003).

Implications for the Household Ethanol Programme

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67 http://www.fao.org/docrep/v5595e/V5595e02.htm#n4.1

The creation of an effective ethanol production system with the associated long-run tax revenues accruing to the state may require linked reform and regularisation of the land tax regime.

3.1.4 Land Degradation

Land degradation is one of the most serious and widespread problems for the agricultural sector in Madagascar. The degradation dynamics in the uplands and lowlands are often linked, reinforcing each other. With the stagnation of yields in the irrigated lowland areas and demographic growth, farmers extend their agricultural activities to the hillsides. Upper watershed land use is often based on extensive and unsustainable management practices, the most important being lack of erosion control and lack of improved soil fertility management on agricultural plots, slash-and-burn agriculture (or *Tavy*), and the frequent burning of pastures. Land degradation is also caused by deforestation for agricultural purposes, with the consequence of increased carbon emissions, biodiversity loss and diminishing ecological services. These practices not only contribute to the degradation and low productivity of uplands but also significantly impact on lowland agriculture. Upland soil erosion and water surface run-off causes sedimentation of downstream infrastructure, contributing to the reduction of cultivated area under irrigation, local flooding of rice paddies in the rainy season and water shortages in the dry season (World Bank, Project Information Document, Watershed Management Project, 2006).

The principle threats to Madagascar's biodiversity come from the small-scale but widespread clearance of habitats, primarily for firewood and charcoal production. Other threats include subsistence agriculture, overfishing and the effects of climate change on marine ecosystems (WWF).

Implications for the Household Ethanol Programme of Land Degradation

The clearance of forests should be avoided during the development of the supply chain for the ethanol household fuel program. This includes clearance for sugarcane growing as well as woodfuel potentially used in the distillation processes. Ecologically sensitive areas should be avoided, and the use of fuel wood should be carried out using sustainable methods.

3.2 Agriculture

The 2008 agricultural sector performance figures were disappointing, despite the liberalisation of the economy, the sharp devaluation of the exchange rate and the privatisation of state enterprises. The under-performance of the agricultural sector is a major cause of the deep poverty in rural areas. Weak infrastructure hampers the transportation of produce, whether for export or for the domestic market. Agricultural productivity is also hampered by lack of access to agricultural technology, inputs and other agricultural services. Agricultural extension services are all but non-existent. Only 1.5% of Madagascar’s small farmers have access to credit, and a mere 5% of total lending goes to agriculture. Traditional land tenure systems do not give farmers sufficient security as discussed in previous sections (World Bank, 2006).

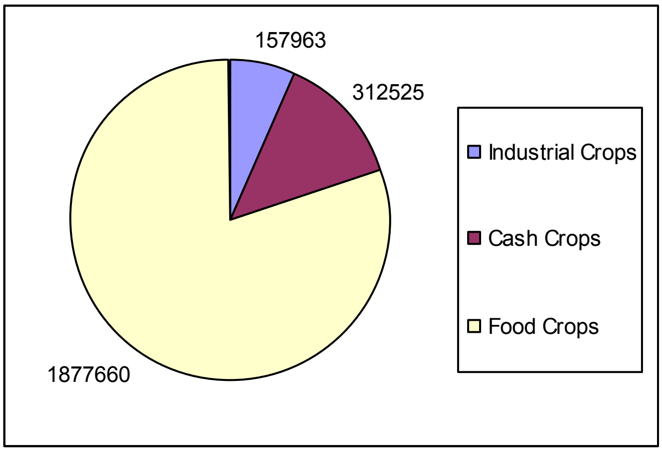
Agriculture in Madagascar is typically practiced on very small holdings, the median and average cultivated areas being 1.0 hectare and 1.71 hectares respectively (World Bank, 2003). Food crops, including rice, tuber crops and maize, account for approximately 75% of agricultural production in Madagascar. Farming systems are still very traditional with two-thirds of rural households farming on small plots and living on a subsistence level. Rice is the main crop, accounting for 70% of total farm output. The productivity of food crops is very low due to numerous constraints along the supply chain, from production and processing to marketing (World Bank, 2003). A rising population and growing food insecurity has led to a focus on staple food production.

In 1993 agriculture provided nearly 80% of exports, constituted 33% of GDP, and employed almost 80% of the labour force. Export crops, including vanilla, cloves and coffee, cover approximately 17% of cultivated area, mostly in the east of the country and constitute the second most important category of agricultural production (World Bank, 2003). Revenues from this sector, although significant, are in decline primarily due to problems of security, liquidity and price-quality differentiation (World Bank, 2003), as shown in Figure 3.3.

Industrial crops, including cotton, sugar, sisal and groundnuts cover approximately 8% of total cultivated land (World Bank, 2001). The industrial crop sector is also in decline, due, in particular, to a lack of diversification and efficiency in the sugar and cotton industries. Livestock is widespread, with about 60% of rural families depending on it for their income, and fishing and aquaculture are becoming increasingly important sub-sectors of the Malagasy economy (World Bank, Rural Development Support Project, 2008).

Coffee production averaged 1.1 million bags during the 1980s but fell sharply in the '90s with a low of between 300,000 and 400,000 bags in the year 2000. Production and exports fluctuate sharply owing to occasional cyclone damage, and the impact of individual severe cyclones is clearly visible in longer term export statistics. The last restrictions on coffee exports were removed in 1997 and the trade in coffee is now entirely liberalized. Coffee in Madagascar is almost entirely produced by smallholders, with 350,000 producers accounting for 90% of the total coffee cultivated area. They are widely dispersed, often in areas that are not easily accessible. The average small farm occupies between 1-1.5 hectares and coffee is typically grown on just 10–15% of the holding. A number of growers exploit coffee trees that have literally become a wild forest crop, harvesting whatever fruit is available once a year (http://www.eafca.org/madagascar.htm).

Figure 3.3: Areas under agriculture in 2000 (ha)



Regional Breakdown of Agricultural Production

Rice is grown in practically every part of the country, with the exception of the South and South West where the predominant crops are maize and tubers. In 1998, the Highlands, including the Lac Alaotra region (a major surplus area and the rice basket of Madagascar), as well as several zones of intense rice production such as Antananarivo, Fianarantsoa and Vakinankaratra, accounted for 39% of total rice production (Minten and Randrianarisoa, 2001). The East Coast is characterized by a high relative importance of cassava, representing 41% of national production, as well as up to 95% of national production of coffee, vanilla and cloves (Minten and Randrianarisoa, 2001). Besides scattered sugar-cane production by small farmers in the Highlands, most sugar-cane production is concentrated near the sugar-processing industries; SIRAMA in the North, North West, and East (in Brickaville), and SIRANALA in the Center West. Cotton production is mostly located in the Western part of the country (Minten and Randrianarisoa, 2001).

Implications for the Household Ethanol Programme of agricultural production

In order for economic and efficient yields to be achieved in sugarcane production it will be necessary to provide extension support to the agricultural sector to improve practices and address issues of security, liquidity and price-quality differentiation. This is likely to be the case for whichever scale of production is promoted, or combined. However, the predominance of small-holder farmers offers the potential for effective out-grower schemes if the terms are agreed and producer co-operatives/associations are engaged or developed.

3.2.1 Sub-Sector Analysis: Rice Farming

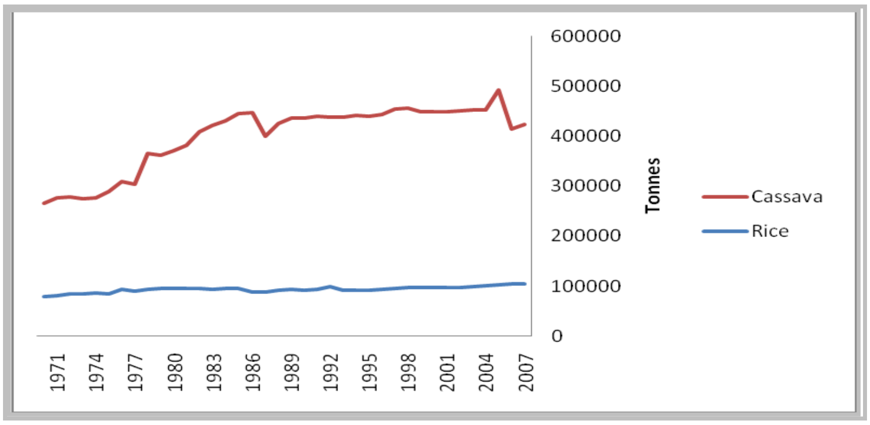
Importance of Rice

Rice cultivation is the single most important economic activity in Madagascar with direct value-adding, and in 1999 contributed to 12% of GDP (World Bank, Sector Review, 2001). However, average paddy yield per hectare in Madagascar has been stagnating for the last forty years, with yields of less than 2000 kilogram per hectare. Since 1980, domestic rice production has not kept pace with demand. Madagascar, a country that used to export rice, has come to rely on imports to compensate for the deficit. Rice consumption per capita has steadily declined, while consumption of cheaper alternatives such as cassava has increased (World Bank, Sector Review, 2001). Yields of rice are highest under irrigated conditions and, as discussed previously, very poor where the *Tavy* method is used. Although the conditions for high yield rice production are inherently favourable in Madagascar, the potential has largely been unmet (Figure 3.4). Green Revolution technologies for agricultural productivity did not reach Madagascar, and improved practices such as the System for Rice Intensification (SRI) have generally not been adopted. Rice yields have stagnated or decreased compared with other countries where fertilizers, soil health improvements, and/or improved seeds were adopted (World Bank, 2003). Access to credit is extremely low in rural areas and small farmers generally do not have the capital required to invest in farm inputs needed to increase yields.

Moreover, without access to equipment, hired labour and animal draught power, it is difficult for small rice farmers to improve their yields; although results from a World

Bank study showed that diversification of agricultural production systems can have a positive impact on rice yields (World Bank sector Review, 2001).

Figure 3.4: Cassava and Rice Production[68]



Smallholder sugar-cane cultivation could provide such diversification and thus improve the rice yields while supplementing farmers' incomes. However the potential for such initiatives to succeed and bring long term benefits will depend on farmers having access to credit and agricultural inputs.

Below, in Table 3.1, is a brief analysis, provided by the Ministry of Agriculture, of the rice farming sector in Madagascar. The main factors contributing to the decline in productivity are categorized as physical, technical, economic and institutional. Many of the barriers which exist for enhancing small-scale rice productivity could be assumed to exist for small-scale sugar-cane production.

Table 3.1: Analysis of the Rice Farming Sector in Madagascar

1. Physical Barriers	- Weather, including cyclones and changes in intensity of rainfall - Isolation of production zones - Deterioration of the natural environment and declining soil fertility - Underdeveloped irrigation system
2. Technical Barriers	- Lack of equipment - Low application of improved agricultural techniques
3. Economic Constraints	- High cost of labour - Scarcity and high cost of credit, limited range of financial instruments - Scarcity of land tenure, complexity of land acquisition procedures - Deficiency in rural markets, fragmentation of rice market - Fear of financial risk - Strong competition in the international market

68 FAO data

4. Institutional Barriers	- Concentration of resources on irrigation and extension - Slow approach to decentralisation - Tax policies: exemption from customs duties and import taxes on agricultural machinery and equipment, technical, economic and institutional constraints

The proposed solution for Madagascar is to double or triple production by 2009-2012, or to reduce population growth to a rate in line with current production levels (GoM website).

Implications for the Household Ethanol Programme of Rice Production

The crisis in agricultural productivity is already recognised across many sectors in Madagascar and the Ethanol as a Household Fuel Program should take linked initiatives, particularly around important sectors like rice. In this way it is possible that linkages may be made and the potential for sugarcane production for ethanol acting as a support to on and off-farm income diversification may be realised.

3.2.2 Foreign Investment in Agriculture

The Government of Madagascar has previously stated that, in order to enhance productivity and development in the rural sector, agriculture and food policy relating to small-scale farming, must be complemented with the opening up of the sector to investors, both domestic and foreign (Interim Poverty Reduction Strategy Paper). This approach has led to a recent call by the Government for investment in rural development resulting in a number of bids for agricultural developments in various sectors including jatropha and rice.[69] In November, 2008, Daewoo Logistics of South Korea was reported to have secured a large tract of farmland in Madagascar to grow food crops (corn and palm oil) to send back to Seoul, in a deal that diplomats and consultants said was the largest of its kind. The company leased 1.3m hectares of farmland from Madagascar (constituting an estimated 50% of the total arable land) for 99 years (Financial Times, 2008). The Government of Madagascar insisted that the deal with Daewoo was in line with its broader policy direction regarding rural development; however the agreement was suspended following political unrest which culminated in the ousting of President Ravalomanana by the opposition leader, Rajoelina, in March 2009. Foreign investment has been encouraged in the sugar industry, with the government recently leasing two of the Sirama sugar production sites, Ambilobe and Namakia, to a Chinese company that is already leasing the Siranala and Morodava sites (La Vérité, October, 2008). However, the agreement with Daewoo demonstrates the previous government's eagerness to attract large scale foreign investment in the agricultural sector, and could indicate that similar investment would be sought in the future for the scale up of the sugar industry. It remains to be seen whether the new government will be take the same approach to foreign investment in the agricultural sector.

Implications for the Household Ethanol Programme of Foreign Investment in Agriculture

[69] Madagascar Ministry of Agriculture, http://www.maep.gov

The guidance of the project steering committee will be required in order to establish the extent to which foreign investment in sugarcane production is sought, but if the Chinese deal reaches fruition then foreign players may become dominant factors in the sector. Such a scenario would present a significant challenge to the Ethanol Household Fuel programme in that foreign investors are unlikely to target the domestic household ethanol market or support local small-holder farmers since foreign markets will almost certainly appear more lucrative, and development benefits accrued in Madagascar may not be factored into their activities. The Government of Madagascar may consider building local supply proportions and out-grower commitments into lease conditions or ensure that other local players are also encouraged into the sector to mitigate this.

3.2.3 Food Security and Food Prices

Currently 67% of all Malagasy people (59% of all households), live in a condition of food insecurity. The highest rates of food insecurity occur in the eastern provinces, highlighting a direct relationship between poverty and food insecurity. Following decreasing real per capita incomes, the calorie intake per person per day has gone down over the last 25 years, falling from 2,490 calories in 1975, to 2,021 calories in 1995, and to just 2,001 calories in 1998 (Bergeron, 2002). Food intake in Madagascar is not diversified, but consists of essentially two staples: rice (303g/person/day) and cassava (209g/person/day) (World Bank sector Review, 2003). Cassava-growing is of particular importance as it provides households with a nutritional buffer during lean crop periods.

The Government of Madagascar recognizes that small holder agricultural productivity must be improved if these high rates of food insecurity are to be addressed. It is believed that increased food crop productivity would (World Bank sector Review, 2003):

- Improve food security
- Free up land and labour for diversification
- Reduce pressure on Madagascar’s precious ecological assets

Implications for the Household Ethanol Programme of Food Security and Food Prices

The causes of food insecurity are multiple and interlinked and a household ethanol fuel program cannot seek to solve these. However such a programme can ensure it doesn’t exacerbate any existing food insecurity issues by ensuring that land currently used for food production is not turned over to fuel crops. It can also play an important role in enhancing food security by providing additional incomes for farmers in rural areas as an additional cash crop. Ensuring that these outcomes are achieved rather than the possible harmful impacts of exploitative ethanol production exacerbating hunger and income disparity must be a main focus of the design of the household ethanol fuel programme.

3.2.4 Policies and Regulations

The Ministry of Agriculture, Livestock and Fisheries (MAEP) is responsible for drafting, implementing and coordinating the Malagasy State's policy on agriculture, livestock and fishing, as well as on State-owned and private land, which was redefined in the 2003 poverty reduction strategy (Chapter II). The National Rural Development Programme (Programme national pour le développement rural or PNDR), adopted in 2005, focuses on raising income in rural areas, in principle taking into account environmental aspects. According to the 'Madagascar Action Plan' (MAP) concerning the country's economic and social development strategy for the period 2007-2011, rural development will consist of a 'sustainable green revolution' and agri-business centres will be set up to assist in training and in meeting needs such as irrigation, seeds, fertilizer and storage facilities. The expansion in production needed to accomplish this green revolution will be achieved through more intensive cultivation, expansion of the area under crops, as well as the supply of seeds and fertilizer and assistance in using them. The authorities hope that this green revolution will lead to greater food security and to surpluses that can be exported to sub-regional markets (WTO, 2008).

At present, the principal tax-related support measures for farmers, livestock breeders and fishermen are: exemption from company profits tax (IBS); the minimum tax on new companies engaged in agriculture for the first two financial years with a 50% reduction for the third financial year; the summary tax (applicable to individuals or companies whose turnover or annual gross income does not exceed MGA 6 million) at a reduced rate of 6%; as well as various other tax benefits under the free zone regime for export-oriented companies (Chapter IV, WTO, 2008). Since 2002, the import of agricultural inputs such as seed, fertilizer and herbicide has been subject to a zero tariff, although VAT must be paid (WTO, 2008).

The main objectives of the agricultural sector are the expansion of rice production to achieve self-sufficiency, increased quality while limiting the increase in export products, diversification into other crops, most particularly oilseeds, and developing the capacity of national agricultural research in plant breeding and pest control. These policy options have resulted in the launching of several programs supported by donors, mainly the World Bank. Among the current programs are: the National Agricultural Extension (PNVA), and the Agricultural Research and the Rural Finance Program. Others currently being negotiated include the Program for Promotion of Agricultural Exports and the Environment Program (the latter benefitting from funding provided by large consortium of donors, including the International Fund for Agricultural Development (IFAD)).[70]

Implications for the Household Ethanol Programme of Policy and Regulations

Production of sugarcane for ethanol, particularly with reference to household fuel, should be firmly incorporated into the national planning on agriculture in order to avoid possible overlap or conflict between these inherently interlinked policy areas.

3.3 Household Energy

In total, 5.9 million m^3 of fuelwood is produced annually for household cooking and 2 million m^3 for charcoal production (IRG Jariala Report, 2005). The UN Data Centre gives the non-commercial wood harvest total as 11 million m^3 in 2005 and 13.1 million m^3 in 2007 (these are FAO statistics on non-commercial wood production[71]). It places charcoal production in 2005 at 910,395 tonnes and in 2007 at 989,100 million tonnes (UNdata at http://data.un.org).

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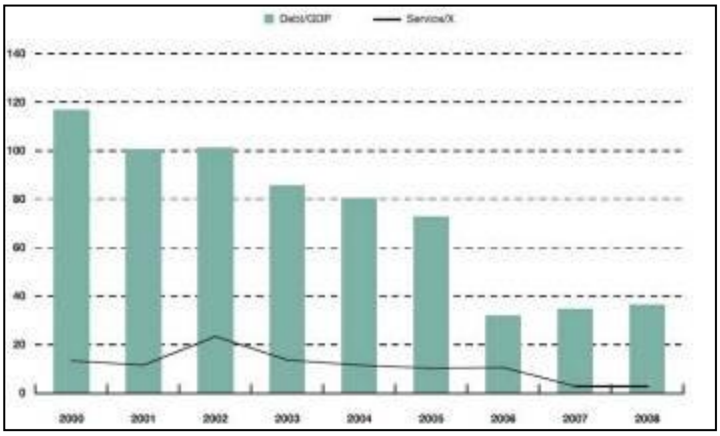
[70] 70 Madagascar Ministry of Agriculture, http://www.maep.gov

[71] At: http://data.un.org/Data.aspx?q=Madagascar+wood&d=FAO&f=itemCode%3a1628%3bcountryCode%3a129

Figure 3.5: Madagascar External Debt (% GDP) and Debt Service (% of exports of goods and services)



Although Madagascar has both onshore and offshore oil and gas deposits, none are yet commercial. Thus while Madagascar may eventually become an oil and gas producing economy, it is not yet so and it could be many years before oil and gas are produced commercially, much less processed or refined. As elsewhere, most sectors of the economy are dependent on petroleum fuels, therefore, the current high price of oil is a great handicap for Madagascar's economic growth[72]. As an importer of oil, the energy sector in Madagascar remains very vulnerable to oil price fluctuations; the price has almost tripled since 2001 and there have been several shocks during the decade, notably 2007–2008, which negatively affected all non-oil producing Sub-Saharan African countries. Countries which had received debt relief began to find their debt mounting again, shown in Madagascar in Figure 3.5 (African Economic Outlook, AfDB/OECD 2007).

According to the IMF African Department (IMF-AD 2008), the effect of the oil cost increase caused by the oil price shock of 2007-2008 (caused by the increase in the cost of oil and its refined products), equated to 3.1% of Madagascar's GDP. Madagascar's overall account balance for 2008 was *minus* $2.26 billion or 24.4% of GDP. The impact of the oil price increase on Madagascar was less than for other countries (such as Ethiopia and Malawi) because there are no explicit subsidies on fuel products in Madagascar, and its budget was exposed only via direct operational costs and additional transfers to the state-owned electricity company. This accounted for only about 0.1% of GDP in 2007 (IMF-AD 2008), but about 0.5% of GDP in 2008 (IMF Country Report 09/11, January 2009).

Such price increases have a direct impact on Madagascar's economy, and the Government tried to limit distributors' and taxi drivers' transfer of energy through costs to consumers. In 2008 it proposed budgetary items worth 0.4% of GDP to offset rising prices, such as a temporary suspension of VAT on lighting and cooking fuel and fuel subsidies for certain categories of urban transport. The IMF-AD discouraged this intervention and encouraged the government to permit the full pass-through of international oil prices to domestic prices (IMF-AD 2008).

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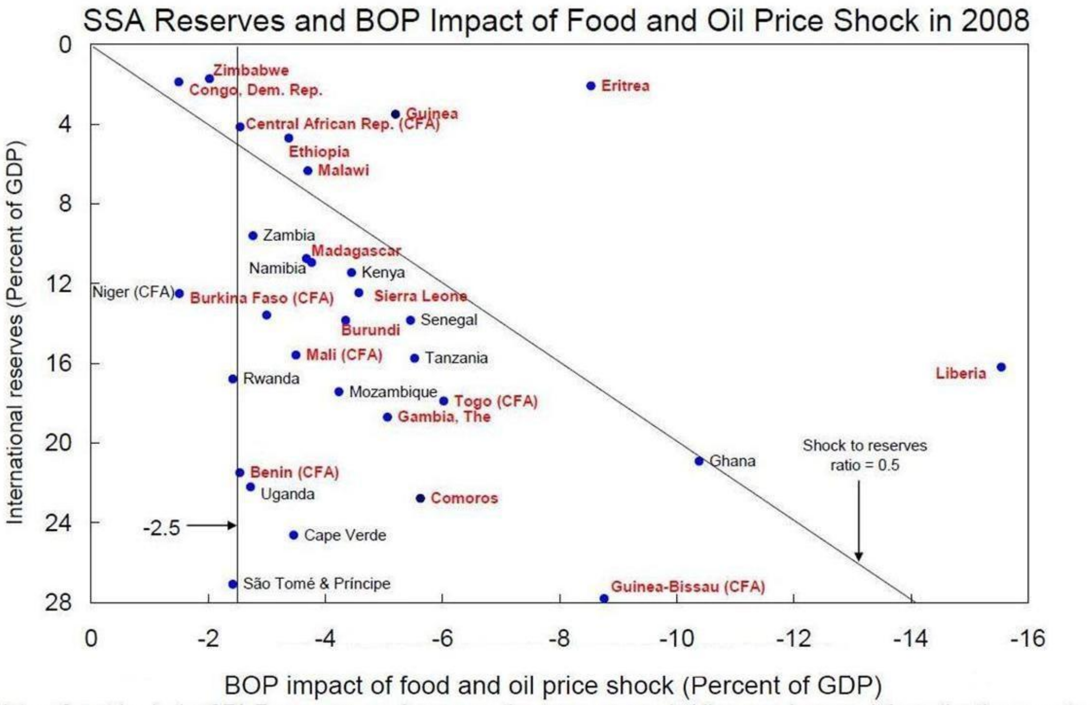
[72] www.mbendi.com/indy/oilg/af/md/p0005.htm; http://www.madagascaroil.com/index.php

In contrast, the IMF recommended lower electricity price increases for first-time units of consumption (new users) to alleviate the impact on the poor, as well as endorsing temporary VAT reductions on lighting fuel.

Figure 3.6: SSA Reserves and BOP Impact of Food and Oil Price Shock of 2008



Notes: Countries in the CFA Franc zone pool reserves, the group reserve holdings can be more informative than country reserve ratios.

Figure 3.6 highlights the IMF's "Countries of Concern" in regard to the oil price increases, highlighted in red. Madagascar qualified both because the oil price shock was greater than 2.5% of GDP and also because it was very close to the 50% of international reserves mark for Madagascar. The countries at or above the line, and towards the top left are the most vulnerable to such oil price changes (IMF African Department, The Balance of Payments Impact of the Food and Fuel Price Shocks on Low-Income African Countries: A Country-by-Country Assessment, June 30, 2008).

3.4 Sugar Cane Production

3.4.1 Overview

Industrial Scale Sugar Cane

In the past, the sugar industry was among the most important food processing industries in Madagascar, in 1986 accounting for 60% of the value of total food processing output. Developing its agro-industry was one of the goals pursued by the government after independence, and, since the time of independence, the sugar industry has been protected. Nominal Rate of Assistance (NRA) trends started to reverse after 1984, when imports sharply increased due to reduced domestic production. Sugar-cane farmers continue to be implicitly taxed as their production prices are very low relative to world price. Cane out-growers not only face price disincentives but also long delays in receiving payment for crops delivered to the state processing factory.[73] SIRAMA and SNCBE, the two original state-owned sugar companies, were rehabilitated in 1985 and 1987 when the companies were merged. Prices for the domestic retail market were then fixed by the Ministry of Trade until liberalisation in 1989 when wholesalers and retailers were free to fix their own margins.

Currently the local production of sugar is at a low - 20,000 MT in 2007, down from 70,000 MT in 2000 and a high of over 100,000 MT in 1996. The SIRAMA sugar factory is operating at a fraction of its processing capacity. This low capacity, combined with relatively low sugar-cane yields and the high cost of fuel and other inputs, results in sugar production costs being substantially higher than those of other Southern African countries as well as Mauritius (Integrated Framework, 2003; UNData). Imported sugar, which has exceeded 100,000 MT in recent years, is 50-60% less expensive than SIRAMA's sugar, even taking account of high tariffs and other taxes applied to imported sugar (Integrated Framework, 2003; UNData on raw and refined sugar; UNICA Data)[74]. This low capacity combined with relatively low sugar-cane yields and comparatively high costs for fuel and other inputs results in sugar production costs being substantially higher than those of several other Southern African countries (Integrated Framework, 2003). Imported sugar, which has exceeded 30,000MT in recent years, is 50-60% less expensive than SIRAMA's sugar, even taking account of high tariffs and other taxes applied to imported sugar (Integrated Framework, 2003).[75]

Although Madagascar has been a net importer of sugar since 1991, it has had export quotas since 2001 of 7,258MT to the USA and 10,760M to the EC[76]. With various technical difficulties facing the state sugar company, production has recently been poor, with Madagascar barely filling its quota to the EU, and stopping its export to the US.[77] The favoured export price under the preferential access given by Europe to ACP countries has been decreasing and was due to expire in 2009.

By 2001 privatisation of the state monopoly was supposed to have occurred as part of a market led approach, but to date this is still being debated. Instead, technical assistance relating to control of management was contracted to private firms up to the end of 2006. Where privatization has moved forward, the process has been slowed by recent political uncertainties.

Estimates of Consumer Tax Equivalent (CTE) for processed sugar showed an average reduction of 35% during the period 1988 to 2005 suggesting that government policy actually created an implicit subsidy to consumers (Figure 3.7). Local communities have grown dependent on a policy-dependent sugar industry,

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73 Payment to growers is basically done in three parts. The first at delivery at a firm's gates (where the price is fixed by a joint commission represented by the company), the Centre Malgache de la Cane et du Sucre (CMCS) (an entity responsible for the supervision and regulation of the sugar industry value chain), and the growers. The Queensland formula is used to calculate the pre-campaign price, and for the second and third part of the payment, the price is 75% revised post-campaign. [Source: CMCS]

74 http://data.un.org/Data.aspx?q=sugar+imported&d=ComTrade&f=_l1Code%3a18; http://english.unica.com.br/dadosCotacao/estatistica/

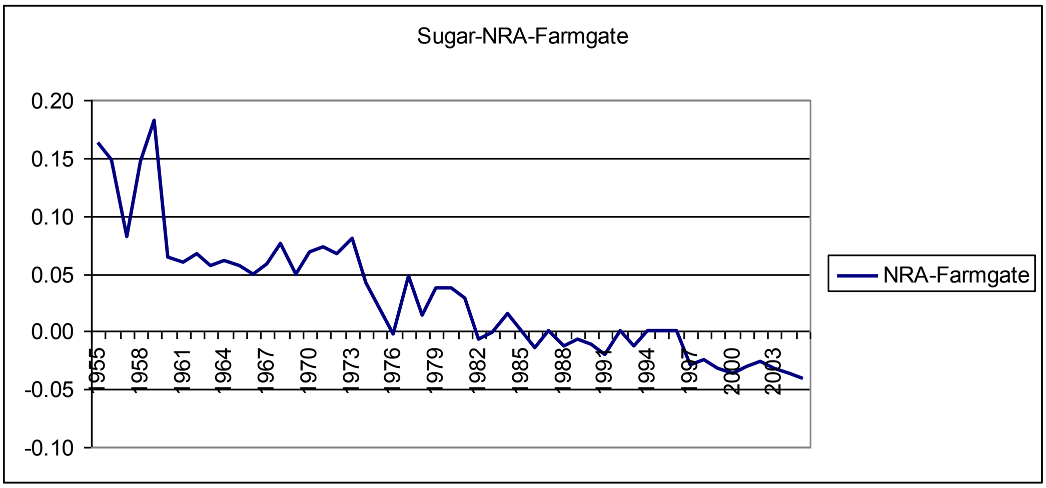
75 http://www.integratedframework.org/files/english/Madagascar_dtis_aug03_en.pdf.

76 UN Data shows that in 2008 6,340 MT of raw sugar were exported and 4,070 MT of refined sugar, just enough to fulfill its EU quota.

77 According to the Sugar Protocol of the Lome Convention, Madagascar has a quota of 10,760 tonnes per year of sugar with the EU, a quota of 7,258 tonnes per year of brown sugar to the United States, another quota of 2,500 tonnes under the Special Preferential Sugar (SPS), and a quota of 4,200 tonnes in the Everything But Arms framework (EBA) (La Vérité, October, 2008). Under all agreements, exporters receive guaranteed minimum prices from the EU, which are highly beneficial to the exporting countries.

which makes the political cost of reform high (Akyiama et al, 2003). Domestic distribution of sugar is inefficient, with only five firms licensed to wholesale sugar in the domestic market (Fenohasina Maretniel, 2006, Agricultural Distortions Research Project Working Paper).

Figure 3.7: NRAs[78] and Consumer Tax Equivalent for Sugar-Cane and Refined Sugar



Potential Capacity of Existing Production Sites

The sites at Ambilobe and Namakia are Sirama's two most important, with sugar production capacities of 70,000 tonnes and 23,000 MT, respectively. If Sirama's four sites are considered together, they have an annual production capacity of 119,000 tonnes of sugar, 10 million litres of pure alcohol (from molasses) and 400 tonnes of yeast. These production figures have been falling steadily since 1998, reaching 20,000 MT of sugar, representing less than 20% of their full capacity (La Vérité, October, 2008). At the same time, domestic consumption of sugar has declined significantly in recent years, due to the low purchasing power of households, estimated to be 7.13 kg / capita / year in 2006. This represents only 10% of local sugar production for the artisanal (small-scale) production of raw sugar 'Siramamy Gasy' (La Vérité, October, 2008). Currently the industrial demand for sugar is 10,000 MT per year and is only being partially satisfied domestically, imported sugar is coming from Brazil and other countries.

According to one source, the Malagasy sugar industry needs 160 million Euros to revive itself. The sugar sector in Madagascar is facing a difficult situation characterized by a deterioration of agricultural infrastructure, roadways failing and serious delays in the maintenance of Sirama's various facilities. The sector employs 4,800 seasonal employees, and 15,000 direct employees. As mentioned previously, the government has leased two of the Sirama production sites, Ambilobe and Namakia, to a Chinese company that already holds the contract lease of Siranala at

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78 During the 1980s Mozambique shifted from being a net exporter to a net importer, but during the 1990s when protection was granted to the domestic market, production increased but oriented towards the national market as import substitution (relatively profitable), and exports were limited to the more profitable preferential markets. Protection is high, as sugar has a large positive Net Rate of Assistance (NRA) based on a very high import surcharge. http://www.tralac.org/unique/tralac/pdf/WP11%20Sandrey%20Future%20prospects%20Afr%20sugar%20FINAL%2018122007.pdf

Morodava, with a total Chinese investment of $54 million. The future of the Maromamy site at Brickaville and the Djamandzar site at Nosy Be remain uncertain.

Small-scale Sugar-cane

Small-scale sugar-cane production takes place in almost every region of Madagascar, but is particularly common in the Ambositra region. In most cases, small-scale production is used to make *toaka gasy,* a locally made rum (see section 4 for more information on its production process). Sugar-cane is rarely sold at market because the producers earn a higher price for *toaka gasy* which is easier to transport.

Policies and Regulations

The sugar industry accounted for 60% of the total food processing output value in 1986, but farmers continue to be implicitly taxed as their production prices are very low relative to the world price. Since 1991, Madagascar has become a net importer even if exports rebounded in 1999. Despite the fact that sugar imports are subject to import tax (35%) and VAT (20%), inefficiencies associated with low capacity utilization, low yields, and high input costs lead to high production costs for domestic sugar and therefore make imported sugar cheaper. As mentioned before, local communities have grown dependent on a policy-dependent sugar industry, which makes the political cost of reform high (IFPRI, 2007, Future Prospects).

Implications for the Household Ethanol Programme of Sugar-cane Production

The household ethanol programme has the potential to create a very substantial new domestic market for one of the co-products of sugar cane, but if domestic production of sugar cane is to increase to meet this opportunity then efficiency and productivity improvements will be needed at all scales of the sugar cane industry. This might take the form of eliminating Government import duty on better equipment, public-private partnership with foreign micro-distillation vendors and Malagasy entrepreneurs, and investment in large scale production facilities.

In an interview conducted with the former General Manager of SIRAMA, M. Henri Tsimisanda, he stated of domestic sugar cane production: “One should not panic about the yields. They have been very bad because of extremely poor management dating to 1990. Cane has been untidily cared for because of misappropriation of funds and because of lack of investment and maintenance. . . . In well irrigated fields, we have achieved 90 to 100 TC/Ha on a crop with peaks of 120 TC/Ha for seed cane. This can be achieved on ground level but former Sirama cane fields have to be refurbished.” [79]

[79] Interview by email with Henri Michel Tsimisanda, former General Manager of Sirama Sugar Factory, conducted 13 Jan 2010.

3.5 Ethanol

3.5.1 Overview – Existing Capacity

The government of Madagascar is in the process of finalising plans for the implementation of an ambitious national bio-ethanol program. The programme will initiate the development of industrial scale ethanol production facilities linked to the existing sugar factories as well as the development of small scale production (micro-distilleries). Artisanal ethanol production is carried out at the village level in many parts of Madagascar, with the ethanol produced serving the local alcohol (rum) beverage market, which may or may not be useful experience for the development of a fuel ethanol industry. The alcoholic beverage industry is illegal and therefore what is taking place is essentially unregulated and trade of the locally produced rum, known as *Toaka Gasy,* occurs outside of the formal economy. *Toaka Gasy* producers face hefty federal fines if caught transporting or retailing their product, which is very inconsistent in quality.

It has been suggested that the government's strategy regarding this artisanal production should be to legalize it and encourage its transition from beverage to fuel-grade ethanol production (CNRIT, 2005). Currently the automotive fuel sector in Madagascar is extremely small, while the market for ethanol as a household fuel could be quite large.[80] Whatever ethanol production strategy is developed in Madagascar, the most important recommendation is that the household ethanol market is fully incorporated into any expansion plans, at any scale, if the benefits of this expansion are to be distributed amongst the Malagasy population. The impacts on health and the environment of increased Malagasy production of ethanol as a household fuel are analysed in Component A, and in later Chapters of this report, and should be factored into public ethanol policy and commercial plans. Currently artisanal scale ethanol production is not an effective or efficient way of producing high quality ethanol and as such it would make more sense for policy to support micro-distillation production rather than artisanal scale.

3.5.2 International regulations and drivers

Ethanol is an internationally traded commodity, and the growing global market opportunities for ethanol are governed by factors such as countries' targets for renewables, market liberalization, technology development for enhancement of ethanol production, international prices of petroleum fuels and prices of feedstock for ethanol production.

Requirements of countries to meet their emissions quotas and national biofuels targets are major driving forces that open enormous opportunities for ethanol production. Recent revision of the national biofuels strategy in the U.S., targets 17 billion gallons by 2017, equivalent to the replacement of 20% of transport fuels within the next ten years. Economic and environmental concerns in Brazil, Europe, India and China are forcing governments to set new targets and incentives which aim to increase production and consumption of renewable fuels and reduce the use of

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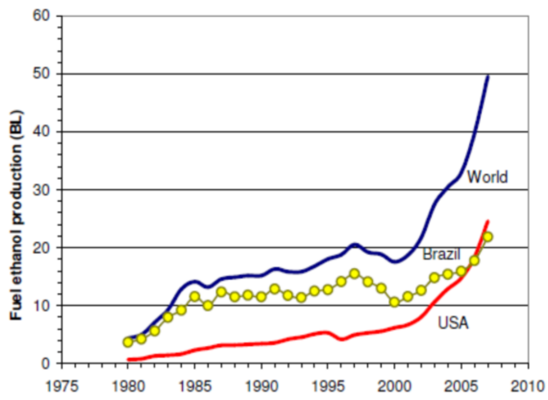
[80] Madagascar ranks 129 out of 133 countries ranked for number of automobiles owned. NationMaster (http://www.nationmaster.com/) shows Madagascar at one vehicle per 100 persons, comparable with Ethiopia, Mali and Nigeria, and just above Malawi and Afghanistan. See Section 3.8.

petroleum[81], with each of these countries aiming to replace between 5 to 20% of their gasoline consumption with ethanol. Market liberalization through national import-export policies will further stimulate the global market for ethanol. Growing ethanol demand coupled with market liberalization will drive investments in research in technology development for enhanced production of ethanol.

With rising petroleum prices, the demand for ethanol as a gasoline extender has developed at an enormous rate. The wider market for ethanol in the transport sector has pegged the price of ethanol with that of gasoline and this will further encourage production worldwide. Although the potential for ethanol as household fuel is huge, its role in the global arena is highly dependent on a number of other factors, such as the overall supply and demand of ethanol and its competitive uses.

Figure 3.8: World fuel ethanol production (1980-2007)



(Brazilian Biofuel – A sustainability Analysis, DEFRA 2008)

3.5.3 Global Ethanol Production

Historically, Brazil has been the world's leading producer and consumer of ethanol. Since 1980 Brazil's ethanol production has grown by five-fold from less than 4 billion litres to about 24 billion litres with 80% of it being consumed locally as fuel (Fig. 3.8).

An unprecedented ethanol production growth rate has been seen in the U.S. since 2002, and by 2007 U.S. production had surpassed that of Brazil. Besides the U.S. and Brazil, China, Canada, France, Germany, Spain, Russia, Ukraine, South Africa, India, Pakistan, Thailand, Indonesia, the U.K., Colombia, Argentina and Australia are major producers but together contributed less than 10% of the world total in 2007, given the dominance of Brazil and the U.S.

Although the contribution by producers other than U.S. and Brazil is relatively small at the moment, it is expected that in the very near future the installed capacity in these nations will surpass 8 billion litres.[82]

3.5.4 Ethanol Fuel Trade Flows and Prices

Brazil is the major producer, consumer and exporter of ethanol in the world. Ethanol export from Brazil has continuously grown reaching over 5,118 million litres by 2008[83]. In the same year, the price of ethanol reached US$ 450 per cubic meter

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[81] Ethanol 2020: Global market survey, trend analysis, and forecasts, Emerging Market Online, 2008.
[82] FO Licht, World Ethanol and Biofuels Report, Vol. 7, No. 4, 23 Oct 2008.
[83] Brazilian Secretariat of Foreign Trade, elaborated by UNICA (Brazilian Sugarcane Industry Association. Accessed on the web at: http://english.unica.com.br/dadosCotacao/estatistica/

(US$0.45/litre), which is slightly lower than the current price of ethanol in Madagascar (US$0.48/litre).

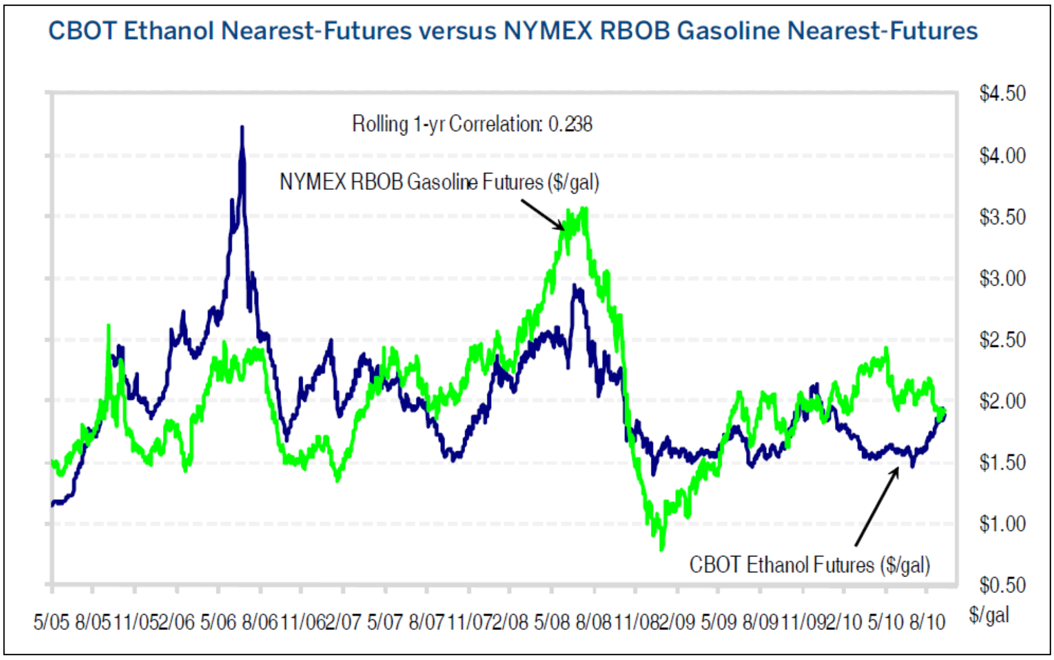
Without major investment, technology transfer and training, countries like Madagascar will not be able to compete in price with major producers and exporters of ethanol in the world market. In particular small producers need to carefully consider their strategic market advantage, namely which demands they should serve first i.e. local consumers of ethanol for household cooking.

The need for foreign earnings may compel poorer countries to export their ethanol even at prices lower than the international market.[84] Technology limitations and handling issues associated with gasoline blending, joined with the high capital costs necessary to provide or upgrade the infrastructure for fuel blending, may limit the advantages that can be obtained from substitution of transport fuels by ethanol.

The value of ethanol in the household sector as a substitution for imported fuels may be overlooked if the fuels that are intended to be replaced are firewood and charcoal, rather than kerosene or LPG. The health, social and environmental advantages that can be obtained from the use of ethanol in place of solid fuels may not be valued. In Ethiopia, where kerosene is widely used in the cities for cooking, the value of import substitution has been recognized and valued by the government. However, in Madagascar, where kerosene is not widely used, the opportunity for import substitution may not be significant. If ethanol is to replace petroleum fuels, either in the transport or household sectors, its price will certainly be influenced by the price of the fuels being displaced.

[84] In the years 2003-2006, Ethiopia exported ethanol from its first industrial distillery at several cents per litre below market price. This was due to several factors, among them the small amount of ethanol available for sale, and the cost of the buyer to deliver it to port (Ethiopian Petroleum Enterprise Agency).

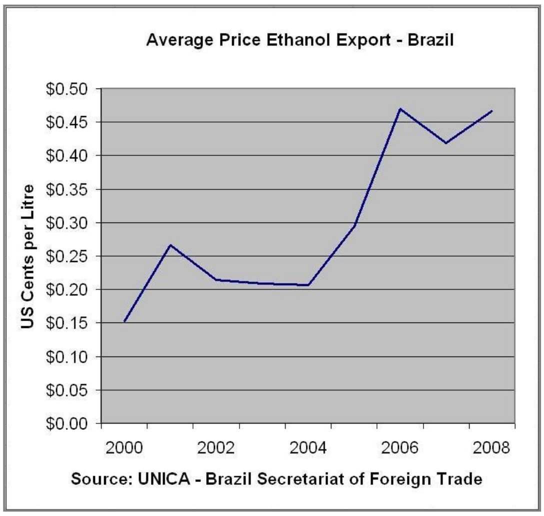
Figure 3.9: Ethanol commodity price relationship with gasoline

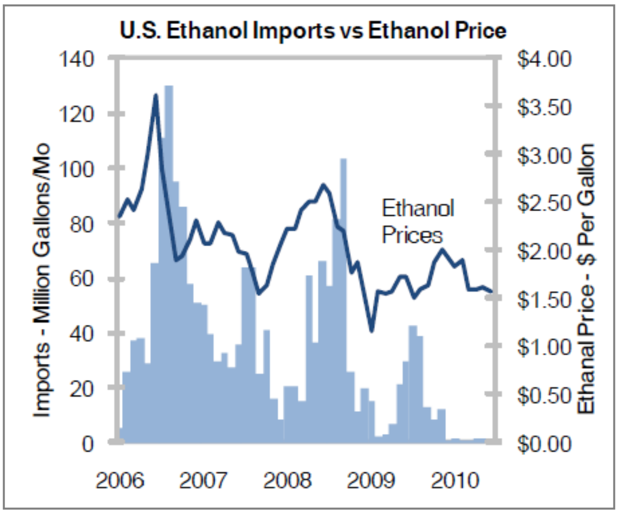


CME Group Ethanol Outlook Report, 6 Sept. 2010[85]

The price of ethanol when it is traded internationally generally follows the pattern of the price of petroleum; thus, the wholesale price for ethanol in the U.S. was the highest when the petroleum price peaked in mid 2008 (Figure 3.9). The price of ethanol reached a high, US$3 per gallon, when the oil price was above US$140 per barrel. In early 2009, the ethanol price dropped following the price drop of petroleum fuel.

Figure 3.10: Price of Ethanol exports in Brazil and Ethanol imports and price in USA





UNICA **CME Group**

[85] CME Group accessed on the web at: http://www.cmegroup.com/newsletter/web2lead/web2sf-old.html

However, the price of ethanol is also governed by the price of production, the seasonal and the global supply picture. Figure 3.10 (left) shows the increase in the average price of ethanol exported from Brazil and Figure 3.10 (right) shows the price paid in the U.S. market. These trends are affected not only by the price of gasoline but perhaps more directly by the supply and demand relationships in the country of export and the country of destination.

3.5.5 Ethanol Demand and Supply Projection in Madagascar

Projected ethanol production in Madagascar is calculated from the projection for scaling up of sugar cane production. It is also assumed that the current usage of ethanol in Madagascar is only for clinical and industrial applications, mainly in hospitals, chemical and beverage industries.

The projected production of ethanol from the three sugar companies, namely Sirama, Morondava, and Nouvelles Unites, is 12.7 million litres, but this is expected to grow to 23 million litres by 2015. With the plan to increase ethanol production, the need to use ethanol for gasoline blending will no doubt come, and the current gasoline demand for Madagascar is estimated to be about 60 million litres per year. The total demand for ethanol in Madagascar for gasoline blending (E-10), industrial and other applications is estimated to be 7 million litres at present and is expected to grow to about 10 million litres by 2015 (Table 3.2).

Table 3.2: Ethanol production and demand estimation, 2008-2015 (million litres)

Ethanol production	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Sirama	6.4	8.3	9.6	10.3	10.6	10.7	10.9	10.8
Morondava	1.5	2.1	2.2	2.2	2.2	2.2	2.2	2.2
Nouvelles Unites	-	0.5	0.9	2.8	4.6	6.4	8.3	10.1
Total supply from Madagascar (L)	**7.9**	**10.9**	**12.7**	**15.3**	**17.4**	**19.4**	**21.4**	**23.2**
Gasoline demand	50.0	53.5	57.1	61.1	65.3	69.8	74.6	79.8
Ethanol (absolute) demand for blend (E10)	5.0	5.3	5.7	6.1	6.5	7.0	7.5	8.0
Ethanol demand for industrial & other uses	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6
Export (committed) – Not Available								
Total demand in Madagascar (D)	**6.0**	**6.4**	**6.9**	**7.3**	**7.8**	**8.4**	**9.0**	**9.6**
Ethanol available for cooking (S – D)	1.9	4.4	5.9	8.0	9.6	11.0	12.4	13.6
Can cover demand from: ('000 households	**5.3**	**12.3**	**16.3**	**22.2**	**26.5**	**30.5**	**34.5**	**37.8**

@ 360L/household)								

*Sources SIRAMA (PGS) – CMCS (Malagasy Centre of Sugar Cane)

The amount of ethanol available for household cooking is estimated as the surplus after the demands for transport fuel and industrial applications have been met. Assuming a consumption of 1 litre of ethanol per day per household, there will be enough ethanol to supply over 16,000 households in 2010, with the number of households that could be served growing to 38,000 by 2015, provided that ethanol supplies keep pace with predicted demand.

Potential for Ethanol Production

Madagascar produced 0.86 Million tonnes of sugarcane in 2008 and processed about 100,000 tonnes of sugar. Domestic production of sugar covers about 70% of the domestic demand, the rest is imported. The Government of Madagascar (GOM) plans to increase domestic sugar production to meet the domestic demand and start to export sugar. The plan is to increase sugar output three-fold, to 0.3 million tonnes of sugar, by 2015. If this expansion is accompanied by ethanol production from sugarcane molasses there is potential to produce 23 million litres of ethanol by 2015, which will be enough to meet the cooking demand from 65,000 households.

3.5.6 Future Plans

The Malagasy industrial sugar producer, SIRAMA, has sugar-cane plantations and factories located in 3 regions: SOFIA (Ambilobe, Namakia, Nosy-Be), ATSINANANA (Brickaville) and MENABE (Morondava), which include implanted land plantation of sugar-cane and factories. The initial construction of industrial scale units for ethanol production at Ambilobe, Katsepy and Brickaville/Farafangana was due to begin in 2009, and the plants will have the capacity to produce sugar, ethanol and electricity from bagasse. It is projected that there will be 18 such plants fully operational in Madagascar by 2012 (WB Overview of bio-ethanol program).

Plans for Improving Artisanal Production

The production of local beverage alcohol from sugar-cane has become a significant source of revenue for Malagasy households and is a widespread activity in rural Madagascar. The practice is particularly prevalent among communities in the district of Ambositra in the region of Amoron'I Mania. Given the importance of the activity for diversification of rural livelihoods, the government, including the President of the Consultative Council for the Development of the Region Amoron'I Mania, has launched a programme to improve the production and market diversification of sugar-cane alcohol in the region (CNRIT, 2005).

Toaka gasy is produced in various parts of the country in artisanal and small distilleries. The Masoala peninsula, as well as the eastern central region of Madagascar (especially in and around Tsinjoarivo), is a high production zone. A survey of producers in the Tsinjoarivo region showed that the minimum yearly production for one producer was very small, around 400 litres, with the maximum production being 2,790 litres (Irwin, 2004).[86] Although national statistics for *toaka gasy* production are difficult to find, one survey does show that in 2004, 24% of Malagasy farmers manufacture rum using small artisanal distilleries for their own consumption, for use during festivals, and for sale between villages.[87] Although large quantities of *toaka gasy* are produced in Tsinjoarivo, local consumption is low, and the bulk of production is sold to wholesalers in 20-25 litre jerry cans who then transport it to Antananarivo and other urban centers. Although officially illegal, the production and sale of *toaka gasy* is a vibrant cash market in Madagascar. The main markets are located in Ambohimitombo, Fahizay, Kirisiasy, Ambinanindrano, and Miarinavaratra, and the sale of the alcohol takes place in at least one of these locations every day except Sunday. Thus, the sellers typically travel from market to market selling their *toaka gasy* and collecting more from the producers as they go. The *toaka gasy* markets are specific to it, but *toaka gasy* is also sold clandestinely in regular markets.

The price per litre is variable, depending on its quality and the location of the market. The *toaka gasy* retails for up to 6,000 fmg (1,200 ariary) per litre during holiday periods and 3,000 fmg (600 ariary) during the rest of the year. The price per litre can be 5,000-7,000 fmg (1,000 – 1,400 ariary) in Ambositra and up to 15,000 fmg (3,000 ariary) in Antananarivo. In the Tsinjoarivo region, prices range between 300-800 ariary per litre.[88]

Improving *Toaka Gasy* Production

It has been proposed by CNRIT that the technical process of distillation could be much improved by the dissemination of new techniques and equipment designs. For example, stainless steel piping could be used to avoid contamination of the product from rusted pipes (CNRIT). More efficient means of heating could be used during distillation to reduce the demand for fuelwood and the associated negative environmental impacts. It has been suggested that bagasse from the cane stalks could be used instead, in improved burners or boilers. It has also been proposed that regulating the production and sale of artisanal alcohol would lead to improvements in production processes and standardization of the quality of the final product.

3.5.7 Scenarios for ethanol stove uptake

The following section models 3 ethanol stove alternatives, in addition to an improved biomass, an improved charcoal, and a traditional stove, and seeks to understand how their uptake in the Malagasy economy can be predicted. The ethanol stove alternatives are:

- Stove 1: An introduced ethanol stove built of high-grade materials with no price subsidy, costing US$40 (80,000 MGA)

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[86] Irwin, Mitchell T., Ravelomanantsoa, Hasina Vololona. *Illegal rum production threatens health of lemur population at Tsinjoarivo, eastern central Madagascar: Brief report and request for information*. Lemur News, Vol. 9, 2004. Pages 16-17

[87] http://deposit.ddb.de/cgibin/dokserv?idn=970953313&dok_var=d1&dok_ext=pdf&filename=970953313.pdf

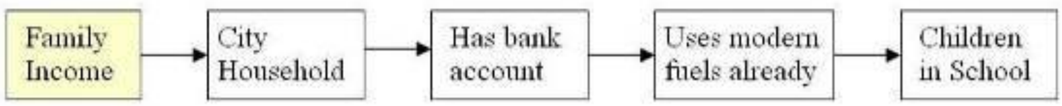
[88] Irwin, Mitchell T., Ravelomanantsoa, Hasina Vololona. *Illegal rum production threatens health of lemur population at Tsinjoarivo, eastern central Madagascar: Brief report and request for information*. Lemur News, Vol. 9, 2004. Pages 16-17

- Stove 2: Same stove technology priced with cost reductions strategies (local manufacture, materials substitution, subsidy, etc.), costing US$20 (40,000 MGA)
- Stove 3: A stove of local design, costing US$10 (20,000 MGA)

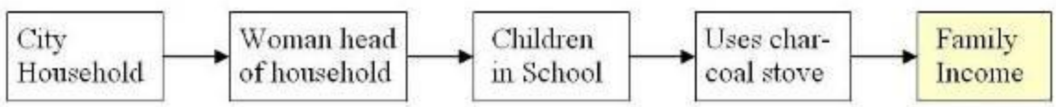
Absorption Model for Ethanol Stoves in a Low Income Economy

To introduce a new technology such as an ethanol stove into Madagascar the population needs to be broken down into target groups, ranked according to the likelihood for new stoves to be purchased first by these groups, before moving on to other target groups. Not one, but several, economic or social groups should be selected, with a different rate of absorption postulated for each group. Such a model can be used to predict how and at what rate stoves can be absorbed into an economy such as Madagascar.

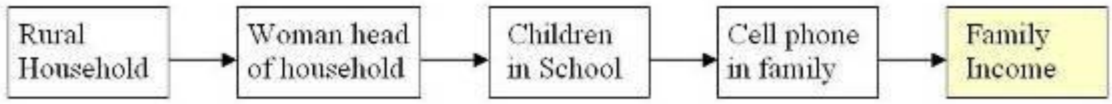
How target groups or populations are identified and the hierarchy (taxonomy) of indicators that is chosen to identify these target groups may be critical to understanding the market. A target group can be identified with the following key indicators:

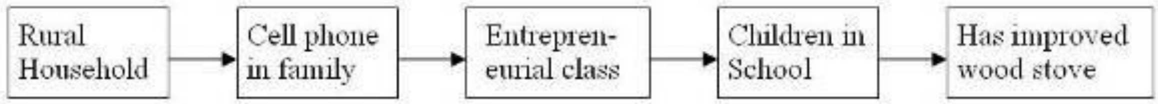


This may be quite different from a target group that is identified with the key indicators in a different order:



In short, family income may not necessarily be the best indicator for who the buyers are, and thus how to reach them. Given the heavy dependence on wood use in Madagascar, side by side with the difficulty of meeting wood fuel supply sustainably, both now and as a growing problem in the near future, a model needs to be constructed, and a strategy developed, for the introduction and uptake of ethanol stoves into rural markets. This is particularly the case if small or micro-scale distilleries can be developed which can produce the cooking fuel on a widely distributed basis, within the rural markets being served. The following indicates the taxonomy of two groups of users that could be identified and prioritized as market leaders:





In both examples, family income is important but not necessarily an effective way of identifying who the early users/market leaders will be. In the first case, a woman head of household may indicate she's receiving a remittance income from abroad, indicating a higher spending power, yet the household should be identified not because of outward signs of income, but rather because the house is headed by a woman and there are children in school, particularly if the children stay in school to secondary level. Thus, a household run by a woman, with older children in school, even if it is currently uses a wood burning stove, could be an ideal customer for a modern ethanol stove.

In the second example, all rural homes with at least one family member in the home owning a cell phone might be identified as a target market, as it might be that these homes are also engaged in entrepreneurial activity, which is why they own a phone, as well as a reason why they can afford a phone, and might be able to save to buy an ethanol stove. They might be farming families that sell produce directly, or sell charcoal or wood at the roadside, or have a loom and sell woven fabrics, but the possession of a mobile phone might be an important indicator.

If a household has purchased and is using an improved wood stove, such as the Fatana Pipa stove, which is not an inexpensive stove, then this is another significant indication that the family could be a candidate for an ethanol stove. Charcoal stove users are also a good target audience for an ethanol stove dissemination programme.

Examples of other absorption models which may hold significant lessons for the entry of ethanol stoves into Madagascar are detailed in Annex 4, and include the Absorption Model of Millennium Gel Fuels carried out in Ethiopia in 2003, the Millennium Gel Fuel Absorption Model carried out in Madagascar in 2004, and the Private Sector CleanCook Stove Market Study carried out in Ethiopia in 2007.

Implications for the Household Ethanol Programme of ethanol manufacture

A serious concern with artisanal ethanol production is related to its inefficient process of distillation. *Toaka gasy* typically only contains around 40-50% alcohol by volume, which is much lower than is needed for use as a fuel. Traditional distillation involves boiling the fermented sugar-cane juices in a pot still for many hours, even several days, which requires a significant amount of firewood. Unless the fuel for distillation can be substituted, for example for bagasse, which is usually discarded, and the fuel requirement reduced, then promoting artisanal ethanol production may be problematic. The problem remains to bring this alcohol up to a standard suitable for fuel use. For this, new distillation equipment will be necessary. *Toaka gasy* manufacturers will essentially have to replace their pot stills with distillation columns.

It has been suggested that *toaka gasy* producers could sell their product to a redistiller who would distill the 40 to 50% ethanol up to a fuel grade ethanol. This has been proposed in the literature on micro distilleries in Brazil, with cachaça producers linked in a dairy cooperative (Scholtes, 2010).[89] While this is certainly possible, it may not be financially feasible, as the inherent inefficiencies in the transaction between small distillers and the redistiller might result in an ethanol too costly for sale as fuel. Levels of control would need to be sufficient to ensure that the legal production of *toaka gasy* did not bring with it increased health problems associated with excess alcohol drinking before denaturing took place.

3.5.8 Policy and Regulations

The draft biofuels policy document outlines the legal and regulatory framework for the production, sale and distribution of biofuels in Madagascar, as well as the required licensing and taxation procedures. Article 4 of the draft policy states that the production, import, export, processing, transport, storage and distribution of biofuels is open to:

- Any person of foreign nationality or Malagasy
- Any legal person incorporated under Malagasy law (Draft Biofuels Policy)

Thus, the government affirms its openness to the possibility of foreign investment in the sector. The policy also aims to 'promote socio-economic development, improve living standards in rural areas and environmental protection through support of the biofuels industry in the national territory' and to 'promote Public - Private Partnerships and between foreign investors and Malagasy' (Draft Biofuels Policy).

Article 18 states that 'Approval of use of biofuels is a property right, transferable, transferred, leased, likely to mortgage and pledge.' This would suggest that similar procedures apply to obtaining a license to produce biofuels as do for titling land or registering property. If this is indeed the case, it could mean that obtaining a license might well involve lengthy and complicated procedures.

Article 24 states that 'Madagascar will apply to biofuels standards, codes and practices established by organizations recognised in the international biofuels industry in terms of quality, industrial safety and environmental protection.' This suggests that the government is open to exporting biofuels and is concerned with ensuring quality and sustainability of the product.

Article 25 states that 'the price of biofuels and margins will be freely determined by supply and demand', implying that the government is not planning to subsidize these products.

Crucially, Article 26 states that 'biofuels which are produced in pilot activities for technological development of cleaner products shall be exempt from excise duty, the total exemption of charges of OMH and the environmental tax.'

Moreover, the same article states that the producers of biofuels benefit from the exemption of business tax, the suspension of customs duties on imports of materials and equipment, exemption from IBS on the first 5 years then 10% of profit from the

[89] Scholtes, Fabian, Status quo and prospects of smallholders in the Brazilian sugarcane and ethanol sector: Lessons for development and poverty reduction, Center for Development Research, University of Bonn, 2010.

6th year. This is a very significant tax break for a new business and could be a strong incentive for foreign investment in biofuels production.

3.6 Water

3.6.1 Overview

In Madagascar there are five hydrographical areas (WaterAid 2002):

- The slopes of Ambre mountain in the north of the Island
- The slopes of Tsaratanana in the north-west
- The eastern slopes which go down to the Indian Ocean
- The western slopes facing the Mozambique Channel
- The southern slopes of Mandrare, Manambovo, Menarandra, Linta and the Mahafaly plateau which have neither surface water nor rivers

Two major basin groups can be distinguished in Madagascar; one draining to the west to the Madagascar Channel and one draining to the east to the Indian Ocean. Rainfall in Madagascar varies from that of tropical rain forest to near desert conditions. The types of irrigation vary according to the three main ecological regions of the country: the Highlands, the West and the narrow East Coast. Because of the high altitude, the Highlands are cool in the dry season (June-October), which limits crop production.

The West is hot and the dry season is very long, up to nine months in the far south-west, with rainfall less than 400 mm/year. The East Coast is warm and humid with rainfall that can exceed 3000 mm/year and with almost no dry season. Irrigation potential has been estimated at 1.5 million hectares and over 70% of this area already benefits from irrigation, although large areas need rehabilitation, as shown in Table 3.3 (FAO, 1997, Irrigation Potential in Africa: a Basin Approach).

Table 3.3: Madagascar – Irrigation potential, water requirements and areas under irrigation

Country	Irrigation potential (ha)	Gross potential irrigation water requirement		Area under irrigation (ha)
		per ha (m^3/ha per year)	total (km^3/year)	
West	1000000	16000	16.000	700000
East	500000	14500	7.250	387000
For Madagascar	1500000		23.250	1087000

The renewable water resources are estimated at 337km^3/year, which is almost 15 times the total water required for the development of Madagascar's irrigation potential.

3.6.2 Irrigation Capacity

Irrigation occupies an important place in the agricultural sector, supplying water to more than one million hectares, or 40% of cultivated lands (as compared to 6% on average in sub-Saharan Africa). Irrigated crops represent 15% of Gross Domestic Product (GDP), whereas 70% of agricultural production and 88% of rice production originates from irrigated agriculture. It is estimated that 85% of the active farming population are directly or indirectly employed by the irrigation sector. Since the 1950s, irrigation has benefited from public investment, however the impact of these investments on rural incomes is mixed, and sustainability is far from imbedded. The rapid degradation of infrastructure requires frequent rehabilitation, and many schemes are caught in a vicious cycle of poor yields, low capacity of water users to pay for operation and maintenance (O&M), and rapid degradation of the schemes. Weak capacity to pay is accompanied by low willingness to pay, reinforced by institutional weakness of Water Users' Associations (WAS) and a lack of support from local authorities. Moreover, erosion of upstream watersheds is weighing heavily on the cost of maintenance of downstream irrigation schemes (World Bank, 2006).

3.6.3 Irrigation of sugar-cane

Sugar-cane requires approximately 800 mm of irrigation per hectare to produce an average yield of 1,333 litres of ethanol (FAO, 2008, p 64). Henri Tsimisanda, former General Manager of SIRAMA Sugar Factory, states that in well irrigated fields, typical crops of 90 to 100 TC/Ha are achieved, with crop peaks of 120 TC/Ha for seed cane.

Rain irrigated cane, which is the norm for the eastern part of Madagascar, provides yields of 60 to 70 TC/Ha. With rain-watered cane, the most crucial requirement is weed control and drainage of excess water from the fields.[90]

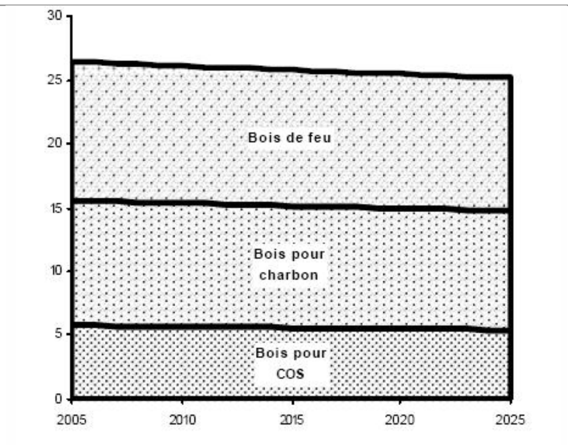
[90] Interview with Henri Michel Tsimisanda, January 13, 2010.

3.6.4 Charcoal Supply

Most charcoal is produced traditionally (very inefficiently), which means that only 10-15% of the total wood energy is converted to usable charcoal (Gade and Perkins-Belgram, 1986). In addition, the charring process normally requires up to two weeks to complete, after which it must be cooled for several days before it can be bagged and shipped (Gade and Perkins-Belgram, 1986). As per Gade and Perkins-Belgram, a one hectare coppiced eucalyptus grove yields about 350-400 m^3 of firewood or, if carbonized, about 1,500 sacks of charcoal.

In most cases, the retail price of fuelwood is double that at its place of production (Gade and Perkins-Belgram, 1986). Constrained supply during the rainy season forces prices to rise by up to 70% over those in the dry months (Gade and Perkins-Belgram, 1986). It is estimated that sustainable wood production will fall annually by approximately 100,000 m^3 for a number of reasons, including poor management and the set aside of additional forest lands for conservation purposes (IRG Jariala, 2005). Figure 3.11 shows projected levels of production of fuelwood, charcoal and wood for construction.

Figure 3.11 Projections for the annual production by type of wood in million m^3



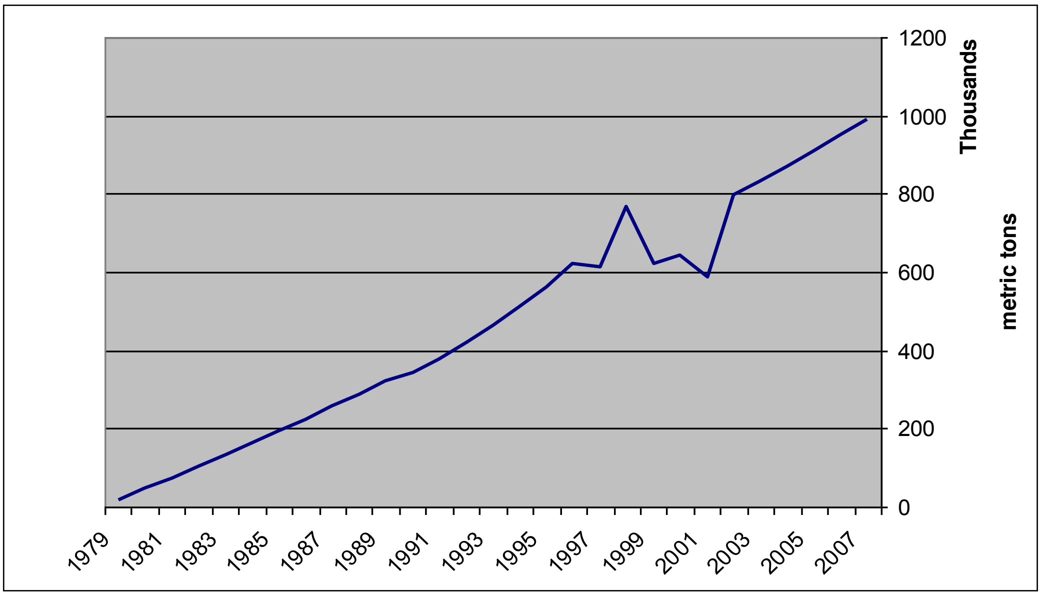
In 2003 the average market price for eucalyptus wood was 520,833 MGA per m^3 and for ordinary wood was 778,482 MGA per m^3. The price per kilogram of firewood is approximately 140 MGA/Kg (IRG Jariala 2005).

Charcoal production in 2007 from charcoal manufacturers who are tracked is 989,000 MT, up from 950,000 MT in 2006 and 910,000 MT in 2005 (UNdata web portal for Madagascar, http://data.un.org/Data.aspx?d=EDATA&f= cmID%3aCH, accessed 1-12-10). Charcoal produced on a small scale in the informal sector may add to these figures. The U.N. data shows no imports of charcoal and an export value of 29,000 MT per year over the last decade. The U.N. data shows a national consumption rate by all users of 960,000 MT, up from 921 in 2006 and 881 in 2005, but these are estimates.

The latest source that could be found estimates contemporary wood use for charcoal production at 8.5 million m^3 (IRG Jariala Report, 2005). This is 2.55 million tonnes of wood using a conversion factor of 1 to 3.3 (metric ton to meter cubed, stacked wood) (http://Bioenergy.ornl. gov/). This is over 250% of the value shown for the charcoal manufacture, above, but within a range of magnitude. It is a value that probably captures both formal and informal manufacture of charcoal. It provides a reasonable range in which to situate the scope and scale of charcoal manufacture in Madagascar.

Charcoal manufactured from plantation biomass is produced primarily from the wood of eucalyptus trees in operations organized by entrepreneurs who purchase standing trees from woodlot owners (Gade and Perkins-Belgram, 1986). The entrepreneurs pay local farmers to make the charcoal, as well as providing jute sacks for the farmers to bag the product and haul it to market in trucks or ox carts.

Figure 3.12 Growth in Charcoal Consumption 1979–2007



Ref: UN Data

The charcoal making season typically extends from July to October (i.e. the dry season) when wood is driest and time can be spared from the busiest phases of rice cultivation (Gade and Perkins-Belgram, 1986).

Traditional charcoal-making involves covering a pile of logs and branches with fresh leaves and soil to exclude most air (aside from some vents to allow smoke to escape), and setting it on fire. To achieve the levels of heat needed for carbonization, most of the energy in the wood is consumed, and only 10-15% of the total wood energy is converted to usable charcoal, making the process highly inefficient (Gade and Perkins-Belgram, 1986).

Eucalyptus woodlots are started on previously cultivated land, with seedlings, four to five months old, planted in pits from nursery plants. The first harvest, 10 to 15 years after planting, is generally used for construction wood if the boles are straight. Suckers that sprout from the stump develop into stems that in six to eight years are used as woodfuel, either cut into firewood pieces or converted into charcoal.

Coppicing of the stumps is repeated three or four times, after which the trees lose their vigour and the woodlot must be replanted. During its lifetime, a one-hectare coppiced eucalyptus grove yields about 350-400m^3 of firewood or, if carbonized, about 1,500 sacks of charcoal[91] (Gade and Perkins-Belgram, 1986).[92] The charring process normally requires up to two weeks to complete, after which the charcoal must be cooled for several days before it can be bagged and shipped (Gade and Perkins-Belgram, 1986).

The need for more efficient methods of production has been recognized by the government and the donor community and a number of improved charcoal making projects are currently underway. To date, successful projects have involved the dissemination of improved techniques such as better insulation and the addition of metal chimneys to increase efficiencies (CARAMCODEC, 2008). Improved techniques can double the efficiency of the carbonization process and reduce the amount of wood required by 50% (CARAMCODEC, 2008).

In the informal sector, charcoal is produced by local inhabitants where the trees are cut, then transported by ox-cart to locations along the highways accessible by large trucks. The bagged charcoal is then sold to distributors who transport in into the urban areas for sale (http://www.cipec.org/research/madagascar.html, Centre for the Study of Institutions, Population and Environmental Change (CIPEC)). It is also sold to individuals, either independent truckers or commuters on their way into the city. They often buy smaller quantities (whatever they can afford to buy or haul) for personal use or re-sale. Each new road that is built or improved provides another conduit for charcoal into the city, where there is a cash economy to pay for it.

At least one fifth, and perhaps more, of the cost of charcoal, when sold in the city, is accounted for transportation to the city (Gade and Perkins-Belgram, 1986). This cost increases as plantations decline from extended coppicing and charcoal comes into the city from further and further away. Antananarivo is the largest market for charcoal and charcoal is often transported from 200km or more, coming by rail from Antsirabe or along the five main highways into the city. According to Gade and Perkins-Belgram (1986), more than 50% of the charcoal sold in the capital comes from the Llempora region, 100km south on the Antananarivo-Antsirabe rail line. This is undoubtedly from the eucalyptus and pine plantations in that region.

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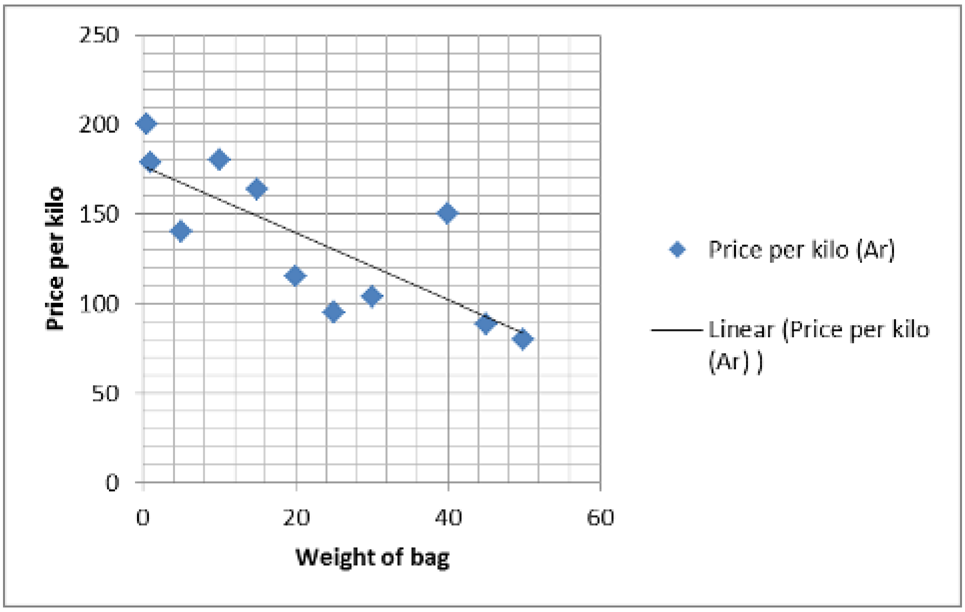
[91] Smaller bags of charcoal in Ambositra weigh from 0.5 kg, 1 kg, 5kg, to 10kg. Larger bags weigh, generally, 20kg, 30kg or occasionally 45kg (project survey data).

[92] This yield was cross checked by reference to several yield studies of coppiced eucalyptus plantations in Brazil and elsewhere and found to be reasonable, indeed conservative. Yields of 1,500 sacks (at 50 kg) of charcoal per hectare over the 30-year life of a eucalyptus plantation, even with less than ideal charcoal manufacture practices, are reasonable and likely.(Betters, Wright and Couto, 1991)

Betters, David R., Wright, Lynn L., and Couto, Laercio, Short Rotation Woody Crop Plantations in Brazil and the United States, Biomass and Bioenergy, Vol. 1. No. 6, PP. 305-31 6, 199l.

Gade, D.W. Prof. Dr., and Perkins-Belgram, A. N., Department of Geography, Woodfuels, Reforestation, and Ecodevelopment in Highland Madagascar, GeoJournal 12.4, 1986, pp. 365-374.

Figure 3.13: Unit Price of Charcoal in Quantity Sold



Source: Project Baseline Survey (Component A: April, 2009)

Figure 3.13 shows how the unit price of charcoal decreases quite substantially as the weight of the bag increases. This trend favours middle and upper income buyers, who can afford to purchase the larger bags of charcoal, while disadvantaging lower income buyers who purchase smaller bags of charcoal at a higher unit cost. The cost of a large bag of charcoal (30-50 kg) along the roadside ranges to 16,000 MGA per bag, and the closer to the city, the more expensive it becomes (Figure 3.14). Charcoal quality is quite variable and affects price, and prices along the roadside are usually negotiated between the buyer and seller. Families in the middle income range try to buy their charcoal outside of the city in large bags, so they get the best price. The most commonly available large-sized bags in the city markets are 30kg in weight (PAC survey data). These bags typically last an average family 1 to 1.5 months (Tiana Razafindrakoto, field report, January 2010).

The cost of charcoal in Antananarivo is double the cost in the countryside, and as of January 2010 was about 286 MGA per kg. One large hand-full of charcoal (two hands held open together) costs about 200 MGA and will fill the fuel compartment of an improved charcoal stove. Most families of lower income cannot afford to buy large bags of charcoal and must buy their charcoal on a daily basis in small quantities. In this case, a family of 5 members cooking three times a day, will spend between 500 and 800 MGA (Tiana Razafindrakoto, field report, January 2010).

Figure 3.14: Sale price of charcoal delivered to Antananarivo and surrounding areas - April 2010

Charcoal from Eucalyptus wood in 35 kg sacks (approximate weight; price in Ariary)

Location	ANTANANARIVO	ARIVONIMAM**O**RN 1 – 4O Km*	MANJAKANDRIA**NA**RN 2 – 45 Km	ANKAZOB**E**RN 4 – 90 Km	ANTSIRAB**E**RN 7-170 Km
At the site of production			5,000 Ar		
Along the highway		7,000 Ar	7,000 Ar	4,500 Ar	
In the market	13,000 Ar				6,000 Ar

**RN: Along National Route No. 1*
**The price of firewood in Arivonimamo is 8,000 Ar for a cartload (about 2 cubic meters) and 5,000 Ariary in Manjakandriana.*
Reference: FOFIFA: Centre de Recherche Agricole, INSTAT: Institut National de la Statistique

Sale Price of Charcoal

In 2008 in Antananarivo the price of charcoal was about 200 Ar/kg. For ten years, charcoal and wood prices have increased, in parallel, with the rising cost of living. Between 2000 and 2008, the price of charcoal doubled, paralleling cost of living increases. As in many African countries, charcoal price increases seem to have been restrained by the lack of purchasing power of consumers. Charcoal prices are generally not directly correlated to those of other domestic energy prices (fuelwood, kerosene and butane gas), and the consumption patterns of these other fuels appear inelastic, which can be explained by the difficulty of households to change their energy consumption patterns, given income, eating habits and preferences, and ownership of cooking equipment.

The prices are relatively higher in the richer provinces, namely those of Antananarivo and Antsiranana, which reflects both higher purchasing power of consumers and the remoteness of the sourcing of the fuel (affected by transportation cost and quality of the roads). Prices are lowest in the province of Toamasina, which is relatively rich in forest resources. Prices are 10% higher during the rainy season (January to April) because the production conditions (humidity) and transportation (accessibility of the roads) are more difficult (Moser and Minten, 2008). In the rainy season, the yield is about 30% lower than that obtained in the dry season and 50% of the roads are impassable.

For over 30 years, Madagascar has not experienced any charcoal supply shortages. But the supply in the city is minimal, and inventories held by producers as well as the traders are small. In the 1990s, retailer inventories accounted for less than a week of consumption. Few traders have sufficient cash to purchase large volumes, but the lack of supply crises is a sign that effective channels exist to deliver charcoal to the market in quantity and with regularity (PPIM Summary: Mahajanga Integrated Pilot Program for a pattern of domestic energy supply, 1999; PNEBE, 1999-2000). However, some supply problems still occur each year in the rainy season when the passage on the roads is so difficult that the supply chain is interrupted.

Figure 3.15: Average price of charcoal in main cities (Unit = Ariary/ 1kg):

Year	Price per 1 kg Bag (MGA)
2001	135
2002	158
2003	155
2004	192
2005	214
2006	235
2007	247
2008	257
2009	269
Average	206.9

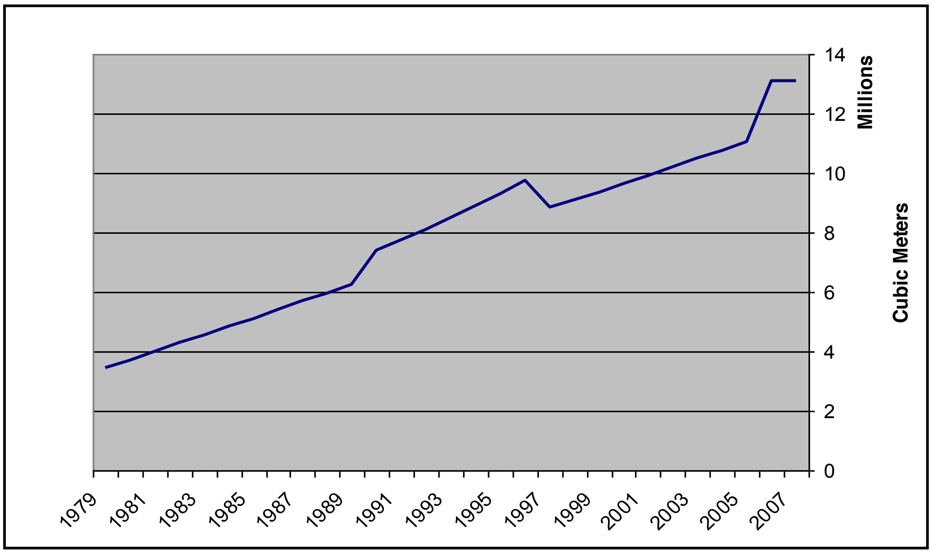
Source: INSTAT/DSM *(based on statistics from the Antananarivo, Fianarantsoa, Toamasina, Mahajanga, Toliary, and Antsiranana).*

As shown in Figure 3.15 above, the retail price for a small bag of charcoal, purchased by lower income families, has been steadily increasing over the last nine years. Within the last decade, the cost of one small bag of charcoal (1 kg) has essentially doubled.

3.6.5 Wood

Non-commercial wood production has been fairly steadily increasing over time in Madagascar, with production passing 12 million cubic metres in 2005-6 (Figure 3.16). Under Malagasy law, rural households have certain rights to wood from non-protected forests and woodlots close to their villages. Firewood may be extracted free of charge provided that it is not commercially traded (Gade and Perkins-Belgram, 1986). An official permit must be obtained in order to sell wood, however illegal cutting is commonplace, particularly in areas where fuelwood is in short supply.

Figure 3.16: Non-commercial Wood (Fuelwood) Production 1979 – 2007



Fuelwood is typically transported from rural areas to urban markets for sale. Most firewood sold in Antananarivo is transported from 60km or more away, although some wood is collected for sale on the outskirts of the city (Gade and Perkins-Belgram, 1986). In most cases, the retail price of fuelwood is double that at its place of production (Gade and Perkins-Belgram, 1986). Constrained supply during the rainy season forces prices to rise by up to 70% over those in the dry months. Fuelwood expenditure accounts for between 10% and 20% of annual income for most households in Antananarivo (Gade and Perkins-Belgram, 1986).

In 2003 the average market price of eucalyptus wood was 520,833 MGA per m^3 and for preferred local species the price was 778,482 MGA per m^3 (Jariala Report). The price per kg of firewood in city markets is approximately 140 MGA per kg (Jariala) (Tiana Razafindrakoto). Woodlots and plantations cover some 320,000 hectares, and together with coppiced trees on farms, these forests supply the majority of fuelwood consumed in rural areas as well as a significant level of urban consumption. Some 80,000 of the 320,000 hectares are industrial plantations of fast growing pine and eucalyptus. A USAID-funded project (the Jariala Report[93]), in which the U.S. Forest Service provided technical guidance, stated in a 2005 report that the productivity and efficiency of harvesting and regeneration of these forests had to be improved in order for their management to become sustainable (Reforesting Madagascar - A Concept for Success, 2005).

The Jariala programme estimated demand or consumption of woody forest products (fuelwood, charcoal, poles and lumber) would grow from 20 million m^3 per year in 2005 to 23 million m^3 per year by 2025. Under existing constraints, sustainable production of these products is estimated to be no more than 17 million m^3 per year. However, production would be significantly impacted by the creation of new forest preserves being planned on 5 million hectares of important remaining forests. Given anticipated restrictions on the extraction of wood from these areas, the sustainable production of forest products would decline to about 9 million m^3 per year, resulting in

[93] Jariala Report. See also: Reforesting Madagascar – A Concept for Success, January, 2005, accessed October 10, 2009 on the web at: http://www.irgltd.com/Resources/Publications/Africa/Improving_Forest_Management_in_Madagascar.pdf

a deficit between supply and demand for woody forest products of 14 million m^3 by 2025 (Jariala report).

The Jariala Report notes that most of the industrial plantations and farm woodlots lie outside of the sensitive conservation areas. It states that the success of the long-term protection of the forest preserves would depend on the ability of Madagascar to shift to alternative sources of supply for forest products, and the ability of the preserved areas to yield some revenue, livelihoods and local incomes. The Jariala report made clear the need for considerable efforts to be made to promote good management not only of the conservation areas, but also of the productive forest lands outside of the forest preserves. Jariala recommended not only the development of additional fast growing commercial forestry plantations, but also the rehabilitation and restoration of the large expanses of cut-over, depleted forest lands. The report notes that in the last 40 years 12 million hectares of forest in Madagascar has been cut and lost, primarily to slash and burn agriculture (tavy). In contrast the amount of agricultural land has only increased by some 100,000 hectares, less than 1% of the amount of land converted from forest, since cleared and temporarily cultivated tavy lands are abandoned after production drops. These degraded and abandoned lands, together with the farmed lands, could be used, Jariala notes, to reforest Madagascar to allow it to meet the nation's needs for forest products. Jariala states that it will be necessary to expand the area of plantations by some 38,000 to 41,000 ha each year.

A key finding of the Jariala report states (Jariala, Sustainable Environment and Forest Ecosystems Management, Jan 2005, p. 27):

"There is an urgent need to move ahead with the support of income generating livelihoods linked to the development of forest-based enterprises and with the promotion of plantation forestry, farm forestry, widespread tree planting and other measures to develop forest resources as an integral part of rural production systems, on a scale that corresponds to the growing demand for forest products and services."

Figure 3.17: Fuelwood and charcoal sales along road from Fianarantsoa to Ambositra

Photo by International Resource Group (USAID, January 2005)

Charcoal and fuelwood produced from locally managed trees on farms, woodlots and small scale plantations are sold along paved roads (Figure 3.17). Increasing demand is being placed on these farm woodlots and the remaining forests outside of preserved areas. These are a significant contributor to forest product supplies, particularly for the growing urban centres.

A new forest conservation programme is now beginning in Madagascar, under the U.N. Reducing Emissions from Deforestation and Degradation (REDD) programme, described in the next section.

U.N. REDD in Madagascar: Reducing Emissions from Deforestation and Forest Degradation

Madagascar is currently engaged in a significant expansion of its protected area system, moving from a protected area network based principally on strict conservation areas to a system, begun in 2009, that includes new categories of protected area which have many more residents and allow for many more human uses of natural resources. These new protected areas are based on community forest management agreements where certain rights and responsibilities are transferred from the national government to local community associations through time-bound contracts. Using this new approach, the protected area network has more than tripled in size (Ferguson, Barry, REDD in Madagascar: An Overview of Progress, Madagascar Conservation and Development 4, 2: 132-137, 2009.)

An important feature of REDD is the intent to manage from a human economic needs perspective, especially on a local level, as well as from a conservation perspective, providing resources for both objectives. Madagascar is fully engaged with the REDD process, both in- country, through a national working group with five pilot REDD projects, and internationally, with support and engagement from the Forest Carbon Partnership Facility (FCPF) and USAID's Translinks Project (Ferguson, 2009).

Madagascar is considered to have a high potential for REDD and for CDM-funded activities because of its historically high rate of deforestation and its relatively low forest cover. The idea of linking avoided deforestation to carbon finance for Madagascar first began in 2000, and took form in 2008 with the establishment of a Madagascar REDD technical committee, known as the REDD Task Force (Ferguson, 2009). Knowledge about deforestation rates and the capacity to monitor it is currently NGO-led, but the Malagasy government has allocated resources for improving its own capacity for monitoring forest cover (Ferguson, 2009).

Forest Carbon Partnership Facility (FCPF)

Madagascar is one of the first group of countries to formally enter the World Bank Forest Carbon Partnership Facility (FCPF), which it did so in July 2008 (Aquino, 2008)[94]. Madagascar submitted a REDD Readiness Project Identification Note (R-PIN) to the Forest Carbon Partnership Facility (FCPF) in March 2008 (GoM, 2008a)[95], which was approved in July 2008. This allowed the Government to proceed to the next step for receiving funding through the REDD preparation mechanism. The Malagasy REDD Technical Committee (CT-REDD) has contracted with a consultancy firm to provide support to the CT-REDD to develop a final action plan. The focal point for climate change is the Directorate for the Valorisation of Natural Resources (DVRN) in the Ministry of Environment and Forests (MEF).

Deforestation Rates and the Potential for REDD in Madagascar

Madagascar is a biodiversity hotspot in part because of the high rates of deforestation it has sustained over a number of years (Ferguson, 2009), although there is some controversy over Madagascar's cumulative rate of deforestation because of disagreement about its original natural forest cover. However, this can be viewed as an issue of academic or scientific importance rather than practical economic importance. Whatever the original percentage, the national rate of deforestation in the period since the introduction of remote sensing is very significant. Harper *et al.* (2007)[96], as quoted in Ferguson (2009), estimate that between 1950 and 1970 Madagascar experienced a rate of deforestation of 0.3% per annum, accelerating to 1.7% between 1970 and 1990 (the socialist era), and slowing with the advent of conservation programs to 0.9% between 1990-2000. Recent estimates for 1990-2000 suggest a slightly lower rate of 0.83% per year, and a rate of 0.53% per year for the most recent period analyzed (2000-2005). This relatively high rate of deforestation, combined with the low level of remaining forest cover (15.88%) has

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[94] Aquino A, 2008a REDD en Madagascar Organizando el proceso REDD en Madagascar – Curso Internacional Diseño de Actividades Turrialba, Costa Rica – October 29.
Aquino A, 2008b, FCPF Launch Presentation World Bank Building, Anosy District, Antananarivo, 7-08.
[95] GoM, 2008a, The Forest Carbon Partnership Facility (FCPF): Readiness Plan Idea Note (R-PIN) for Madagascar, April, 2008.
[96] Harper GJ, Steininger MK, Tusker CJ, Juhn D & Hawkins F, 2007 Fifty years of deforestation and forest fragmentation in Madagascar, *Environmental Conservation* 34 (4): 1–9. As quoted in Ferguson, 2009.

identified Madagascar as a candidate for REDD and for CDM Reforestation Credits (Westholm et al. 2009:78)[97].

3.6.6 Other Sources of Household Energy Supply

Electricity

In rural areas, only 0.02 to 0.07% of households have access to electricity (INSTAT/DSM/EPM2005). Electricity production peaked in 2004 due to a large increase in the number of industrial subscribers. Madagascan electricity has been heavily subsidized since the 1970s, but this is now changing. The state-run electricity provider, JIRAMA, relies heavily on expensive diesel-fuelled power plants, and the rising cost of diesel fuel over the past two decades has led to the inevitable elimination of subsidies, which is already bringing a significant increase in electricity costs to the consumer. In 2005, when JIRAMA was forced to cut back on its consumption of diesel fuel, the result was widespread blackouts which crippled businesses and caused nation-wide protests (BBC, December 2006).

Restructuring of the state utility company has been repeatedly delayed even though electricity sector reforms are desperately needed to reduce costs. To forestall an electricity price shock in 2007, the authorities postponed tariff increases until October 2008, but even following a tariff increase of 15% in October 2008, the state utility was still operating at a sizeable deficit. The prospect of continued rate rises is a certainty, and electricity sector reforms have been established by MAP as a priority (IDA and IMF, 2008)[98]

Kerosene and Liquefied Petroleum Gas (LPG) Supply

Madagascar depends completely on foreign imports to satisfy its oil needs, but refines some petroleum for export and therefore produces some LPG in its refinery. The household consumption trends for both kerosene and LPG are shown below, in Figure 3.18, and both generally show an increase over time, but a drop in refinery production from 1999.

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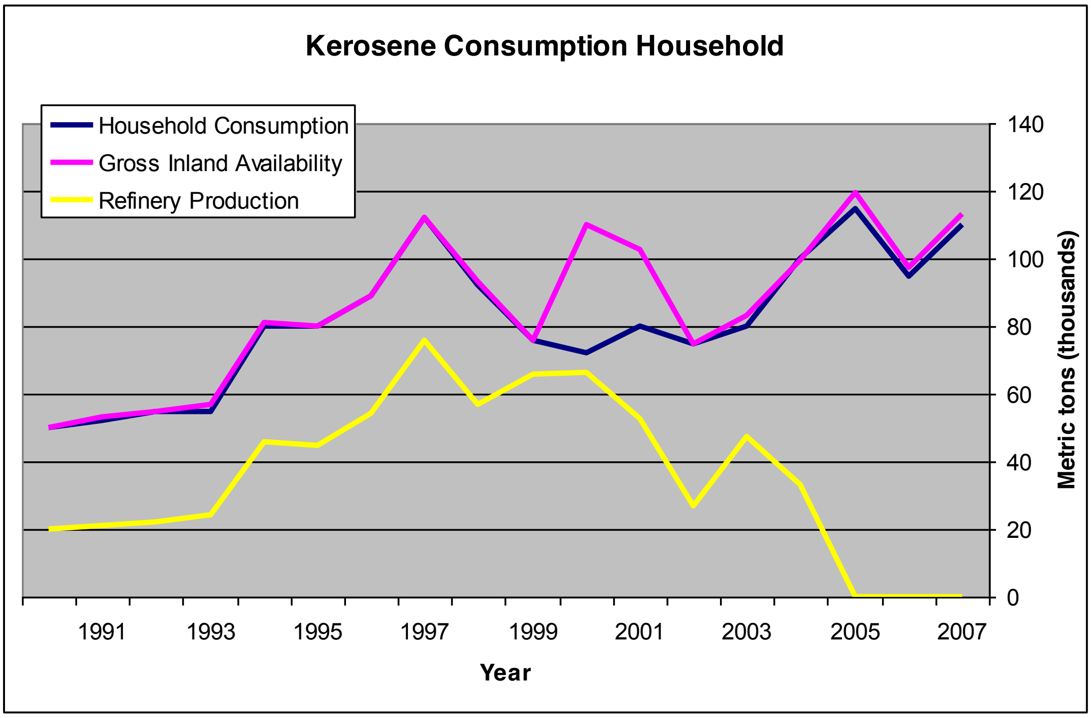
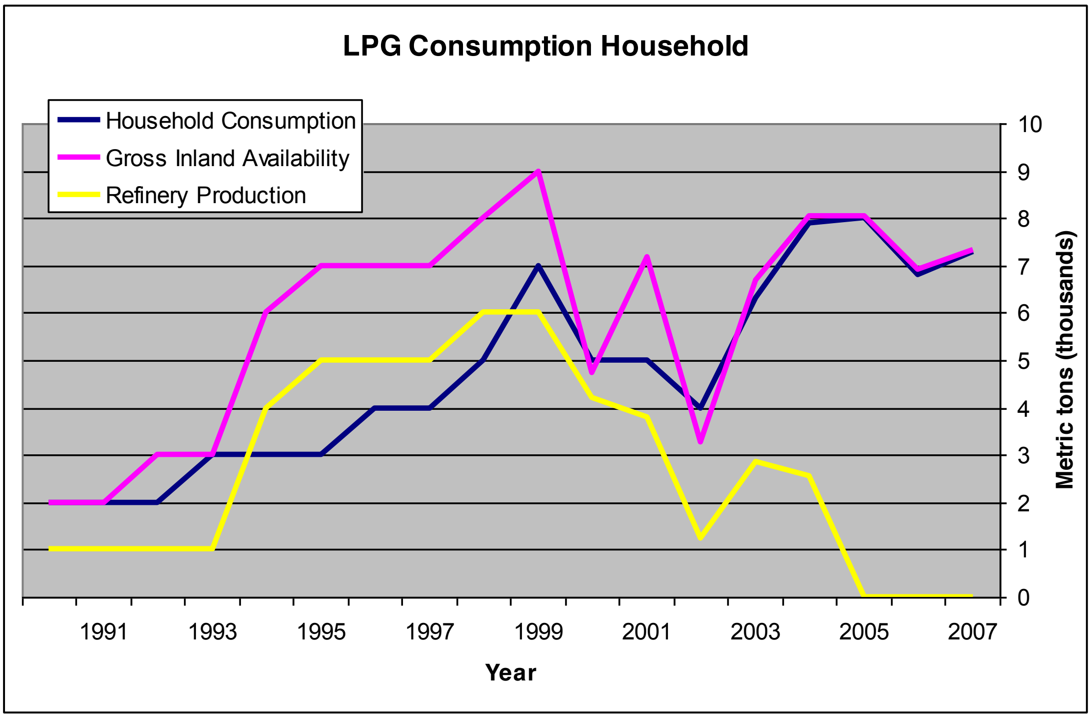
[97] Westholm L, Henders S, Ostwald M, Mattsson E. 2009 Assessment of Existing Global Financial Initiatives and Monitoring Aspects of Carbon Sinks in Forest Ecosystems – the Issue of REDD, FOCALi Report, Gothenburg, Sweden. As quoted in Ferguson, 2009.

[98] International Monetary Fund, Republic of Madagascar Poverty Reduction Strategy Paper, Joint Staff Advisory Note, IMF Country Report 09/11, January 2009. Accessed 6-15-10 at http://www.imf.org/external/pubs/ft/scr/2009/cr0911.pdf.

Figure 3.18: Kerosene and LPG Household Consumption (UN data)





3.6.7 Policy and Regulations

Broad policy objectives for the energy sector include assisting the poor directly, through the provision of a sustainable supply of good quality energy at a reasonable price, and focuses on the following three fundamental principles:

- Economic: streamline supply conditions, production, distribution and consumption of energy
- Environmental: respect the fundamental ecological balance and encourage sound management of rural areas in the use of forestry for energy use
- Social: enable people in rural and urban areas to access a minimum level of energy service

In the medium term, among the main strategies highlighted by the government for achieving these objectives is a plan to 'establish the truth behind the price of petroleum products' by liberalising the import of petroleum fuels and eliminating subsidies along the entire chain of the oil sector (Energy Sector Policy). This could result in significant price increases on kerosene, making it less affordable for cooking in urban areas. Assuming that locally produced ethanol will be competitive with kerosene in terms of price, if kerosene subsidies are eroded, it is likely that ethanol will substitute kerosene as a cooking fuel in urban areas. Other medium term strategies outlined in the policy include implementing a programme to promote gas and kerosene in rural areas as an alternative to wood for cooking and lighting.

Implications for the Household Ethanol Programme

Production of sugarcane for ethanol should be incorporated into the national planning on energy, including supply and demand scenarios, in order to avoid possible overlap or conflict between other aspects of the energy policy.

3.7 Forestry

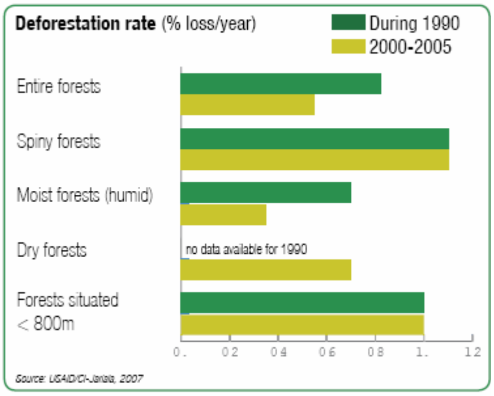
3.7.1 Overview and Trends

The forestry sector in Madagascar represents 5% of GDP and 17% of the primary sector. Recent surveys conducted by PAGE (a US-funded program) show that out of the total average annual household agricultural income of US$240, over $110 comes from forests products, especially non-timber products. Forest-related activities provide the primary source of cash income in rural areas, primarily through employment, with over 16 million work days per year paid in cash (World Bank PID, 2003).

Malagasy forest resources have, for several decades, been in a state of regression. The principle causes of deforestation are land clearance for agriculture, wild fires and for fuelwood for household energy. The indirect causes are population growth, particularly in the rural areas, extension of the Tavy agricultural system (discussed in previous sections), the use of fire for managing pasture land, household dependence on wood fuel for energy, use of wood for construction as well as institutional problems relating to forestry governance and an ambiguous framework of land rights (IRG Jarialy). Forest cover constitutes less than 25% of the total land area of Madagascar (FOSA 2000).

According to the World Wide Fund for Nature (WWF), most of Madagascar's dry forests have been cleared for slash-and-burn agriculture, pasture, firewood, or a construction material, which is now largely covered by secondary grasslands (WWF, 2007)[99]. Madagascar has already lost 80% of its natural areas, and continues to lose an estimated 200,000 hectares annually to deforestation. Recent studies by the Centre for Applied Biodiversity Science at Conservation International (CABSCI) indicate that if the rate of forest reduction remains at current level (i.e. 0.55% per annum as shown in Figure 3.19), all of Madagascar's forests will be lost within 40 years (WWF, 2007)[100].

Figure 3.19: Deforestation Rate Madagascar 1990–2005



(Source: WWF)

3.4.2 Sources of Deforestation

Given that only 4% of the land in Madagascar is cultivated, and more than 77% of the population depends on agriculture for their livelihoods, it is easy to see how the demand for farm land has led to the large scale clearing of forests. The population of Madagascar has more than tripled since 1950 (UN 2001), and continues to grow at nearly 3% per year (UNDP 2003), thus the demand for cultivable land is set to increase, and with it, the threat to its forests.

Although the majority of deforestation can be attributed to agricultural clearing, it is estimated that direct consumption of forest products accounts for between 5 and 20% of all deforestation (Jarialy). The Jariala programme estimated demand or consumption of woody forest products (fuelwood, charcoal, poles and lumber) would grow from 21.7 million m^3 per year in 2005 (Table 3.4) to more than 23 million m^3 per year by 2025.

Table 3.4: Estimation of annual consumption of various wood products (Jarialy)

Type of wood	Rural (m^3/pers)	Urban (m^3/pers)	Total (millions m^3)
Fuelwood	0.686	0.134	9.026
Charcoal	0	1.75	8.575
Construction	0.24	0.22	4.127

[99] http://www.worldwildlife.org
[100] http://www.worldwildlife.org

Total	0.93	1.97	21.728

The same report estimates that in the immediate future, the total amount of available forest product (wood) will be 18.5 million m^3, of which 7.9 million will be available for charcoal production and 5.7 million for construction and services (Jarialy). Importantly, the report points out that 20% of the total productivity for charcoal will be provided by eucalyptus plantations (Jarialy), as shown in Table 3.5. Total sustainable production is predicted to decrease by 100,000m^3 per year in the coming years. Given that consumption of forest products is set to increase, it is predicted that by 2025, forest production will no longer be able to meet demand (Jarialy).

Table 3.5: Assumptions of sustainable productivity per hectare for various types of forest

Forest Type	Average Annual increase (m^3/ha)
Dense Humid	5.89
Dense Dry	1.04
Thorny	0.84
Mangrove	5
Pine Plantation	15
Eucalyptus Plantation	20
Total:	47.77

Ref: Jarialy

3.4.3 Forestry Regulations

Commitment to the conservation of the natural environment is a key feature of the Madagascar Action Plan (MAD) and forest protection has been recognized by the Government as central to this aim. In 2003, the President of Madagascar reaffirmed the countries' commitment by announcing plans to expand national conservation areas from 1.7 million hectare in 2003 to 6 million hectare in 2008 (Jarialy). In 2004 an inter-ministerial decree was promulgated to ensure that conflicts between the mining and forest sectors would be avoided during the time that it takes to identify sites for protection and implement the required legislation. Under this decree, the granting of mining and forest licenses was suspended in the zones reserved as 'conservation sites' (Jarialy).

Madagascar is currently implementing the third phase of its 15-year National Environmental Action Plan (PNAE), with the support of a consortium of development assistance agencies through a well coordinated Environmental Program (EP3). Over the past 10 years, significant progress has been achieved in establishing a new National Environmental Office (ONE) and in restructuring the institutional framework for the management of Madagascar's national parks and protected areas (USAID, 2005). The network of parks and protected areas has greatly expanded, under management of a new institution, ANGAP (National Association for the Management of Protected Areas), as highlighted in Table 3.6.

Table 3.6: Forest Cover by Type of Protected Area

Category of Forest	Number	Total Surface Area	% of Total

		(ha)	
Integral Natural Reserve	8	329	4.6
National Park	15	1,007	14.2
Special Reserves	23	382	5.4
Classified Forests	166	2,735,836	38.6
Forest Reserves	89	1,494,939	21
Perimeters of Afforestation and Restoration	151	1,129,372	15.9
Forest Stations	2	17	0.3

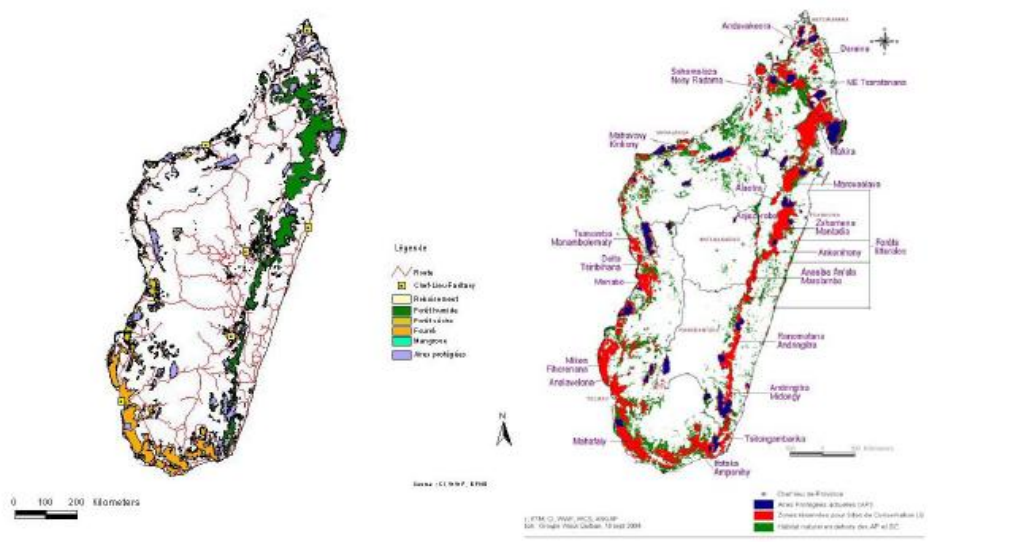
3.4.4 Problems of Governance

As mentioned previously, all natural forests are the property of the state and all extraction from forest areas (Figure 3.20), whether for commercial or subsistence purposes, even from private properties, requires a permit (World Bank, rural sector review, 2003). ANGAP exerts direct control over access to biodiversity resources within protected areas. However, in terms of regulating access to forest resources, the capacity of the forests administration is weak and is mostly restricted to issuing permits to commercial loggers at the regional level (World Bank, rural sector review, 2003). At the local level, permits are usually only issued for subsistence users if the forest administration is located nearby. Moreover, permits are often issued without any field verification or monitoring for compliance and in very remote areas where forests are abundant and the authorities are not present, and access to forests is often free and open (World Bank, rural sector review, 2003).

In more densely populated areas there is typically some sort of local regulation of forest access, usually connected to traditional land tenure rights and/or local taboos (World Bank, rural sector review, 2003). In areas where the state is also present, problems may arise when permits are issued for logging on land that is informally administered by the community (World Bank, rural sector review, 2003).

Generally, governance within the forestry sector is poor and is characterized by a high frequency of illegal permits for logging, failure to adhere to official quotas for protected species and a high level of tolerance for petty corruption within the forest institutions. It has been observed that the majority of forest products which arrive at the market, originate from illicit exploitation (Jarialy).

Figure 3.20: Increase in Natural Forest Conservation Zones (USAID, 2005)



Map 1: Prior to 2004, wood extraction was possible in 87% of the remaining natural forests of Madagascar

Map 2: As of December 2004, 74% of the natural forests are now or within proposed conservation sites (red zones)

Implications for the Household Ethanol Programme

The Ethanol as a Household Fuel Programme should not exacerbate existing challenges in the forest sector and should not add pressure to deforestation. Regulatory linkages between agriculture, energy and forestry are necessary in order to minimise negative impacts, offer livelihoods generating alternatives and reduce damage to the dwindling forest resources. A properly designed and implemented ethanol programme should by contrast reduce pressure on forests by growth of sustainable sugarcane and production of ethanol without unsustainable reliance on woodfuel.

3.8 Industrial Capacity

3.8.1 Transport Infrastructure

The national figure for road coverage in Madagascar is 6 kilometres of paved road per 100 square kilometres (World Bank sector review, 2003). Of about 50,000 km of classified roads or highways, only some 5,800 km are paved, or less than 10%[101]. The severely underdeveloped road network in rural Madagascar contributes to high levels of rural isolation and market stagnation and increases downstream collectors' margins to 17-25% (World Bank sector review, 2003).

Madagascar ranks 129th out of 134 countries in number of vehicles, equating to one motor vehicle per 100 persons, or one vehicle per quarter square mile. This may

[101] United Nations World Statistics Pocketbook and Statistical Yearbook 2008, accessed 8-16-10 at http://www.nationmaster.com/country/ma-madagascar/tra-transportation. See also: Africa South of the Sahara 2004, Europa Publications 2003, 33rd Edition, pp. 636-7.

mean that there are 200,000 to 250,000 vehicles operating in Madagascar, possibly 50% of which are spark engines (using gasoline), and 50% of which are compression-ignition engines (using diesel fuel). About 95,000 spark-ignition-engine vehicles were imported in 2008, and about 1,300 diesel-engine vehicles (UNdata, 2008)[102]. Madagascar ranks on a par with Nigeria, Ethiopia and Mali for number of vehicles per capita; among African countries, only Malawi ranks lower.

The northeast region of Madagascar includes Toamasina, Madagascar's major port, and secondary ports such as Manakara, Mananjary and Tolagnaro, which could be developed into attractive ports. However, road infrastructure remains very poor, limiting such development. Transportation in the Centre sub-region remains especially underdeveloped. There is no direct road connection from the populous Northeast to the populous Southeast sub-region, and the most accessible route is the Pangalanes canal (Minten, 2001), which runs 600 km from Toamasina to Farafangana, and not all of this length is navigable (Europa, 2003)[103]. The National Road (RN2) links the Northeast region to the Highlands from Toamasina through Antananarivo, while a series of roads link the Southeast to Fianarantsoa and then to the central Highlands. There is also the railway connecting Manakara to Fianarantsoa and three rail lines in the north, one linking Antananarivo to Toamasina; however, these lines are frequently damaged by cyclones.

Implications for the Household Ethanol Programme

A deficient roadway infrastructure could have serious negative implications for the expansion of industrial sugar and ethanol production and the development of a large domestic ethanol fuel market. A functioning road network is essential for transporting ethanol to distant cities and paved roads are important for the movement of heavy ethanol tankers, tandem tankers hauling upwards of 45,000 litres. The main large scale sugar and ethanol sites are in the North near Ambilobe and in other coastal areas such as Toliara, Ankaramena and Mahajanga, all distant from Antananarivo, with Brickaville-Toamasina being the sugar cane region closest to the capital. Is must be noted that an improved road network could give rise to a corresponding increase in road traffic as well as an increase in illegal logging and charcoal production (and reduced costs of transporting charcoal), as well as positively affecting ethanol production.

The absence of a well developed national highway system might be conducive to the development of more decentralised markets, and improving the rural road system is important for the development of smaller scale, less centralized alcohol production. This would be especially true for the small-producer model where farmers bring low grade ethanol to a central distillery for distillation.

Conversely the underdevelopment of the transportation system has positive implications for a household ethanol program, given that relatively few gasoline vehicles exist in Madagascar (possibly less than 150,000), with the demand for ethanol for gasoline fuel blending likely to be much less than in a country with a more vibrant transport sector. Projections from Ethiopia show that the stove fuel market is much larger than the gasoline fuel blending market, which is quite limited

Table 3.7 shows the 2010-11 projection of ethanol production in Ethiopia and the ethanol that will be consumed under a number of scenarios of the transport sector,

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[102] UN Data portal, accessed 8-16-10 at http://data.un.org/.
[103] Africa South of the Sahara 2004, Europa Publications 2003, 33rd ed., p. 636.

with the highlighted yellow rows being the most likely scenario. If the Ethiopian government decides to blend ethanol at a rate of 10% for automobiles in Addis Ababa and its region (65% of national use), 15.8 million litres will be required. As the projected production for 2010-11 is 18 million litres, this leaves a potential 2.2 million litres for stove fuel use. This scenario of a limited need for ethanol for fuel blending, but a large need for ethanol for a household fuel, is typical for many developing countries, including Madagascar.

Table 3.7 highlights that by 2015-16 over 111 million litres of ethanol will be produced and that only 20 million litres will be absorbed into the fuel blending market, leaving 91 million litres of ethanol for the stove fuel market, which is indicative of what might happen in Madagascar. Unless the Government values its local household fuel needs above its balance of payments, there is a serious risk that all the ethanol will go to developed countries, whilst imports of fossil fuels are not reduced.

Table 3.7: Projected Ethanol Markets in Ethiopia – Fuel Blending vs. Stove Fuel

Year	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Ethanol Production '000 litres	7,100	18,000	34,665	46,765	74,027	106,488	111,204
Ethanol Demand							
Gasoline consumption ('000 liters)							
Country Level	231,610	243,190	255,350	268,118	281,523	295,599	310,379
Addis Ababa (65% of country level)	150,547	158,074	165,978	174,277	182,990	192,139	201,746
Ethanol for Fuel blending							
5% blending rate							
Country Level		12,160	12,768	13,406	14,076	14,780	15,519
Addis Ababa	7,527	7,904	8,299	8,714	9,149	9,607	10,087
10% blending Rate							
Country Level		24,319	25,535	26,812	28,152	29,560	31,038
Addis Ababa		15,807	16,598	17,428	18,299	19,214	20,175
Ethanol available for cooking							
5% blending rate							
Country Level		5,841	21,898	33,359	59,951	91,708	95,685
Addis Ababa	-427	10,096	26,366	38,051	64,878	96,881	101,117
10% blending Rate							
Country Level		-6,319	9,130	19,953	45,875	76,928	80,166
Addis Ababa		2,193	18,067	29,337	55,728	87,274	91,029

(Ethiopian fuel blending and stove fuel scenarios for Ethiopia, Mekonnen Kassa for Project Gaia, July 2010, based on data from the Ethiopian Petroleum Enterprise Office, Addis Ababa.)

3.8.2 Technology and implementation

A series of technologies will be required in Madagascar if ethanol is to succeed as a household fuel including various production, processing and appliance technologies at various scales. Kenya, Zimbabwe and others have shown that it is possible to build a production system for ethanol using mainly indigenous resources, but it remains to be seen whether Madagascar can replicate this. However ethanol has been produced in Madagascar on an industrial in the past few decades and is widely produced on an artisanal scale. Therefore, the know-how on ethanol production, and growing and processing sugar cane, already exists in the country; Madagascar is no stranger to ethanol distillation. Some industrial capacity continues to exist for building, repairing and servicing distilleries, and local businesses were involved in the construction and repair of the Sirama distillery at Ambilobe.

There is a parallel interest in home and farm-scale distilleries and several were built to enable the ethanol stove testing (the Component A part of this study) to be carried out. Again, technology sharing will allow more advanced micro-distilleries to be built in Madagascar, with the right level of support. With the exception of the electronics and some valves and fittings, it is likely that a modern micro-distillery could be built in Madagascar. Eventually semi-standard models of micro distilleries could be developed, built in Madagascar, increasing the chances of wider dissemination.

Implications for the Household Ethanol Programme

Interest and expertise exists in Madagascar around ethanol production, processing and appliance technologies and should be built on and supported as far as possible in the evolution of a sustainable ethanol household fuel sector in Madagascar.

3.8.3 The Business Climate

In 2009, the World Bank ranked Madagascar 144 out of 181 countries for ease of doing business (World Bank, 2008). This ranking is based on how Madagascar features on a number of indicators relating to ease of conducting business, including, for example, starting a business, access to credit, payment of taxes, protection for investors and cross border trade.

One of the most important indicators for assessing a countries' business climate is the ease of starting a new business. When entrepreneurs draw up a business plan and get things under way, the first hurdle they face is the procedures required for incorporating and registering their new company to allow them to operate legally. Economies differ greatly in how they regulate the entry of new businesses; in some the process is straightforward and affordable; in others the procedures are so burdensome that entrepreneurs may need to bribe officials to speed up the process or may decide to run their business informally (World Bank 2008). In 2009 Madagascar was ranked 58 out of 181 economies (up from 65th place in 2008) for ease of starting a business. On average, it requires 5 procedures, takes 7 days, and costs about 11% GNI; overall, the number of required procedures, the time required and the cost involved in establishing a new business in Madagascar has decreased in recent years, and is well below the average when compared to Sub-Saharan Africa (World Bank, 2008).

However, obtaining a construction permit is significantly more time consuming and expensive. On this indicator, Madagascar ranks 102 out of 181 economies, up from 136 in 2008 (World Bank, 2008). On average, it requires 16 procedures, takes 178 days, and costs almost 765% GNI per capita to build a warehouse in Madagascar (World Bank, 2008).

Registering property and titling land is extremely important for economic development and is a key indicator for ease of doing business. The inherent problems in the land tenure system in Madagascar have been discussed in previous sections and these constraints are reflected in Madagascar's ranking regarding property registration; in 2009, Madagascar was ranked 145 (up from 168 in 2008) for ease of registering property. On average, the process requires 7 procedures, which is much higher than the average in Sub-Saharan Africa. Moreover, it takes 74 days, and costs almost 8% of property value to register the property in Madagascar (World Bank).

Lack of access to credit is often one of greatest barriers to starting a business. As mentioned above, a lack of access to credit is a major reason for economic stagnation in the agricultural sector in Madagascar. Not surprisingly, Madagascar is not highly ranked in this regard. In 2009, the country was placed 172 out of 181 for ease of access to credit. This represents a deterioration of 1 place, from 171 in 2008 (World Bank, 2008).

Implications for the Household Ethanol Programme

Although Madagascar is showing improvement in overall ranking in terms of ease of doing business, there is still a long way to go in terms of improving its ranking in terms of indicators such as access to credit and property registration, crucial to starting a new business, as well as actually doing business. Complicated, expensive and time consuming procedures for titling land, constructing buildings and registering property could prove to be major disincentives for investment in ethanol production at any scale in Madagascar. Access to credit and difficulties securing land tenure could make it extremely challenging, if not impossible to regulate small-scale artisanal ethanol production.

3.9. Conclusions

The total surface area of Madagascar is 587,041 square kilometres and about one-half is cultivable, but little more than 5% of the land is currently under crops, with a large part of this cultivated area under irrigation (40%)[1]. Of this, less than 2 million hectares is permanently cultivated; taken together cropland and crop/natural vegetation mosaic accounts for 13% of land cover. Approximately 21% of the total land area is covered by forests and 63% by shrubland, grassland and savanna. However the demand for cultivatable land is on the increase, and is not being matched with an increase in land allocated for agricultural use. Any expansion of sugarcane production needs to ensure it does not encroach on sensitive ecosystems and land required for agriculture and food production, and that sugar cane production does not result in food price rises and decrease food security. The lack of clear land ownership and land tenuring, with an estimated 90% of land titles for 90% of land, is believed to be a real hinderance to farmers investing in land and still needs to be addressed. Farmers are unlikely to invest in small-scale sugar cane production without greater security of land ownership. Madagascar's weak land tax system is equally hindering the investment in land by farmers, such as sugar cane production. Madagascar has a recent history of land degradation and any increase in sugar cane production must be sure to not result in forest clearance or increased land degradation. In general the agriculture system in Madagascar underperforms, and requires significant investment in improved techniques and technologies to improve soil quality and production. The use of land for sugar cane to produce sugar and ethanol has the great potential to reduce poverty if managed effectively, but requires a strategic and large scale investment to ensure high yields can be achieved sustainably. Producer cooperatives and associations might be an avenue for increasing productivity and ensuring the local farmers derive the most benefits. A large scale sugar cane initiative can learn lessons from other sectors such as rice production which has recently gone through significant changes to allow farmers to diversify into this potentially profitable production area. One concern is the amount of water that sugar cane requires and this needs to be factored into any production plans. The extent to which foreign investment is sought to increase sugar cane production needs to be carefully assessed to ensure that benefits to local farmers are maximised and the household ethanol fuel market is not ignored. To ensure that the potential benefits of sugar cane production to increase ethanol supply, it needs to be fully integrated into the national agricultural planning.

Madagascar has both on and offshore oil and gas deposits but none are yet commercial and it imports all its fossil fuels. Madagascar is very susceptible to increases in oil price rises and so local production of fuels such as ethanol would be of great benefit to the country. The use of ethanol as a household fuel would create a large sustainable market local that would result in a number of significant benefits to the country. Currently Madagascar's sugar cane production is quite low and there is significant potential to increase its production through just efficiencies and technology. Small-scale sugar cane production is also widespread, but generally with very low yields, and almost exclusively used to produce toaka gasy, the locally manufacturer rum for human consumption. Ethanol production has been growing globally with Brazil and USA being the main producers, but with other actors such as China increasing production, largely due to its increased as a blended fuel for transportation. The supply of ethanol in Madagascar is set to increase steadily over the next 5 years, which could be directed towards use as a household cooking fuel. It has been suggested that artisanal toaska gasy production could be improved, to be used as a fuel instead, but it is unlikely that ethanol of a high enough grade can be produced efficiently, sustainably and competitively from such scale of production, and it is recommended that the installation of micro-distilleries be promoted instead of artisanal scale production. Both wood and charcoal use in Madagascar has been growing steadily, and has directly led to increased deforestation. Electricity is generally not used for cooking, and Kerosene and LPG only accounts for a relatively small sector of the market, compared to both charcoal and wood, particularly in rural areas. Madagascar's forests are some of the most diverse and fragile in the world and increased efforts need to be made to reduce their destruction. This can be carried out through investment in sustainable forest management and more efficient charcoal production, but serious consideration needs to be given to how ethanol production for household fuel can contribute to protecting Madagascar's forests. The transport of household cooking fuels is a big issue in Madagascar, particularly due to the relatively poor road network, which is another reason why micro-distilleries located throughout Madagascar could make a lot of sense for developing a more decentralised sustainable energy production.

References

Gupta, S, Pattillo, C and Wagh, S, Impact of Remittances on Poverty and Financial Development in Sub-Saharan Africa, IMF Working Paper WP/07/38, Feb 2007.

African Economic Outlook – Madagascar, AfDB/OECD 2007. Accessed on the web 1-20-10 at http://www.oecd.org/dataoecd/26/35/38562837.pdf

4. Madagascar Demand Scenario

4.1. Socio-demographics for households in Madagascar

4.1.1. Poverty levels

The household energy demand in Madagascar is greatly influenced by its poverty rate, which soared to 80.7% in 2002 in the crisis following the contested presidential elections in 2001, well above the 70% rate of 1990. Subsequently, the poverty rate fell to 67.5% by 2006, but still very far from the nation's poverty reduction goal of 35% by 2015. The relatively small impact that strong economic growth has had on poverty reduction is likely the result of the type of growth Madagascar has recently experienced, with large, capital-intensive mining projects having limited linkages with the local economy. (African Economic Outlook).

The World Bank poverty assessment estimates that 70% of the population can be defined as being poor while 59% are extremely poor. Almost 80% of the rural population is poor compared with about 50% of the urban population. Two-thirds of the rural population is extremely poor and a third of the urban population (World Bank Poverty Profile for Madagascar, http://go.worldbank.org/UBQUYJZEM0, accessed 10-10-09).

Education Levels in Madagascar

The country has made major progress in universal primary education, with enrolment rising from 71% in 1997 to 96.2% in 2006. The primary education completion rate rose from 39% in 2002 to 52% in 2006. The government is now raising compulsory school attendance from five to seven years, which should be in effect nationwide by 2012. The provision of safe drinking water, school kits and canteen services at school has helped boost attendance, as well as the recent increase in the Ministry of Education's budget (African Economic Outlook).

Many children from the poorest quintiles still don't enter school, and the result is that families in the lower quintiles receive less support from the government than children in the higher quintiles, because they access the delivery systems, such as primary school, less frequently.

The primary-level education subsidy is the most equitably distributed among all wealth quintiles. At the secondary level, the subsidy is biased heavily towards the richest quintiles, with the richest quintile receiving about 10 times the amount received by the poorest quintile on a per capita basis. At the tertiary level, the average per capita subsidy is absorbed almost entirely by the richest quintile. Students in urban areas receive a per capita subsidy that is three times larger than which students in rural areas receive (World Bank Poverty Profile). If the educated person does not find proper employment and emigrates abroad, as part of an employed diaspora, this educated member may still affect consumption patterns at home, and may in fact purchase consumer goods for the extended family through remittances which he or she sends home periodically (Gupta, et al, 2007). The effect of remittances on consumer purchases is discussed in more detail in Annex 6.

4.2. Madagascar's household energy market

4.2.1. Household energy distribution

It is estimated that 95% of households in Madagascar depend on woody biomass, primarily fuelwood and charcoal, for their household energy needs, although LPG is used by around 10% in the larger towns. According to the USAID-funded IRG/Jariala report on production and consumption of woody biomass, Madagascan families annually consume approximately 9.026 million m^3 of wood as firewood and 8.575 million m^3 as charcoal, as shown in Table 4.1 (IRG Jariala, 2005).

4.2.2. Energy Consumption by End-Use Device

The amount of fuel consumed by the domestic sector depends on the type of stove used, and is presented, per annum, in Table 4.1. Per capita energy consumption by fuelwood stoves is less than that of charcoal stoves, and for both wood fuel and charcoal stoves the energy consumption is less when an improved stove is used (Table 4.1).

Table 4.1: Per Annum Energy Consumption by the Domestic Sector End-Use Devices

End-use device	Energy consumption/annum (kg)	
	Per capita	Per family
Charcoal	-	-
Improved metal stoves [104]	100	495
Improved clay stoves [105]	100	460
Traditional stoves [106]	135	660
Fuelwood	-	-
Improved metal stoves [107]	80	390
Improved clay stoves [108]	66	325
Traditional stoves [109]	-	-

N.B. Number of persons per family is assumed to be 4

Within Madagascar as a whole, the monthly household energy consumption and expenditure in various cities is presented in Table 4.2 (Bazile), and shows that the highest share of monthly expenditure for fuelwood and charcoal is demonstrated by Toliara. It also shows that most city households use charcoal (79%) rather than wood fuel (18%).

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[104] http//www.hedon.info/improvedstovesAsAMeansOfPovertyAlleviation
[105] http//www.hedon.info/improvedstovesAsAMeansOfPovertyAlleviation
[106] http:/ieea.erba.hu/ieea/fileshow.jsp?att_id=64141
[107] http//www.hedon.info/improvedstovesAsAMeansOfPovertyAlleviation
[108] http//www.andrewleestrust.org/Reports/energy-fact-en-May08pdf
[109] http//www.hedon.info/improvedstovesAsAMeansOfPreventingDeforestatio-MythOrReality

Table 4.2: Monthly Energy Consumption in Various Cities of Madagascar

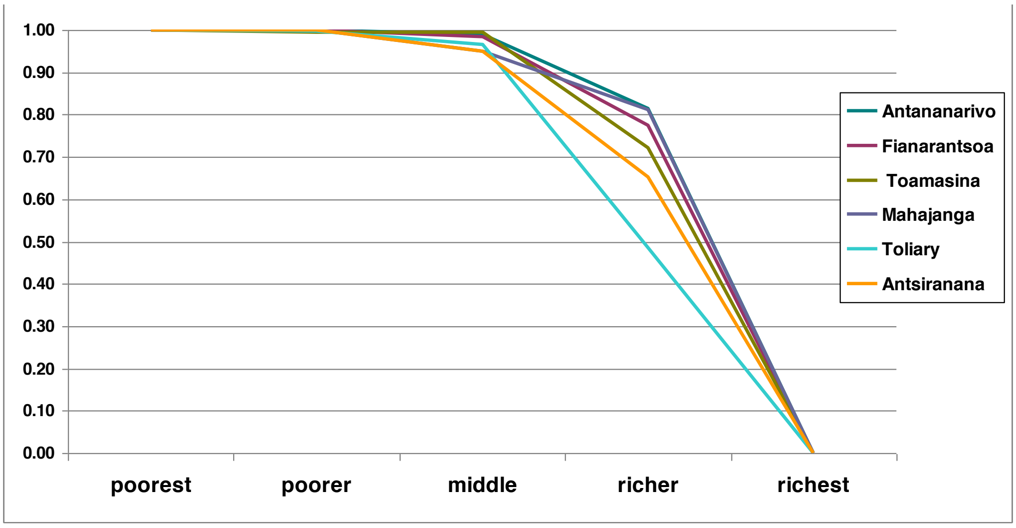
	Main users		Costs (FMG/month)	
City	Charcoal	Firewood	Charcoal	Firewood
Ambatolampy	69	27	37862	25955
Arivonimamo	66	34	35825	28752
Miarinarivo	44	53	45882	33069
Tsiroanomandidy	63	33	31826	25955
Toamasina	69	12	32183	36811
Ambatondrazaka	62	31	21956	31526
Vatomandry	14	81	21364	18173
Mahanoro	25	72	17448	18083
Toliara	79	18	48284	51635
Tolagnaro	71	28	39314	26070
Betioky	50	50	28397	41266
Ambovombe	23	77	45075	48278
Fianarantsoa	71	26	31688	24265
Ihosy	51	48	45382	36807
Ambositra	47	51	36467	13429
Ambalavao	66	34	21745	30097

[1] As per April 1, 2001, 1USD = 6750 FMG (Malagasy francs)

4.2.3. Energy Use by Income Group

Fuelwood is the predominant fuel for poorest, poorer and middle income quintiles, whilst charcoal predominates for the richer and richest quintiles (Figure 4.1). Electricity, natural gas and kerosene captures very little of the market even for the richest quintile (Figure 4.2).

Figure 4.1: Fraction of households with firewood as primary cooking fuel by wealth quintile and region, Madagascar 2003



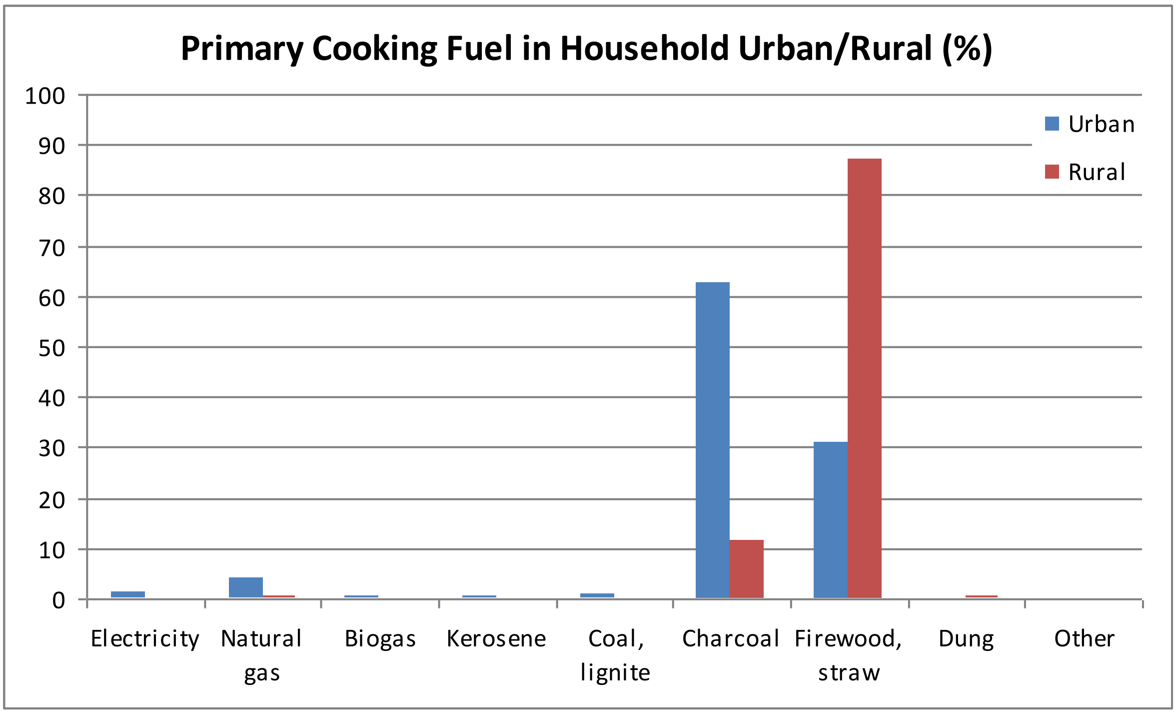
The table shows that 100% of the poorest and the poorer, 98% of middle income, and 74% of the richer group rely heavily on fuelwood and straw; while, in the reverse order 90% of the richest income group, 24% of the richer and 2% of the middle income group use charcoal fuel.

Table 4.3: Primary Household Cooking Fuel by Wealth Quintile (%)

Wealth quintile	Electri-city	Natural Gas	Bio-gas	Kero-sene	Coal, Lignite	Char-coal	Fuelwood or straw	Dung	Other	Total
Poorest	0	0	0	0	0	0	100	0	0	100
Poorer	0	0	0	0	0	0	100	0	0	100
Middle	0	0	0	0	0	2	98	0	0	100
Richer	0	0	0	0	1	24	74	1	0	100
Richest	2	6	1	0	1	90	0	0	0	100
Total	1	3	0	0	0	43	52	0	0%	100

Source: Demographic and Health Survey, Madagascar 2003

Figure 4.2: Primary Household Cooking Fuel in Urban/Rural Areas



Source: Demographic and Health Survey, Madagascar 2003

Table 4.4: Estimation of annual consumption of various wood products (Jariala)

Type of wood	Rural (m^3/pers)	Urban (m^3/pers)	Total (millions m^3)
Fuelwood	0.686	0.134	9.026
Charcoal	0	1.75	8.575
Construction	0.24	0.22	4.127
Total	0.93	1.97	21.728

Figure 4.2 and Table 4.4 highlight a picture of primary household cooking fuel use in Madagascar, taken from the Demographic and Health Survey (EDSMD-III) undertaken in Madagascar from November 2003 to March 2004. In particular it highlights the predominance of wood over charcoal use. Although charcoal dominates in the cities, wood use dominates overall. The EDSMD-III[110] contains information collected from 8,420 households, 7,949 women aged 15-49 and 2,432 men aged 15-59 years. The results are significant at the level of residence (capital, other cities, total urban and rural) and at the level of the six provinces. The data was sorted by fuel use, residence type, location and family income.

Table 4.5: Use of Wood and Charcoal for Household Cooking by Wealth Quintile (%)

Primary Fuel for Cooking based on Household Report (Wood & Charcoal)					
Wealth Quintile	Charcoal	Firewood/straw	Dung	Other	Total
poorest	0%	100%	0%	0%	100%
poorer	0%	100%	0%	0%	100%
middle	2%	98%	0%	0%	100%
richer	24%	74%	1%	0%	99%
richest	90%	0%	0%	0%	90%
Notes:					
Based on a sample size of 8414 households					
Source: Demographic and Health Survey, Madagascar 2003					

Those that use wood typically fall into the rural and/or lower income category. Those that rely on charcoal typically fall into the urban and/or higher income category, as shown in Table 4.5 (Demographic and Health Survey Madagascar, 2003).

Urban energy use

Charcoal is the primary cooking fuel in approximately 63% of urban homes and almost 80% of homes in the capital or main province cities, while 15% of homes in the main cities use modern fuels like electricity and LPG (Table 4.6). Almost no kerosene is used for cooking. These households belong primarily to the two highest wealth quintiles of the population. Charcoal use remains high in smaller cities, but drops off steeply in rural areas, where most of the workforce is employed in agricultural labour (Table 4.4). In Antananarivo province, 86% of the wealthiest quintile use charcoal, which climbs to 96% in Fianarantsoa province and 98% in Toamasina and Toliary provinces. But charcoal use drops off very quickly for the second wealth quintile and is barely used by the third. For Toliary charcoal use drops to 49% for the second quintile and 4% for the third. This pattern is consistent throughout the country.

Use of natural gas (LPG or bottled gas) is recorded as almost 11% of the main cities, but negligible in the small cities. This suggests that bottled gas use could be greater if a distribution infrastructure were built to supply the smaller cities, however, since

[110] Institut National de la Statistique (INSTAT) [Madagascar] and ORC Macro. 2005. Enquête Démographique et de Santé, Madagascar 2003–2004: Rapport de synthèse. Calverton, Maryland, USA: INSTAT and ORC Macro.

roads are narrow and sometimes unimproved, and the distances are often quite long, this may be a barrier and may be the reason why bottled gas use does not show up in the small cities. Since charcoal use is still large in the small cities, at 55.5%, and this is the preferred fuel of the wealthiest quintile, it suggests that bottled gas use could be higher.

Bottled gas supply and distribution are highly centralized and charcoal supply and distribution highly localized. Bottled gas use drops off by 90% from large to small cities, while charcoal use only drops by 30%. Some use of bottled gas shows up in the countryside, although this is very small. Almost no kerosene is used for cooking, whether in main cities, small cities, or the countryside.

Table 4.6: Primary Cooking Fuel Use by Residence Type and Urban/Rural Status

Primary Cooking Fuel in Household by Capital city/Urban/Rural Status (%)					Primary Cooking Fuel in Household by Urban/Rural Status (%)		
Fuel Type	Capital	Small City	Rural		Fuel Type	Urban	Rural
Electricity	2.63	0.48	0.06		Electricity	1.11	0.06
Natural gas	10.66	1.1	0.47		Natural gas	3.88	0.47
Biogas	1.51	0.03	0		Biogas	0.46	0
Kerosene	0.66	0.08	0.06		Kerosene	0.25	0.06
Coal, lignite	0.53	0.67	0.16		Coal, lignite	0.63	0.16
Charcoal	79.86	55.51	11.52		Charcoal	62.57	11.52
Firewood, straw	3.55	42.01	87.47		Firewood	30.86	87.47
Dung	0.53	0.05	0.22		Dung	0.19	0.22
Other	0.07	0.05	0.03		Other	0.06	0.03

Source: Demographic and Health Survey, Madagascar 2003

Firewood as the primary fuel is used in only 3.55% of households in the main cities while it is close to parity with charcoal in the small cities and dominates in the countryside at almost 90%.

Rural energy use

The USAID-funded Jariala Report (2005) estimates annual consumption of firewood in rural areas at between 480 kg and 945 kg per capita, while in the urban areas, per capita annual consumption of firewood is estimated at only 94 kg. Annual charcoal consumption per capita in the urban areas is estimated to be 110 kg (IRG Jariala Report, 2005)[111].

[111] Support Sustainable Environment and Forest Management in Madagascar, Report on an Action Plan to improve Governance in the Forestry Sector, International Resources Group (IRG), January 2005. Jariala is the Malagasy name for the USAID funded SEFEM project/ IRG contract.

In rural households the primary source of energy is fuelwood, followed by charcoal. By contrast, in urban areas charcoal is the most commonly used household fuel. According to IRG Jariala, current annual consumption of fuelwood in rural areas is in the range of 480 to 945 kg per capita per year, which is quite high, while in the urban areas, per capita annual consumption of fuelwood is approximately 94 kg per year. Total annual consumption of fuelwood was estimated as 9.02 million m^3 in 2005 of which 8.37 m^3 was consumed in rural areas and 0.65 m^3 in urban areas. Moreover, annual charcoal consumption per capita in the urban areas is estimated was estimated at 110 kg (IRG Jariala 2005).

4.2.4. Cooking Energy Used by Regions

It can be seen that by provincial region, the proportionate use of wood and charcoal is fairly consistent, with the exception of Antananarivo province, which shows a reverse relationship between wood and charcoal use (Table 4.7).

In Fianarantsoa, charcoal use is around one third of wood use, while it is has been calculated as 50%, 53%, 48% and 78% of wood use in Toamasina, Mahajanga, Toliary, and Antsiranana provinces, respectively. On the other hand, it is more than twice the wood use in Antananarivo province. This is the wealthiest region, with the most widely spread cash economy, and no doubt it is the top two or three wealth quintiles, particularly in terms of income, that are responsible for this high rate of charcoal use. This suggests that there is a significant commercial trade of charcoal into Antananarivo province and into the city in particular.

As detailed in Table 4.7, charcoal and fuelwood are the main household fuels used in most regions of Madagascar. Antananarivo predominantly uses charcoal (62%), but correspondingly uses less wood fuel, whilst Fianararitsoa predominantly uses wood fuel (72%), but uses less wood than the rest of the indicated regions.

Table 4.7: Primary Energy used for Cooking by Region, Madagascar 2003

Fuel Type	Antanana	Fianaran	Toamasin	Mahajang	Toliary	Antsiran
Dung	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Biogas	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Charcoal	62.00%	27.00%	33.00%	34.00%	32.00%	42.00%
Kerosene	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Electricity	2.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal, lignite	0.00%	0.00%	0.00%	1.00%	1.00%	1.00%
Firewood, straw	28.00%	72.00%	66.00%	64.00%	67.00%	54.00%
Natural gas	6.00%	0.00%	0.00%	1.00%	0.00%	2.00%
Source: Demographic and Health Survey, Madagascar 2003						

4.2.4.1 Future trends

The household sector in Madagascar is expected to be heavily dependent on wood fuels for some time to come, with the FAO predicting an increase in household wood fuel consumption (Figure 4.3), with little substitution with electricity or kerosene due to the high cost of the fuels and appliances (FOSA, 2000). Moreover, without significant investment in the development of hydropower, it is unlikely that electricity will be an affordable option for the average household in Madagascar (FOSA, 2000).

Figure 4.3: Predicted Trends in Household Biomass Energy Use, Madagascar (FOSA 2000)

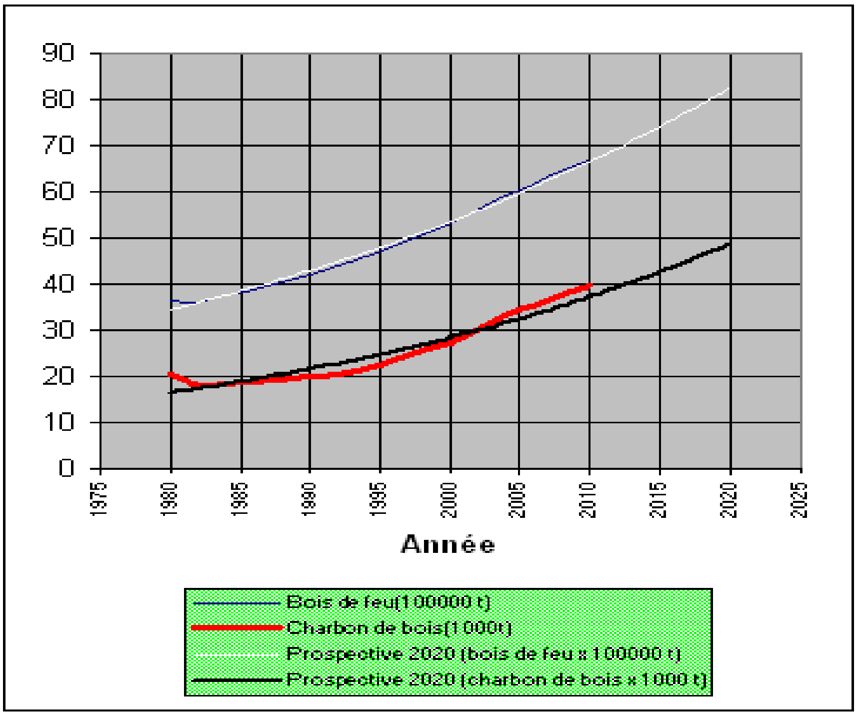
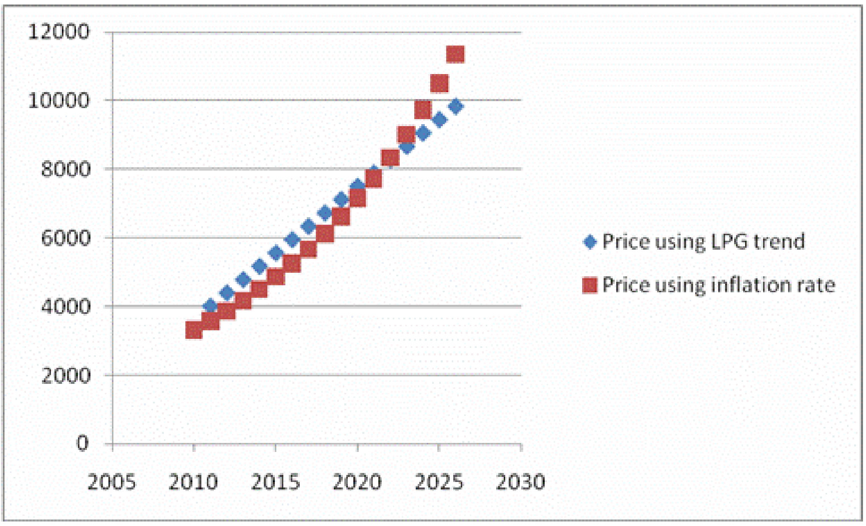


Figure 4.4 predicts how the price of LPG is likely to rise over the next twenty years, taking into account the historical price trends of LPG plus the inflation rate. The LPG price has been increasing steadily, noticeable even on a monthly basis, and from January to September 2010, the price of LPG increased by about 135% (Source: Interview with Vitogaz personnel - VitoGAZ Madagascar).

Figure 4.4: Prediction Curve for Price of LPG in Madagascar



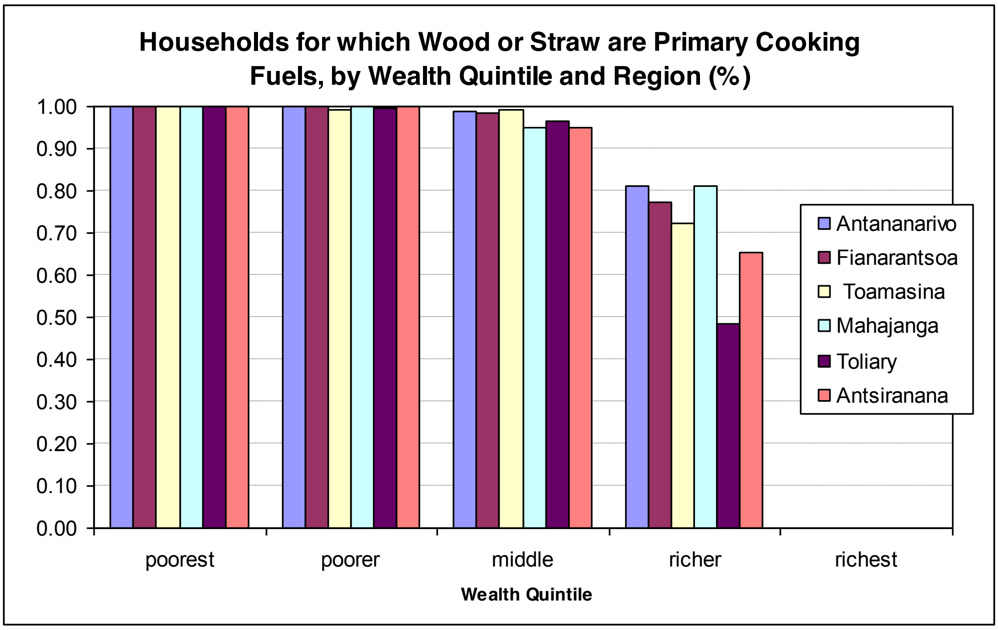
Source: Price history for LPG trend provided by Edouard de Montmarin of VitoGaz, April 14, 2010.

4.2.5 Fuel use by type

4.2.5.1 Fuelwood

Under the law of Madagascar, rural households have certain rights to the wood from non-protected forests and woodlots close to their villages. Fuelwood may be extracted free of charge provided that it is not commercially traded. An official permit must be obtained in order to sell wood, however illegal cutting is commonplace, particularly in areas where fuelwood is in short supply.

Figure 4.5: Households Wood Fuel as Primary Fuel Use – Madagascar



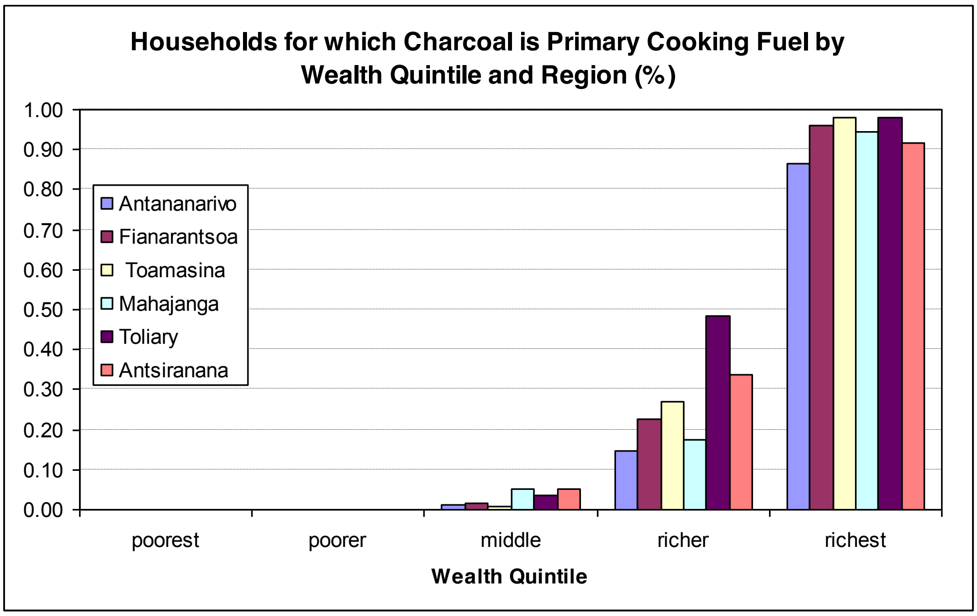
Source: Demographic and Health Survey Madagascar 2003

Madagascar's urban population is estimated at 30% of the total, with the urban population growing at an estimated 3.8 to 4.5% (World Fact Book 2009 and UNEP 2008).

4.2.5.2 Charcoal

Charcoal is a very popular cooking fuel as it is easy to transport (because it is lightweight), store and use, and because it is relatively smokeless and has an energy content double that of fuelwood (IRG Jariala 2005). It is the preferred cooking fuel in Madagascar, chosen over fuelwood by those who can afford it in all regions.

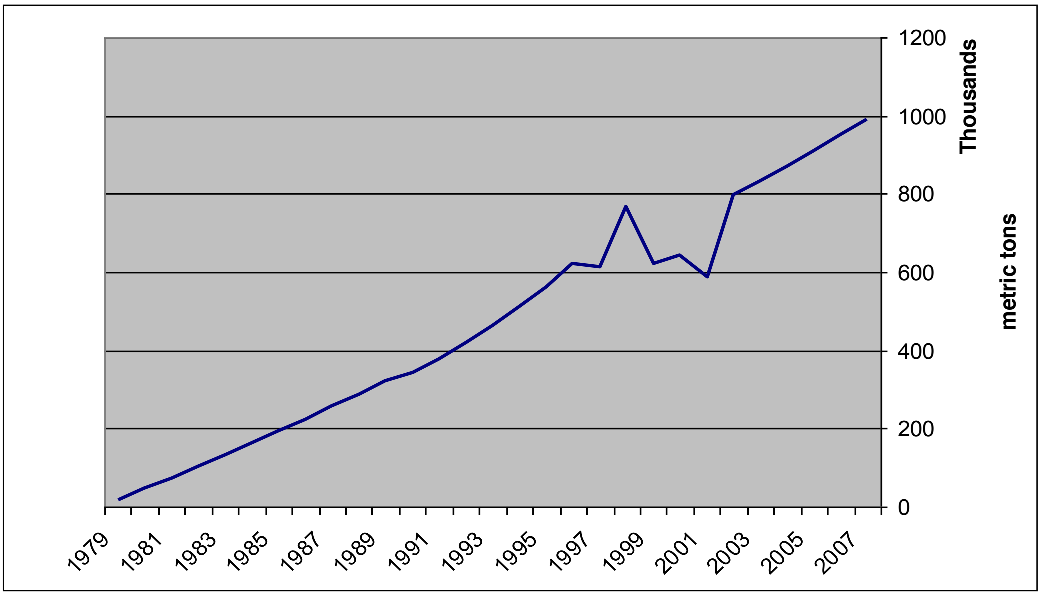
Figure 4.6: Household Charcoal as Primary Fuel Use - Madagascar



Source: Demographic and Health Survey Madagascar 2003

Consumers in the top three wealth quintiles use charcoal, although this usage rate drops precipitously, from 85% to 95% for the highest quintile, from 15% to 50% for the second quintile, and from 2% to 6% for the third quintile (Table 3.2). .

Figure 4.7: Growth in Charcoal Consumption 1979–2007



Ref: UN Data

4.2.5.3 Electricity

The national electricity coverage rate is 15% (MAP), with less than 3% of people living in rural areas having access to electricity. Hydro power accounts for 66% of electricity generation and thermal plants for 34% (IAEA, 2008). Total annual electricity production in 2005 was only 0.83 TWh (IAEA, 2008). Figure 4.8 shows the lack of correlation between the household electricity service and electricity supplied cooking. Even in Antananarivo where 31% of households receive electricity, the DHS 2008-9 household surveys, show that only 0.5% of households claim to use electricity as their primary means of cooking; of these households 34.8% use charcoal as their primary fuel and 62.8% use wood. Thus, it can be seen that electricity is not likely to be an important source of cooking energy in Madagascar for the foreseeable future. It is in fact unlikely that enough electricity could be generated to meet a large cooking load. Promoting electricity for cooking could be ill-advised for this and other reasons, one of which is that electricity is perhaps more urgently needed for industry and commerce than for use in cooking at relatively low efficiency rates when compared to the direct combustion of modern fuels in efficient stoves[112].

[112] Source: Macro International Inc, 2010. MEASURE DHS STATcompiler. http://www.measuredhs.com, September 2 2010.

Figure 4.8: Correlation of Electricity in House and Type of Cooking[113]

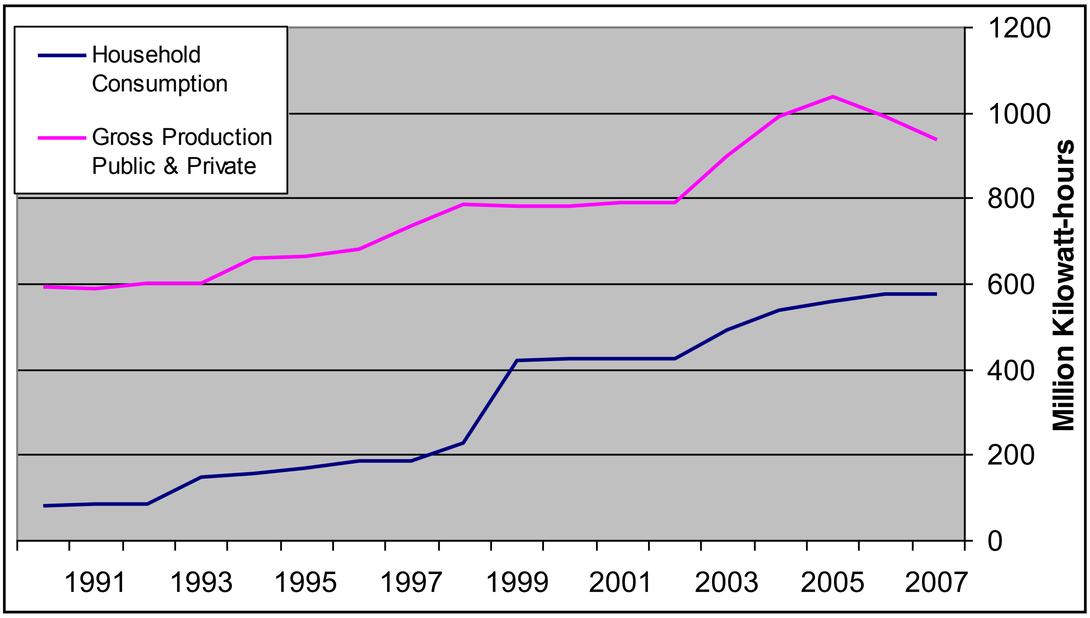
Housing characteristics										
	Electricity in House			Type of cooking fuel						
	No	Yes	No Data	Electricity	LPG, natural gas	Biogas	Kerosene	Coal, lignite	Charcoal	Wood, straw
Madagascar 2008-09 (1)										
Region										
Antananarivo	68.9	31	0	0.5	1.4	0.2	0.1	0.1	34.8	62.8
Analamanga	48.7	51.3	0	0.8	2.5	0.4	0.1	0.2	56.5	39.3
Vakinankarata	87.8	12.2	0	0.2	0.1	0.1	0	0	14.3	85.3
Itasy	91.3	8.7	0	0.1	0.4	0	0	0.1	10.3	89.1
Bongolava	94.7	5.3	0	0.1	0	0	0	0	9.4	90.4
Fianarantsoa	91.8	8.2	0	0	0	0	0	0.1	15.1	84.3
Residence										
Urban	31.4	68.6	0	0.7	2	0.6	0.1	0.3	74.7	21.3
Rural	91.8	8.2	0	0.1	0.2	0	0	0	14.1	85.3
Madagascar 2003-04										
Region										
Antananarivo	55.6	44.4	0	0.7	3	0.2	0.3	0.5	47.7	46.8
Fianarantsoa	92.2	7.6	0.2	0.1	0.1	0	0	0	10.9	88.5
Residence										
Urban	47.3	52.7	0.1	0.9	2.7	0.3	0.2	0.7	59.4	35.5
Rural	89.1	10.8	0.1	0.1	0.6	0	0.1	0.2	15.2	83.3

In rural areas only between 0.02 to 0.07% of households has access to electricity (INSTAT/DSM/EPM, 2005). Electricity production peaked in 2004 (Figure 4.9) due to a large increase in the number of industrial subscribers while household accounts have increased slowly but steadily (UN Data). Electricity in Madagascar has been heavily subsidized since the 1970s, through the state-run electricity provider, JIRAMA, which relies heavily on diesel-fuelled thermal power plants for its electricity generation, with many of its power plants being outdated and in need of substantial repair. The rising cost of oil over the past two decades has led to the gradual erosion of subsidies and significant increases in the cost of electricity to consumers. In 2005, when JIRAMA was forced to cut back on its consumption of diesel fuel for power generation, the result was widespread blackouts which crippled businesses and caused public protests (BBC, December 2006), and these public protests spurred by electricity outages continued well into 2007 (BBC, May 17, 2007).

Electricity consumption by households increased throughout the decade, but the rate of growth was much lower than the 1990's. The rate of growth in the 90s was 550%, but between 2000 and 2008 it fell to 144% and almost flat between 2005 and 2008 (Figure 4.9).

[113] DHS Online Data Statcompiler, DHS Data for 2008-9 and 2003-4. Accessed 8-15-10 at http://www.statcompiler.com/start.cfm?userid=320470&usertabid=345779&action=on&catflag=1&CFID=9082187&CFTOKEN=61833650&_#indicators.

Figure 4.9: Evolution of Electricity consumption by households and industries



The cost of electricity in Madagascar is high relative to other Sub-Saharan African nations, and rates throughout Sub-Sahara Africa are some of the highest in the world, while consumer subscription rates are the lowest. The high cost of electricity is retarding the growth of industry and the expansion of residential customers in Madagascar; only 15% of the population benefit from electrification (Table 4.8). Frequent power cuts and power outages have forced increased reliance on diesel generators, which is a very costly way of producing electricity. A plan in 2007 to raise electricity rates was put off to avoid hurting consumers, already affected by the rapid increase in petroleum fuel prices. When the rate increase finally came, in October 2008, it was a sizeable 15%, but still meant that JIRAMA did not start making profits for another year, and requiring a government subsidy in 2008 of 0.5% of GDP (IMF Country Report No. 09/11, January 2009).

Both the Madagascar Action Plan (MAP) and the IMF call for the restructuring of JIRAMA, to modernize it and bring new power generation online, and several new electricity plants were commissioned in 2008. MAP calls for some deregulation in the power sector with more power to be generated by Independent Power Producers (Business Week, Special Section, January 22, 2009).

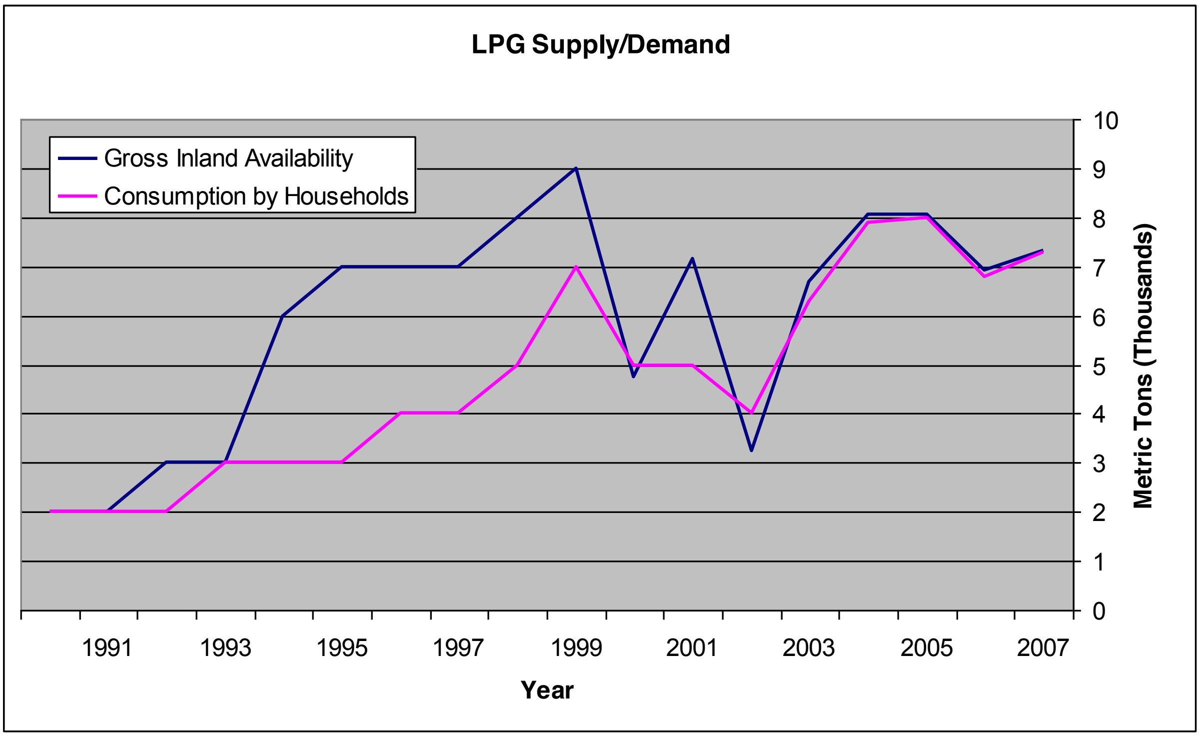
4.2.5.4 Kerosene and LPG

Liquified Petroleum Gas (LPG) or bottled gas is a much more important cooking fuel in Madagascar than kerosene, which is little used for cooking. The Demographic and Health Survey of 2003 showed that in the main cities, 10.66% use LPG whilst only 0.66% of homes use kerosene as their primary cooking fuel. The current cost of kerosene is about 2,000 MGA per litre (about US$1), and a kerosene stove costs about 28,000 MGA ($14.50) (Tany Meva, 2010). LPG costs 56,000 MGA for a 12.5 kilogram bottle and 170,000 MGA for a 39 kilogram bottle (Ministry of Energy and Mines, 2009). Household consumption of kerosene is currently at 110,000 MT per annum, is used by approximately 4.19% of households in Antananarivo, and costs MGA 2000 per litre (2008).

Another report places the average price of LPG at 4,000 to 4,500 MGA per kilogram, and small 4-9 kg bottles of LPG are available for household use as well as the standard 12.5 kilogram bottle (Tiana Razafindrakoto, 2010). A small gas bottle was introduced by Vitogaz, but because of lack of response has been discontinued. The smallest bottle currently available is 9 kg. Madagascar depends entirely on foreign imports to satisfy its petroleum fuel needs, but until 2005 engaged in refining of petroleum fuels for a share of its local needs, as well as for export. It has been reported that domestic refining has ceased since 2005.

The supply of all kerosene and LPG in Madagascar comes from imports, either directly or from refining from crude petroleum. Figure 4.10 shows the supply and demand of LPG between 1991 and 2007.

Figure 4.10: LPG Supply and Demand from 1991-2007 in Madagascar



Source: UNData for Madagascar (Accessed 6-15-10)

The spike in LPG usage most likely corresponds to the start of operations of a new local LPG producing company called Vitogaz (http://www.vitogaz.mg/index.html) in 2005. Raw materials are imported to Madagascar and the final product is produced at a local refinery. The bottled gas from Vitogaz is in direct competition with another gas bottling company, the Galana refinery, which is the former state-owned SOLIMA Company.

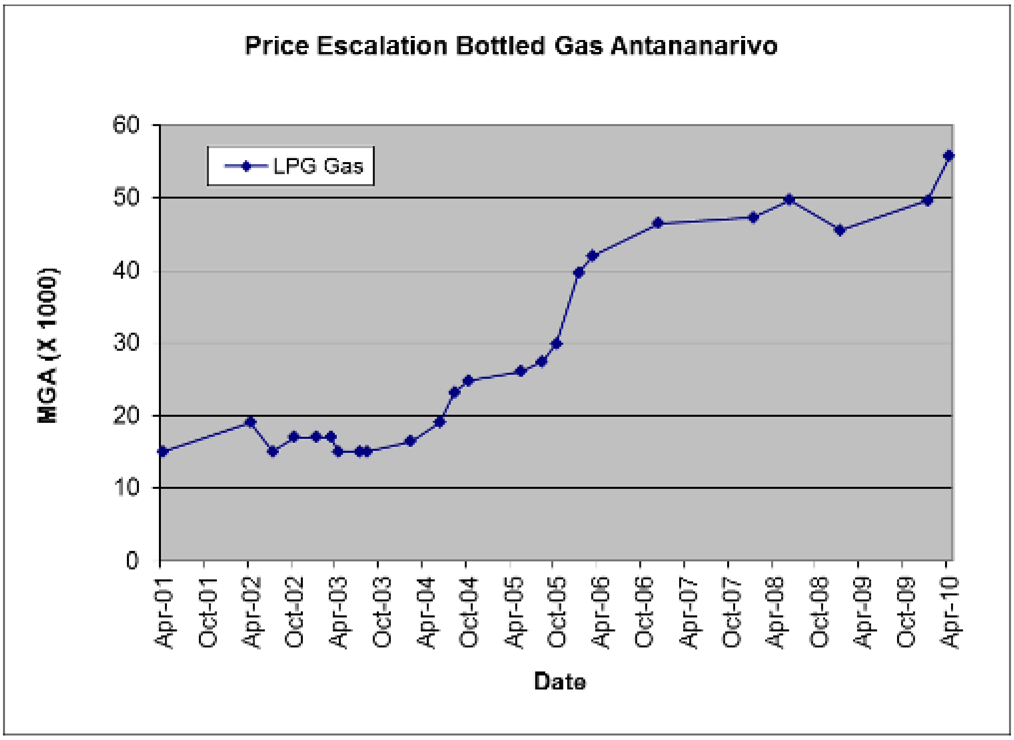
Vitogaz launched with a half-sized bottle of 3.5 kg to try to reach the maximum number of families, and organized a big campaign including a cheap gas stove directly fitted onto the gas bottles, which was supported by the USAID-funded

BAMEX project, the purpose of which was to lighten pressure on forest wood. These small half-sized bottles are no longer available due to lack of demand.

Vitogaz took part in an extensive project to promote LPG for household use, funded by a UNDP managed programme called Growing Sustainable Business (GSB). GSB funded the creation of a profit making company to sell bottled gas and stoves to the low income sector, but the project failed because the Malagasy government gave no positive support to Vitogaz and did not respond to Vitogaz's request for a tax exemption or a tax holiday on the LPG to be sold in the small bottles and stoves to the low income market.

Vitogaz now sell gas in bottles of the following sizes: 9 Kg, 12.5 Kg, 25 Kg, and 39 Kg, and the stove (Fatapera) is still offered with the 9 kg bottle (Reference: Interpretation from Henri Tsimisanda: from an email from Henri Michel Tsimisanda to Harry Stokes, April 8, 2010).

Figure 4.11: LPG Price Escalation in Antananarivo



Source: Ministère de l'Energie – Direction de l'Energie (Accessed 5-6-10)

The steady increase in the price of LPG, which is sold in 9 kg and 12.5 kg bottles (the standard-size for retail in Madagascar), is shown in Figure 4.11. It is estimated that a 12.5 kg bottle of LPG will last a maximum of about 30 days for an average sized family.

4.3 Results of Project Socio-Economic Survey

A socio-economic survey was conducted by the project team in 270 households in 180 small communities in the Vatomandry and Ambositra regions as part of

Component A of this study, providing the baseline for the entire field study conducted under Component A.

The Household Sampling Criteria for this baseline were as follows:

- Households have at least one child under 5 (to ensure that people are at home for at least part of the day)
- Households generally cook at least two meals on the same stove per day
- Households regularly buy at least half of their fuel (otherwise more affluent ethanol users will be compared with less affluent wood gatherers)

The sample size, of 270 households, carefully preserved all the key segments of a sample, including a control group, an awareness group, as well as biomass stove, charcoal stove and ethanol stove groups, with sample sizes of n equal to or greater than 30. Data from the baseline survey was compiled in SPSS and subjected to a number of analyses, and the data is provided in full in the Component A baseline report.

4.3.1 Household Energy Use

The types of stoves used by the domestic sector depends on a number of factors, including access, performance, price and other issues related to the fuel and the stove itself. These factors will determine the growth of technology, and thus they have to be examined carefully prior to determining the market and product launch.

4.3.2 Type of Fuel Used

The type of fuel used by the domestic sector depended on the season, with the survey showing that charcoal and wood were the preferred cooking fuels in both dry and wet seasons (Tables 4.8a and 4.8b). In the project areas, approximately 69% and 30% of the respondents used charcoal and wood, respectively, as their main cooking fuel in both seasons. As a secondary fuel, though charcoal and wood remain most popular, their percentage share decreased to an average of about 47% and 40%, as households tend to use other fuels, such as bottled gas (6.4%), electricity (3.8%), kerosene (1.3%), and agricultural residues (1.3% in the dry season only); their order of use is shown in Table 4.8c and 4.8d.

Table 4.8: Cooking fuels

a) Primary cooking fuel - wet season

Fuel type	*Percent*
Charcoal	69.1
Wood	30.9
Total	100.0

b) Primary cooking fuel - dry season

Fuel type	*Percent*
Charcoal	69.4
Wood	30.6
Total	100.0

c) Secondary cooking fuel - wet season

Fuel type	Percent
Charcoal	48.7
Wood	39.7

d) Secondary cooking fuel - dry season

Fuel type	Percent
Charcoal	46.2
Wood	41.0

Bottled gas (LPG)	6.4
Main electricity	3.8
Kerosene	1.3
Total	100.0

Bottled gas (LPG)	6.4
Main electricity	3.8
Agricultural residue	1.3
Kerosene	1.3
Total	100.0

Fuelwood

In the wet season, of households who used wood fuel, about 86% bought it, about 5% gathered it, and the remaining 9% both bought and gathered it. In the dry season about 90% of households depended on purchased wood fuel for all their needs, whilst a further 8% purchased and gathered wood fuel.

In the study, in both the wet and dry seasons, the amount of wood fuel used was measured in bundles. For those who use wood fuel, the maximum number of bundles *bought* by a household in a week was about 140, with the majority buying 28 bundles per week. The total maximum weight of wood fuel bought per week in both wet and dry seasons was 280kg, whilst the median value was 56kg (each bundle weighed around 2kg). The total amount spent on wood fuel per week varied from MGA 0 to 14,000 in both seasons, with the most common weekly amount spent being MGA 2800. Wood fuel is generally collected by everyone; women, men, and male and female children.

Charcoal

According to the survey, April 2009, charcoal was the most used fuel type in the surveyed population, and was bought by households in different sized bags. The weight of small bags varied from 0.5kg - 2kg, and large charcoal bags from 5kg to 50kg, highlighting the large range of bag sizes, between 5kg-20kg, used by the surveyed communities.

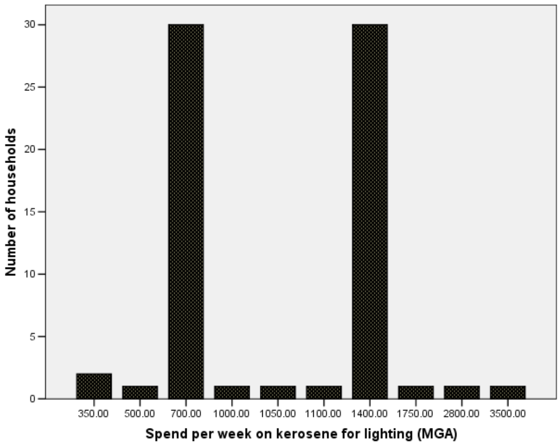
The most common sizes for small purchases and large purchases were 1kg and 30kg respectively, and this had a big impact on what was paid for charcoal on a per unit basis. The cost of small bags ranged from MGA 100-1,500, with about 46% of the bags costing MGA 200. Price per kg for small purchases generally ranged from MGA 180 to 200, with the cost of the larger bags ranging from MGA 800-6,000 (this is up to 20 kg bags), with 30% costing MGA 2,500. When charcoal was purchased in medium bags (5 kg to 20 kg) the price per unit dropped to around MGA 140 to 160. When charcoal was purchased in large bags, 30 kg to 50 kg, the price may drop to MGA 100 to 110.

The survey results showed that about 65% of respondents bought their charcoal in large bags, 34% in small bags, and 1% in both large and small bags. The study also indicated the purchase of large bags was preferred in the wet season, with 1 bag being bought by about 60% of respondents per week, leading to an overall spending of between MGA 200 and MGA 15,000 per family per week, with the largest percentage (14) of surveyed households spending MGA 2,500 per week.

Kerosene

Kerosene was used by very few households for cooking. In the present study all those respondents reported used only kerosene for lighting, reported a price of between MGA 50 and MGA 700 for kerosene per day, with the vast majority paying either MGA 100 or MGA 200 (Figure 4.12).

Figure 4.12: Kerosene spend per week for lighting



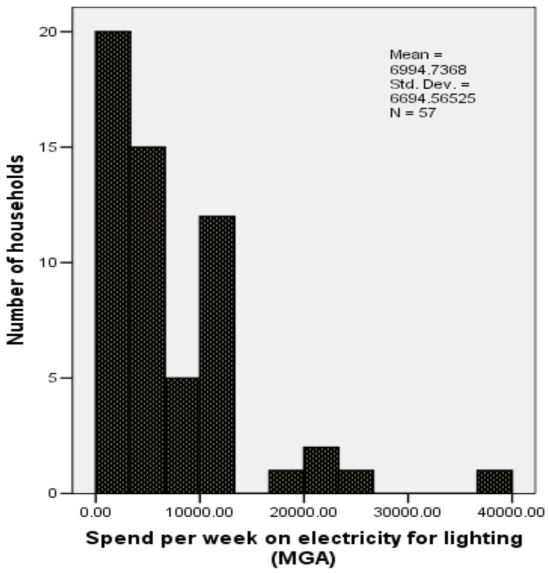
Bottled gas (LPG)

The bottle sizes of LPG available on the market are 9kg, 12.5 kg, 25 kg and 39 kg, with approximately 60% of households using the 9kg bottle size. The cost per kilogram is now almost MGA 4,500 (US$2.25), and about 40% of customers reported that they spent MGA 35,000 per month, suggesting a usage rate of slightly less than 9 kg per month. A more typical usage rate was 12 to 15 kg per month, which suggests that in homes where LPG is used, it is supplemented with another fuel - probably charcoal. In both dry and wet seasons, gas bottles last between 45-120 days, with 40% of respondents claiming their gas bottles lasted for about 90 days.

Electricity

The price of electricity is 310-360 MGA/kWh, in both dry and wet seasons. The survey results showed that nearly one third of the respondents who use only electricity for lighting pay MGA 5,000 per week for the electricity they use, whilst the remaining two-thirds pay about MGA 9,000 per week (Figure 4.13). This is used almost exclusively for lighting.

Figure 4.13: Electricity spend per week



4.3.3 Rationale for Fuel Preference

A number of reasons were given by the survey respondents regarding their choice of fuel.

Speed of cooking (i.e. less cooking time) was seen by 36% of the respondents as the major criteria for fuel selection.

This was followed by convenience, cleanliness, and less costliness of the fuel (Table 4.9).

Table 4.9: Reason for choice of fuel (percent)

Speed of cooking	24.0
Saves time	15.0
Easy to use	14.4
Cleaner	7.6
Cheaper	6.8
Other	32.2

By contrast, the most common reasons noted by the respondents for not liking a cooking fuel were related to health impacts.

Smoke, dirt, suffocation, bad health, were some of the factors that made fuels unfavoured by 58% of the surveyed households (Table 4.10).

Table 4.10: Reasons for not liking cooking fuel (percent)

Smoke	27.1
Dirt	15.3
Bad effect on health	9.0
Suffocation	6.6
High cost	4.9

Other	37.1

In terms of cooking fuel, LPG was observed to stand out as the prime fuel, followed by electricity, kerosene and charcoal.

Ethanol was only the fifth priority preference gaining the interest of 6.4% of the surveyed households (Table 4.11).

Table 4.11: Preferred type of cooking fuel (percent)

Priority order		
1	**LPG**	**57.1**
2	Electricity	14.2
3	Kerosene	9.6
4	Charcoal	7.4
6	Ethanol	6.5
7	Other	5.0

The main reason that households gave for not using their preferred stoves and fuels (LPG, electricity, kerosene, charcoal, improved charcoal stoves and solar) was given as non-affordability by the surveyed groups. With ethanol, the primary reason for not using it was its newness and the lack of awareness by the surveyed respondents of its existence. Ethanol was observed to be used as a fuel for lighting by a minority group (0.3%).

4.3.4 Energy Expenditure

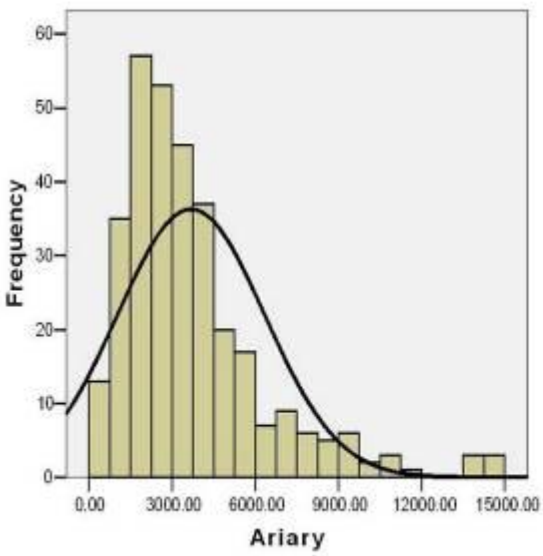


Figure 4.14: Weekly amount spent on fuel for project households (MGA)

Within the project area, spending on fuel is widely distributed, as shown in Figure 4.14, and this pattern is repeated for both the wet and dry seasons.

The majority of households spend around MGA 2,500 with more affluent households spending up to MGA 10,000 to MGA 15,000 per week.

The survey data shows that households spent the most, per week, on charcoal, with fuelwood being the second most expensive energy source (Table 4.12). Median values are higher for wood fuel consumption than for charcoal as it is a cheaper source of energy.

Table 4.12: Weekly spending on fuel by the majority of households (MGA)*

	Wet season		Dry season		% use
	Max	Median	Max	Median	
Charcoal	15,000	2,100	17,000	2,100	81
Wood	14,000	2,800	14,000	2,800	41
Kerosene	200	200	200	200	0.3
LPG	6,220	4,670	6,220	4,670	1.6
Electricity	9,000	9,000	9,000	9,000	0.9

*Households may use more than one fuel, so total % use is >100%

Electricity is generally an additional fuel expense in households that can afford it rather than replacing other fuel types.

4.4 The Ethanol Domestic Cooking Fuel Market

4.4.1 Potential and Rationale for Using Ethanol for Domestic Cooking

Ethanol is currently not used for domestic cooking in Madagascar, however a rationale for adopting a strategy to use ethanol as a domestic cooking fuel in Madagascar is outlined below.

Economic

At the *macro level*, a switch from imported petroleum products (kerosene and LPG for cooking) to ethanol, reduces the government's exposure to international oil prices and the impact this has on the trade balance. Although the volume of petroleum fuel used for cooking is relatively small in Madagascar at present, it can be expected to grow rapidly with a rising population and income levels. Removing the need to import petroleum fuels for cooking will be a positive move for saving hard currency.

At the *micro or household level*, increasing prices for cooking fuels can be a significant burden to households, especially those in the lower income groups. As illustrated elsewhere in this section, households allocate 7% of their income to cooking fuel purchase (higher for lower income groups), and fuel price increases erode what is available for other basic requirements. In recent years, households in Madagascar have suffered substantially due to the very rapid price rise of petroleum fuels (international petroleum prices have increased by 200-300% in the past two years) and depreciation of the local currency. For both petroleum fuels and wood fuels further price rises can be expected due to resource allocating and other constraints.

Production and use of ethanol locally will create significant employment in Madagascar, through the development of a local ethanol production industry, including the manufacturing of ethanol production equipment and stoves, as well as fuel distribution.

Environmental

The non-sustainable use of wood fuel has had a significant impact on forest resources and loss of productivity of land due to soil erosion. Madagascar is reported to have lost about 80% of its forests, half of them in the past forty years (Bergeron, 2002). Land fragmentation, increasing population, demand for food and for fuel are listed as the reasons for this massive deforestation. The World Bank estimates that environmental degradation caused by deforestation reduces GNP by 5 to 15% each year (Haan et. al., 2000). Clearly forest removal for either food or fuel must be stabilized, and wood fuel consumption at present levels can clearly not be supported. Madagascar is a country of exceptional biodiversity, but it is threatened with uncontrolled deforestation through food and fuel demands.

Solid biomass fuel use in poor countries in Africa is reported to be a significant health risk, especially for children under 5 and women over 30 (WHO, 2007). Hundreds of thousands of people in Madagascar are at risk of death or disability due to IAP caused by solid biomass fuel combustion from traditional stoves.

Social and Political

Domestic production of ethanol for domestic fuel will create sustainable employment and reduce resource conflicts that might arise for a diminishing resource such as wood fuel and charcoal, and should gain a wide acceptance by the public and local businesses.

Lessons for Madagascar from Other African Countries

Chapter 2 details ethanol case studies from around the world which provide important lessons for Madagascar, including a number of African countries. In both Ethiopia and Malawi the ethanol is produced from sugarcane molasses, due the priority of blending ethanol with gasoline (E5 to E10), but in both countries ethanol is also promoted as a domestic cooking fuel. The main finding of studies conducted in these countries (UNDP/Malawi, 2007, UNDP/Ethiopia, 2006) indicate that the application of ethanol for domestic cooking is more attractive, environmentally and socially, than for gasoline blending.

- The household ethanol markets are larger than the blending mandates. In Ethiopia, at a maximum blend mandate of E10 only about 20 million litres of ethanol can be absorbed, while there already exists a ready domestic cooking market of 100 million litres
- Using ethanol for domestic cooking entails few changes in the petroleum distribution infrastructure, and is much easier to regulate
- Application of ethanol for domestic cooking is socially more equitable because any gains in better access and reduced costs are more equitably distributed among different income classes (for gasoline blending on the other hand, gains tend to go to the highest 5% income group)

4.5 Stove Absorption Modelling

It is a common assumption that improved stoves must be low-cost to be absorbed into the local economy when incomes are very low. Thus, if incomes are between US$1-5 per day, a stove must cost in the range of US$1-5, or perhaps US$5-10, to be adopted. Many improved stove programmes are tailored to this assumption, and have often gone to great lengths to develop very low cost stoves. However, this approach is limited if the pursuit of a low-cost stove compromises its performance and durability and, moreover, reduces the ability of poor households to exploit fuels other than wood or charcoal.

It is interesting to look at the uptake of mobile phones in Madagascar as an example of a modern technology, as there are many similarities between mobile phones and ethanol stoves insofar as the profit is in the ongoing cost (calls versus ethanol fuel) and not in the capital item (mobile phone versus stove), and is detailed in more detail in Annex 7.

Generally, low-cost stove programmes focus on the exploitation of traditional solid fuels rather than modern, processed fuels such as liquid biofuels, except in a few cases. The Millennium Gel Fuel Initiative (Utria, Energy for Sustainable Development, 9-04), took the approach of gelling or partially solidifying ethanol with a gelling agent (calcium acetate) in order to burn it safely in a simple receptacle beneath a burner or pot support (Annex 8). If liquid ethanol was congealed, the assumption was that it could be simply contained, requiring a simpler, less expensive stove than one designed to hold and deliver liquid fuel to a burner. A number of simple gelfuel stoves were designed, costing just a few dollars, but have serious performance and functional limitations, and as a result, have not been widely embraced by consumers and no gelfuel stove programmes are in operation today.

The question of whether a more expensive, better performing stove can be absorbed into a low wage, low income economy still needs addressing. Related to this is how, and through what means, the absorption or uptake of stoves can be promoted, whether through subsidy, finance or other means, including supportive government policies and programmes.

At one time, the 'Energy Ladder' was thought to explain how people behave with regard to choosing stoves and fuel. As their income rises, consumers 'move up the energy ladder' from solid fuels to liquid and finally to gaseous fuels. But studies have shown that many economies require a multi-fuel, multi-stove approach to cope with changing conditions, thus in some households, an LPG or kerosene stove might be used as well as a wood or charcoal stove. In Ethiopian urban households typically use a kerosene wick stove, a charcoal stove, and an electric stove for cooking, and a wood stove in an outside kitchen for baking i*njera* bread. Some households also occasionally cook with other fuels such as dung. Household surveys need to find out about all stoves and fuels used, not just the main one, and the potential for modern stoves to penetrate households must be evaluated in light of multi-fuel/multi-stove household characteristics. Households that are recorded as relying on wood or charcoal may in fact use other stoves some of the time, which might be a more modern stove.

The cost of fuelwood and charcoal is not always lower than more modern fuels. During the last decade the price of kerosene was lower than the price of biomass fuels in many African countries, before its sustained price increase (and the consequent deregulation of kerosene pricing in many African countries made necessary by balance of trade deficits created by the importation of costly fuels), making it too expensive. Kerosene escalated in price to the extent that it is no longer cheaper than fuelwood in urban settings, but it did used to be the cheapest fuel (Seboka, Yisehak, Kassa, Mekonnen, et al., Situation Analysis Biomass Energy Strategy Methodology, Ministry of Mines and Energy, Ministry of Agriculture and Rural Development, FDRE, August 15, 2008).

Even when an improved fuel is cost competitive with traditional fuels, it might have barriers to entry; a regular and on hand supply, the cumbersome weight of the fuel tank, or the requirement to purchase several month's supply of fuel at once (all features of LPG). The barrier associated with an improved fuel may not just be on price, but convenience, cash flow (how much users can afford at the time of purchase) or limitations in the household. Urban areas are likely to possess more of the positive factors that allow a new stove and fuel to be adopted, than rural areas. These include the expense of purchasing traditional fuels that have to be transported long distances, the existence of suitable infrastructure, the presence of media and educated consumers, a cash economy, and sufficient purchasing power (Heltberg, et al, 2003).

In examining the household energy economy in Madagascar the factors that might predict the likelihood of a household buying a new stove include:

- Household income
- Type of employment
- Location of household
- Current fuel use
- Presence of improved stoves
- Experience with LPG, kerosene, electricity and/or natural gas/biogas
- Employment status of the head woman in the household
- Status of head woman in the household
- Presence of other appliances in household (radio, TV, refrigerator, etc.)
- Access to finance
- Remittance assistance from family members abroad
- Possession of cell phone by household members

National statistics on key indicators such as the number of improved stoves sold (improved charcoal and Fatana pipa), number of kerosene and LPG stoves sold, number of refrigerators, TVs sold, number of bank and cell phone accounts can all help show how easily a modern stove and fuel might be absorbed into an economy.

Heltberg, et al, rightly points out that the type of stove currently used in a household is a good predictor of the willingness of a household to take on a new stove. Household surveys conducted in Addis Ababa in 2004-2006 with the CleanCook stove (Bilan Kassa/Gaia Survey Reports) showed that there was a high propensity of urban household cooks to replace their kerosene wick stoves and charcoal stoves with ethanol stoves. Interviewed cooks stated that they disliked the smell of kerosene fuel, and it tainted the taste of the food, whilst ethanol did not. They accepted ethanol stoves in place of charcoal stoves for other reasons, because ethanol stoves cooked like charcoal stove, could be turned down to a temperature appropriate for particular foods cooked on charcoal (e.g. coffee) and had flames like charcoal flames. Some households said they used the charcoal stove for coffee-making for special occasions but the ethanol stove for coffee-making otherwise, or they used the ethanol stove when they did not have charcoal in the house (Gaia reports).

4.5.1 Potential Market Segment for Domestic Cooking with Ethanol

Madagascar is a low income economy; however it must be noted that significant differences exist between income levels and purchasing capacities. It should also be noted that despite low incomes, the actual level of expenditure on cooking fuels in Madagascar is substantial (US$146 per household per year for the average household).[114] Therefore a substantial market for a good quality and accessible fuel and stove already exists within the Madagascan domestic fuel market.

Factors Determining Adoption of a New Stove (Heltberg, et al, 2003)115
1. The Availability and Price of Traditional Fuels (mainly wood and charcoal)
2. Urban or Rural residency
a. How much access do rural households have to free biomass?
b. What is the cost of wood and charcoal supplied in urban settings, and how easy is it to buy and transport?
c. Dwelling type: Are city residents allowed to cook with wood or charcoal in their dwelling?
3. Cooking Habits and Preferences
a. What similarities or differences do the new stove and/or fuels have with what is currently used?
b. How does the new cooking of food vary from, or match, the cooking of food using traditional stoves and fuel?
4. What are the opportunity costs of the current cooking fuel/practices?
5. What is the level of household education and 'upward mobility'?
6. Is the household served with electricity?
7. Is the woman in the household employed?

Ethanol compares favourably in cooking cost comparisons amongst domestic cooking fuels in Madagascar (Table 4.13). It is significantly cheaper than LPG and kerosene and only marginally costlier than cooking with wood fuel on an open fire. If non-financial measures of fuel-stove combinations are introduced, ethanol cooking with a good quality ethanol stove (e.g. CleanCook) will be preferable to all currently available fuels.

Table 4.13: Daily Fuel Expenses of Household Cooking Stoves

Fuel-stove	Ethanol Stove	Improved Wood	Charcoal Jiko	LPG Standard	Kerosene Wick	Electricity standard	Wood 3-stone
Unit	Litre	kg	Kg	kg	Litre	kWh	kg
Daily need (unit/family)	1.0	4.3	2.1	0.6	0.9	6.8	6.4

[114] Per capita GNI was US$410 in 2008 (World Bank, online, World Development Indicators). This is equivalent to US$2050 per household. In urban areas where charcoal is the main cooking fuel, daily expenditures are about Ariary 600 to 800 (equivalent to US$0.40 or US$146/year). This implies that 7percent of total expenses from the average household go towards cooking fuels. The proportion will be higher for lower income households.

[115] Heltberg, Rasmus, Factors Determining Household Fuel Choice in Guatemala (December 15, 2003). Environment and Development Economics, December 15, 2003.

Price (MGA/unit)	950	140 [1]	300 [2]	3750 [3]	1600 [4]	340	140 [1]
Daily fuel expense (MGA)	950[1]	602	630	2,250	1,440	2,312	896

Notes: Year of price: [1, 2] (2003), [3] (NA), [4] (Dec 2006)

Source: Amount of fuel displaced by a litre of ethanol used with the CleanCook stove is taken from the study for Malawi: UNDP/Malawi, 2007. Feasibility Study for the Use of Ethanol as a Cooking Fuel in Malawi.

A first estimate of the potential market segment for ethanol household cooking (based on relative cost of fuels (Table 4.14) and the purchasing capacity of households) indicates that there would be at least 180,000 households that may substitute their primary cooking fuels with ethanol (Table 4.15). This segment includes all LPG and kerosene users in both urban and rural areas as well as about a third of charcoal users in urban areas.

Table 4.14: Ethanol Market Segment for Madagascar – 2010

All	Geography	Income Quintile	Fuel	%	Main fuel choice criteria	Estimated Ethanol market	House holds
20 Million people (4 million households) – 2009	Urban (30%) 1.2 million households	Poorest	Wood	100	Cost, access		
		Poorer	Wood	100	Cost, access		
		Middle	Wood	100	Cost, access		
		Richer	Wood	85	Convenience, access, cost		
			Charcoal	15		30%	10,800
		Richest	Charcoal	87	Convenience, access	30%	62,640
			LPG	10		100%	24,000
			Kerosene	1		100%	2,400
			Electricity	2			
	Rural (70%) 2.8 million households	Poorest	Wood	100	Cost, access		
		Poor	Wood	100	Cost, access		
		Mid	Wood	100	Cost, access		
		Richer	Wood	75	Convenience, access, cost		
			Charcoal	25			
		Richest	Wood	0	Convenience, access		
			Charcoal	95		10%	53,200
			LPG	5		100%	28,000
						Total	181,040

4.5.2 Adoption Rates for Domestic Cooking with Ethanol

The target population of households who might use ethanol for cooking in 2010 is estimated at 180,000 households (100,000 urban, 80,000 rural), which is believed to be a conservative estimate. This has been based on fuel costs (Figure 4.15) and the cost of a locally produced high quality stove selling at around US$20, or MGA 40,000 (Table 4.15). The upper income households should be able to afford such a stove, considering its benefits of very low emissions, safety, and attractiveness.

Table 4.15: Potential Ethanol Stoves Market in Madagascar

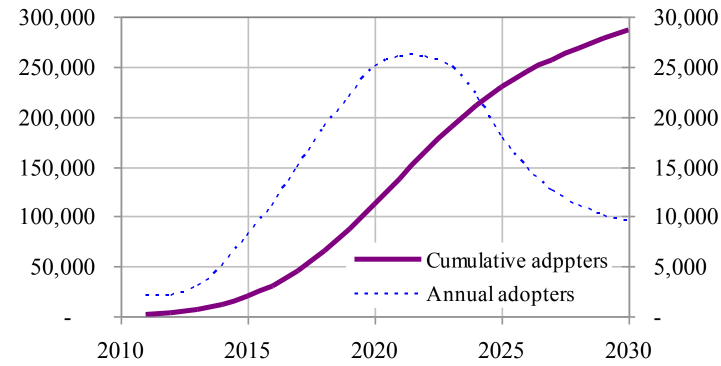
Stove Type	Price US$	Locally Made	Useful Life	O & M Costs	Convenience Usability
Imported high quality stove, imported materials	40	No	10	Lower	High
Imported high quality stove, local materials	20	No	5	Lower	High
Locally produced low quality stove	10	Yes	5	Lower	Medium

The adoption of ethanol for domestic cooking using a locally-produced high-quality stove is estimated based on the following assumptions:

- The target population in 2010 is 180,000, with this segment expected to increase by 2.7%/year, due to population growth, reaching 300,000 by 2030. The segment can be expected to grow faster if incomes increases at a higher rate (per-capita income growth is currently 4.2%/year)
- The urban and rural adoption rate will be different, with faster uptake generally in urban areas

The rate of market penetration for a new technology usually follows a logistic curve, with slow initial take-up, fast growth in the middle and saturation at the end, and it is believed that the market penetration of ethanol stoves will follow such a route over a period of 20-25 years. The early adopters will be few, estimated at around 2,000 households in the first year, growing to 10,000 in year 5, peaking at 25,000 in year 10, and then declining thereafter (Figure 4.8). Following this scenario the associated requirements for ethanol fuel would be 0.7 million litres in 2011, reaching 105 million litres by 2030.

Figure 4.15: Estimated Ethanol Fuel / Stove Adoption: 2011–2030



A methodology for estimating the potential take up of ethanol stoves in Madagascar is detailed in Annex 15, estimating the household ethanol market in Madagascar up to 2026. The methodology looks at the potential for the introduction of stoves, using different prices for both stoves and fuel, and observing the sensitivity of the price on uptake for both fuel and stoves.

4.6 Conclusions

It is estimated that 95% of households in Madagascar depend on woody biomass, primarily fuelwood and charcoal, for their household energy. Madagascan families annually consume approximately 9.026 million m^3 of wood as firewood and 8.575 million m^3 as charcoal (IRG Jariala, 2005). Fuelwood is the predominant fuel for poorest, poorer and middle income quintiles, whilst charcoal predominates for the richer and richest quintiles. Electricity, natural gas and kerosene capture very little of the market even for the richest quintile (Figure 4.2). Most city households use charcoal (79%) rather than wood fuel (18%). Use of natural gas (LPG or bottled gas) is recorded as almost 11% of the main cities, but negligible in the small cities.

The household sector in Madagascar is expected to be heavily dependent on wood fuels for some time to come, with the FAO predicting an increase in household wood fuel consumption, with little substitution with electricity or kerosene due to the high (and rising, in the case of LPG) cost of the fuels and appliances (FOSA, 2000). Under the law of Madagascar, rural households have certain rights to the wood from non-protected forests and woodlots close to their villages. Fuelwood may be extracted free of charge provided that it is not commercially traded. An official permit must be obtained in order to sell wood (for example to urban populations), however illegal cutting is commonplace, particularly in areas where fuelwood is in short supply.

User preferences for household fuels were investigated by the project. The major concern in fuel selection was speed of cooking with 36% of the respondents citing it as the major criteria for fuel selection. This was followed by convenience, cleanliness, and costliness of the fuel. Smoke, dirt, suffocation and bad health, were some of the factors that made fuels unfavoured by the surveyed households. Within the project area, spending on fuel was widely distributed in both the wet and dry seasons. The majority of households spend around MGA 2,500 with more affluent households spending up to MGA 10,000 to MGA 15,000 per week.

Ethanol compares favourably in cooking cost comparisons amongst domestic cooking fuels in Madagascar. It is significantly cheaper than LPG and kerosene and only marginally costlier than cooking with wood fuel on an open fire. If non-financial measures of fuel-stove combinations are introduced, ethanol cooking with a good quality ethanol stove will be preferable to currently available fuels.

A first estimate of the potential market segment for ethanol household cooking (based on relative cost of fuels and the purchasing capacity of households) indicates that there are at least 180,000 households who might substitute their primary cooking fuels with ethanol (LPG, kerosene and charcoal users). The rate of market penetration for a new technology usually follows a logistic curve, with slow initial take-up, fast growth in the middle and saturation at the end, and it is believed that the market penetration of ethanol stoves will follow such a route over a period of 20-25 years. The early adopters will be few, estimated at around 2,000 households in the first year, growing to 10,000 in year 5, peaking at 25,000 in year 10, and then declining thereafter (Figure 4.8). Following this scenario the associated requirements for ethanol fuel would be 0.7 million litres in 2011, reaching 105 million litres by 2030.

5 Controlled Cooking Tests and Comparison of Ethanol Cooking Stoves

5.1 Summary

Madagascar is one of the world's least developed countries where population pressures and an over reliance on traditional biomass fuels have contributed to widespread deforestation. The combustion of unsustainably harvested biomass releases greenhouse gases into the atmosphere and when burnt indoors has been strongly linked to a host of health problems, including acute respiratory infections, a significant cause of death in developing countries – leading to nearly 12,000 deaths per annum in Madagascar alone (Estimated deaths & DALYs attributable to selected environmental risk factors, by WHO Member State, 2002; WHO, 2007).

This chapter presents an assessment of three different ethanol stoves developed to provide a cleaner alternative to biomass stoves. These ethanol stoves were evaluated against each other, and against charcoal and wood stoves, and the test findings are divided into field-based cooking tests, and laboratory tests. The decision to introduce the CleanCook ethanol stove to 30 households in Ambositra and 30 households in Vatomandry, was based on the findings of these tests.

5.2 General Background

According to Madagascar's National Energy policy, the country remains almost entirely dependent on biomass fuels, which account for 95% of the total energy consumption, comprising of firewood, charcoal and crop residues. Firewood is the primary source of energy for rural households, followed closely by charcoal, whilst in urban centres charcoal is the most commonly used household fuel. In Antananarivo 91.1% of households rely on charcoal for cooking (Bazile, 2001)[116].

Current annual consumption of firewood in rural areas is estimated to be between 480 and 945kg per capita, whilst in the urban areas, per capita annual consumption of firewood is only about 94kg (IRG Jariala Report). The annual charcoal consumption per capita in urban areas is estimated to be 110 Kg (IRG Jariala Report). In total, 5.9 million cubic metres of firewood is produced annually for household cooking, and 2 million cubic metres for charcoal production (IRG Jariala Report).

The national electricity coverage rate is 15% (MAP), whilst less than 3% of people living in rural areas have access to electricity. Hydro power accounts for 66.1% of electricity generation in Madagascar, and thermal plants for 33.9% (IAEA, 2008), with the annual electricity production in 2005 being 0.83 TWh (IAEA, 2008).

On a global level the combustion of biomass has major implications for climate change, due to the release of large quantities of carbon dioxide (CO_2) and other greenhouse gases (GHGs). Whilst much of the CO_2 is absorbed back into plants during photosynthesis, if fuel wood is unsustainably harvested this absorption effect is largely negated by the reduction in forest cover. In addition, the use of open fires

[116] Fuel wood (charcoal and firewood) is the main source of household energy in Madagascar; a situation which is alarming because the country's forest areas are decreasing by 2.5% per year.

and cook stoves makes household energy usage a large source of pollution, with the burning of biomass indoors being strongly linked to acute respiratory infections (ARIs) and other health problems. As women are most likely to undertake the cooking, it is they (and their young children who often spend long periods of time by their sides) who are at highest risk from these health problems. Indeed it is estimated that worldwide, ARIs are the biggest killer of children under age five, resulting in over 2 million deaths annually (WHO, Fuel for Life) and around 60% of cases of mortality are directly related to cooking stoves.

Considering both environmental impacts and the negative health effects of burning poorly prepared firewood in inefficient hearths, the Government of Madagascar is seeking alternatives to firewood for domestic cooking. One of the supported initiatives, in collaboration with donors and the private sector, has been the promotion of ethanol as a fuel, including the development of two locally manufactured stoves that burn ethanol (potentially with a high water content).

As part of this research, the Ministry of Energy, the World Bank and the NGO, Tany Meva Foundation, evaluated the Madagascar Proimpex ethanol stove and the Madagascar ISPM stove, and seek to develop an appropriate plan to disseminate ethanol stoves to fully exploit the potential of ethanol as a promising clean cooking energy.

5.3 Stove Evaluation Background

The evaluation was carried out in June and July 2009, by a PAC-led consulting team based in Ethiopia and Madagascar, with representatives from the Ministry of Energy and the Tany Meva Foundation. The study team submitted three stoves to a Controlled Cooking study and to a usability study to assess their appropriateness for use in Component A of this World Bank funded project.

While a stove may be technically feasible and operational, for it to be widely disseminated and accepted, and remain in use, it needs to meet three basic criteria:

- It must be safe
- It must be convenient to use and operate
- It must quickly and easily cook the locally demanded food

To assess a stove against these criteria, research was carried out through a series of laboratory and field tests, as well as ethanol market research, to determine how the stoves perform and how their performance compared with stoves using other fuels also selected for testing. The ethanol stoves were assessed against both traditional and modified wood and charcoal stoves in use in Madagascar as well as the local ISPM and international CleanCook ethanol stoves in the controlled cooking tests (CCT) with cooks in Antananarivo. An additional usability test was conducted only on the ethanol stoves in one of the project locations in Vatomandry, rural Madagascar.

This study was guided by the Aprovecho/VITA international methodology on improved stove programmes, which concludes that improved stove testing should be focused on users who already spend a substantial proportion of their income on cooking fuels. These users are the most immediate beneficiaries of improved stoves and consequently are best placed to determine whether they would adopt any given improved stove. Both controlled condition and field studies were conducted in

Madagascar with complete transparency to allow for interaction and feedback between stove designers, testers and users.

5.3.1 Statement of Impartiality

The PAC-led team carrying out the study, included staff from one of the consortium partners, GAIA Association, which has internationally recognised experience with a range of ethanol stoves, but is a promoter of the CleanCook ethanol stove, currently manufactured in Eastern Europe by Dometic, a Swedish company. As the CleanCook is one of the stoves considered in the stove testing, a potential for conflict of interest has been identified and noted in the contract between PAC and the World Bank. In order to mitigate any issues relating to this conflict of interest, PAC has involved non-GAIA staff in all components where GAIA staff has been involved, and has independently reviewed all work for balance and fairness. Tests were conducted by randomly selected Malagasy cooks and households chosen by Tany Meva, evaluations (where required) were conducted by committees, tests were witnessed by non-GAIA staff, reporting was checked by PAC, and the results presented here are considered to be impartial by PAC.

5.4 Categories and types of stoves tested

A briefing meeting was held with Tany Meva Foundation and the Ministry of Energy at the beginning of the study, and the stoves to be tested were selected by Tany Meva, in coordination with PAC, as follows:

- The CleanCook - manufactured by Dometic
- The Cooksafe – a traditional gelfuel stove design
- The Britelyt - a low-pressure stove using Petromax lantern parts
- The NARI stove – a pressure stove from India
- Proimpex – a locally-developed stove
- ISPM stove – a second locally produced stove

Table 5.1 shows a summary of these stoves and fuels. Unfortunately, both the Britelyt, NARI and Cooksafe stoves were not available for testing.

Table 5.1: Types of stoves tested

No.	Category of Stove	Type of stove	Fuel type	Local Name of Stove	Stove Description and Identifier	Stove Identifier	Remark
1	Modified/ Improved Biomass	Wood burning	Wood	Fatana pipa	Modified wood stove	MWS	Portable clay stove, available for the whole study
2		Charcoal burning	Charcoal	Fatana	Modified charcoal stove	MCS	Portable metal and clay stove, available for the

							CCT
3	Traditional Biomass	Charcoal burning	Charcoal	Fatapera	Traditional charcoal stove	TCS	Portable metal stove - most commonly used stove in the country
		Wood burning	Wood	-	Three stone or traditional wood stove	STWS	Most commonly used in rural areas, only one CCT was conducted due to time constraints
4	Ethanol Fuelled	Ethanol stove	60% Ethanol	Proimpex Small	Proimpex Small	ProS	Single round burner; available for the whole study
5				Proimpex Large	Proimpex Large	ProL	Single round burner with the addition of six small burner openings; available for the whole study
6				ISPM	Institut Supérieur Polytechnique de Madagascar stove	ISPM	Single round burner, similar system to the Proimpex stove; available for the whole study
7			95% Ethanol	CleanCook	CleanCook stove	CCS	Stainless steel single burner stove; available for the whole study
8				Britelyt stove	Britelyt stove	BriS	Stove was not available for the CCT study.
9			Ethanol Gel fuel	Gel fuel stove	Gel fuel stove	GFS	Stove was not available for the CCT but was tested with the CO monitor

5.5 Stove Screening Evaluation

5.5.1 Screening Criteria

The purpose of the testing was to evaluate objectively the performance of a range of stoves that are currently available, or could be made available in the future, to the Malagasy market. Table 5.2 shows the screening criteria used to evaluate and compare the available stoves. For statistical validation, each stove was tested at least three times with the possibility of an additional repeat test in case of anomalous data. Using the Controlled Cooking Test (CCT) protocol developed by VITA/Bailis and with the assistance of three cooks, test engineers were able to test the seven different stoves in one week.

Table 5.2: Screening criteria: Ranking[117]: - High = 4; Medium = 3; Low = 2; Minimal =1

No.	Criteria Group	Criteria	Rank Range
1	Stove Safety	Stability	Yes or No
2		Handling	1 to 4
		Heat Protection	1 to 4
4		Sharp Edges	1 to 4
5	Stove Functionality	Ease of lighting	1 to 4
6		Power regulation	1 to 4
7		Ease of shutting down	1 to 4
8		Time between refuelling	1 to 4
9		Practicality/ Ease of use	1 to 4
10	Stove Design	Durability	1 to 4

Explanation of Criteria

- **Stability** – the tendency of the stove to resist falling over when tipped due to actions performed during cooking
- **Handling** – portability, size and weight
- **Heat protection** – any surface of the stove body that has to be touched during cooking should not be too hot to handle safely
- **Ease of lighting** – how difficult is the stove to light? how long does it take to properly ignite?
- **Power regulation** – how easy is it to adjust the power or flame size? how fine is the adjustment?
- **Ease of shutting down** – how easily and quickly can the fire be extinguished?
- **Time between refuelling** – how long does the stove cook when charged with fuel?
- **Practicality/ ease of use** – convenience while cooking and in refuelling
- **Durability** – sturdiness of the stove and various parts of the stove: workmanship, quality and durability of materials used

5.5.2 Stove Screening Result

All stoves were evaluated in the state they were received, and the preliminary evaluation (screening) was carried out by the committee, consisting of representatives from the Energy Ministry, Tany Meva Foundation and the PAC study team. Based on the results, the stoves were ranked according to their most important characteristics and cooking performance, using a straight-forward, transparent evaluation method. Table 5.3 and Figure 5.1 show that the CleanCook

[117] Most of these criteria are taken from Safety Protocols developed by Nathan G. Johnson from Iowa State University.

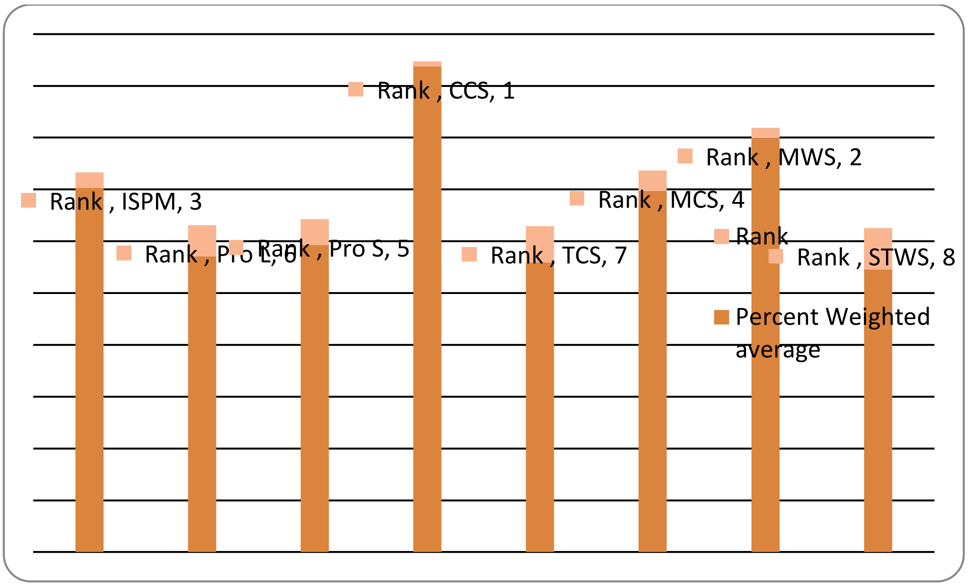
stove was given the highest performance rating and the three-stone traditional wood stove was given the lowest rating. The committee decided to do the CCT for all of the stoves even though some of the stoves received low scores.

Table 5.3: Stove Screening Results

No.	Criteria Group	Criteria	Weight	Rank (1 to 4) and weighted value							
			%	ISPM	ProL	ProS	CCS	TCS	MCS	MWS	STWS
1	**Stove Safety** **40%**	Stability	15%	2.75	2.5	2.5	4	2.5	3.5	4	2
				0.41	0.375	0.375	0.6	0.375	0.525	0.6	0.3
2		Handling	5%	2.5	2.7	3	4	3.25	2.75	2	2.33
				0.125	0.135	0.15	0.2	0.162	0.138	0.1	0.116
3		Surface temperature	10%	3	2.5	2.7	3.5	1.5	3	3.2	1.33
				0.3	0.25	0.27	0.35	0.15	0.3	0.32	0.133
4		Sharp edges/points	10%	3	2.25	2.25	3.75	1.5	3.25	3.5	2.67
				0.3	0.225	0.225	0.375	0.15	0.325	0.35	0.267
6	**Stove Functionality** **50%**	Ease of lighting	10%	2.75	1.75	2	4	2.5	2.5	3	2.33
				0.275	0.175	0.2	0.4	0.25	0.25	0.3	0.233
7		Power regulation	10%	2.5	1.25	1.5	3.75	2.5	2.5	3	2.33
				0.25	0.125	0.15	0.375	0.25	0.25	0.3	0.233
8		Ease of shutting down	10%	3	2.75	2.75	4	1.75	1.75	2	1.67
				0.3	0.275	0.275	0.4	0.175	0.175	0.2	0.167
9		Time between refuelling	10%	2.75	3.25	3.25	2.75	2.5	2.5	3.25	2.33
				0.275	0.325	0.325	0.275	0.25	0.25	0.325	0.233
10		Practicality/ ease of use	10%	2.75	2	2	4	3	3	3	2
				0.275	0.2	0.2	0.4	0.3	0.3	0.3	0.2
11	**Stove Design** **10%**	Durability	10%	3	2	2	3.75	1.75	2.75	4	3
				0.3	0.2	0.2	0.375	0.175	0.275	0.4	0.3
Total		**Sum (out of 40)**		28	23	23.95	37.5	22.75	27.5	30.95	22.99
		Weighted (out of 4)		2.81	2.0	2.37	3.75	2.2375	2.78	3.195	2.3325
Percentage		**Total**		70	57.5	59.87	93.75	56.87	68.75	77.37	57.47
		Weighted average		70.31	57.13	59.25	93.75	55.94	69.69	79.88	54.56
Rank based on weighted average				**3**	**6**	**5**	**1**	**8**	**4**	**2**	**7**

Key: *ISPM = ISPM stove; ProL = Large Proimpex stove; ProS = Small Proimpex stove; CCS = CleanCook stove; TCS = Traditional charcoal stove; MCS = Modified charcoal stove; MWS = Modified wood stove; STWS = Stone traditional wood stove*

Figure 5.1: Stove ranking



5.6 Controlled Cooking Tests (CCTs)

5.6.1 Selection of test protocol

The Controlled Cooking Test (CCT) seeks to assess stove performance according to local conditions by measuring both the mass of food and fuel used, as well as the time taken to cook a typical meal. The test gives a more realistic idea of performance of a stove in practice than the Water Boiling Test (WBT) which is often used as a standardised stove performance test. Although realistic in terms of monitoring food appropriate to the local area, by standardising the meal, the amount and type of food can be cooked, and the person doing the cooking, greater standardisation is achieved than is possible using household monitoring.

- For the CCT, the fuel consumption is expressed in grams of fuel used per kilogram of food cooked. The CCT, in addition to measuring energy input versus energy output, also measures energy used per gram of food cooked and total cooking time per defined task.

- The WBT provides a standardised test for emissions and performance testing but does not always predict the performance of the stove in a cooking task. Stove performance may vary according to the type of food being cooked; a stove that performs well for cooking one particular food may not perform as well when cooking another type of food.

The study team opted for the CCT in field conditions (using the most common meal, comprising staple foods in the study area), in order to assess stove performance in real conditions. For the laboratory emissions testing (conducted at the Aprovecho Stove Research Laboratory in the USA), the standardized WBT was used in order to provide emissions data to compare with stoves used elsewhere.

Limitations of the CCT include not precisely determining the performance of a stove in that there is no unequivocal mechanism for judging when the food is properly cooked, as opposed to when water boils for the WBT. There is some subjectivity involved on the part of the cook to judge when the food is properly cooked. Often the more the food is cooked the lighter it becomes, as more water is boiled away, and more fuel is used in evaporating it. Because of this, the fuel consumption measurement is doubly affected and can incorrectly measure the performance of the stove. All CCT protocols attempt to take this subjectivity into consideration, by aggregating the cooking results of several cooks - in this study three cooks were used to measure each stove.

The CCT protocol used in this study was recommended by the Aprovecho Stove Research Laboratory, however an additional efficiency calculation was added to help to account for the evaporated water and the energy actually absorbed by the food, and to help correct for the variability in the way that cooks cook their meals. The fuel used is adjusted for the moisture content and the fuel leftover at the end of each test. The moisture content of the fuel was measured on a wet weight basis and this amount was subtracted from the total weight of fuel used. The energy that is consumed to evaporate the water within the fuel was also calculated and deducted from the measured weight of fuel. The energy output is thus the energy absorbed by the food, taking the specific heat of the rice and water into consideration.

The amount of heat released by the fuel was calculated, along with:

- Power Output (the rate at which energy is being absorbed by the food)
- Power Input (fire power, or the rate at which heat is being released by the fuel)
- Efficiency ([Energy Output/Energy Input]*100%)

This enhanced protocol was used in developing an improved *injera* (Ethiopian diet staple) stove in Ethiopia as part of the World Bank Energy 1 project.[118] The protocol was adapted to the Malagasy situation, cooking rice and sauce - rice is normally served with beef sauce, which is boiled meat with vegetables and onions. There were thus two major cooking tasks, the preparation of the sauce, which has a number of steps and takes an average 98 minutes to prepare, and the preparation of the rice, which took, on average, about 35 minutes to cook.

5.6.2 Description of Test Setup and Execution

The chosen meal was typical for a low-income urban family in Antananarivo and included rice, meat, a green leafy vegetable and onion sauce (Figures 5.2 & 5.3), and the total food weight cooked was over four kilogram, enough to feed five adult men. After agreeing the cooking task, the food preparation and cooking requirements were recorded so that all stove users and stove testers could understand and repeat.

Standard meal protocol

A standard rice cooking procedure was agreed to as follows:

- Bring 1.5 litres of water to the boil
- Add 690 gm of rice when the water reaches approximately 60^{o}C
- Simmer until it cooks (approximately 35 minutes)

[118] Feasibility study for the use of ethanol as a household cooking fuel in Malawi [ERG, 2007]

- When the rice is well cooked, turn off stove

A standard sauce cooking procedure was agreed to as follows:

- Chop into pieces a 500 gm piece of meat and fry in a pot
- After 25 minutes, add 45 gm of oil
- After cooking for 10 more minutes, add 55 gm of onion
- After 30 more minutes, add 930 gm of washed green vegetables; continue to cook
- After 23 more minutes, add 680 gm of water and 15 grams of salt
- Simmer until it cooks; approximately 10 minutes
- Turn off stove

Total approximate cooking time is 98 minutes

Figure 5.2: Beef and greens sauce with onions and oil

Figure 5.3: Sauce and rice. The sauce took 98 minutes to prepare and the rice 30 minutes

Before the CCTs were begun, demonstrations of the Proimpex (Pro L and Pro S), ISPM, Modified wood (MWS) and the CleanCook (CCS) stoves were given to the study team.

Preparation for each CCT began approximately 20 minutes before the start of cooking, including background information (weight, temperature, etc.) on the rice, sauce, mass of water, temperature of water, temperature of air, mass of fuel with stove and time to light the fire, and the same measurements were taken again after the CCT's were completed.

The CCTs were performed with the Proimpex single burner stove (ProS), the Proimpex multiple burner stove (ProL), the ISPM, the CleanCook (CCS), the modified wood stove (MWS), the modified Charcoal stove (MCS), the traditional charcoal stove (TCS) and the stone (e.g. 3-stone) traditional wood stove (STWS).

5.6.3 Equipment used for the Controlled Cooking Test

The tests were conducted in the Tany Meva Foundation kitchen in Antananarivo, with each stoves being tested one at a time. A total of twenty five tests were conducted on eight different stoves and using four different fuels (wood, charcoal and full strength and diluted ethanol).

The test facility was equipped with digital balances with 1 gm precision and 30 kilogram capacity, digital thermocouples with 1°C precision, and moisture meters for measuring wood moisture as a percentage of the total wet weight. A hydrometer was available for measuring the specific gravity of the ethanol fuel. A HOBO CO data logger[119] was used to measure how much carbon monoxide (CO) was present in the room during each test, an indication of the stove's impact on Indoor Air Pollution (IAP).

Kitchen: The kitchen was a well-ventilated model kitchen (two windows that opened and one door). In order to avoid differences between the tests, all stoves were placed at the same location in the kitchen. IAP measurements were taken according to the University of California, Berkeley's standard protocol. Three cooks conducted all the tests; and each cook had a chance to cook with every stove.

Pot: A metal pot with a capacity of five litres was used for cooking the rice. The height and inside top diameter of the pot were measured at 150 mm and 270 mm, respectively, with the weight of the pot and lid being 1455 grams. A second metal pot with a capacity of four litres was used for cooking the sauce, with the height and diameter of the pot being 125 mm and 250 mm height and diameter respectively and weighing 925 gm. Unlike the WBT, any types of pot can be used for the CCT, and local cooks commonly do not use a standard pot for rice. The three cooks use the same type of pot for the entire study.

Fuels

- **Ethanol:** The ethanol fuel was from three sources and varied in percentage of alcohol by volume, according to the requirement of each ethanol stove being tested (Table 5.4). Grain alcohol at 95% was purchased at a local liquor store, with 5% assumed water content. The Proimpex stove team brought 51% alcohol for their stove test and it was checked using a hydrometer. An additional CCT test was run with 60% ethanol, which was obtained by adding water to the 95% ethanol to reduce it to 60% by volume. The Higher Heating Value of the pure ethanol was assumed to be 29.7 MJ/kg as recommended by the NIST Chemistry WebBook [120].

It is important to note that the calculation of water content by volume is different from the moisture content on a wet mass basis as used in WBT calculations. Give that the density of water is 1 g/ml and the density of pure ethanol is 0.789 g/ml, moisture content on a wet basis is calculated as follows (Aprovecho Research Center, 2009):

MCwet = (1*Vol Water *Present* + 1*Vol Water*Added*) /

(1*Vol Water *Present* + 1*Vol Water *Added* + 0.789 * Vol Ethanol *Present*)

= 0.12

[119]This device, an electrochemical sensor that converts CO gas to an electric signal, measuring CO in the air, is produced by the Onset Corporation. See http://www.onsetcomp.com/.

[120]***webbook.nist**.gov/**chemistry/***

Table 5.4: Percent ethanol by volume and moisture content by weight

Percent Ethanol by Volume	MCwet%
60%	45.8%
52%	53.9%
96%	6.2%

MC = Moisture Content

- **Charcoal:** Charcoal is primarily produced from the wood of eucalyptus trees and is manufactured by entrepreneurs who purchase standing trees from the owner of a woodlot (Gade and Perkins-Belgram, 1986). The entrepreneurs most often pay rural people to make the charcoal, whilst providing jute sacks to bag the product and then haul it to market in trucks or ox carts. The charcoal used in the test was purchased from the local market.

- **Wood:** Eucalyptus tree wood was purchased at a local market for all of the tests needing fuelwood.

5.6.4 Testing

- **Proimpex Ethanol Stove (Pro S and Pro L):** The Proimpex ethanol stove has two models based on size and burner design. The smaller version has a single round burner opening of approximately 6 cm diameter (Figure 5.4). The larger stove (Figure 5.5) possesses the same 6 cm burner opening, but with the addition of six small burner openings approximately 1 cm in diameter arrayed concentrically around the central opening.

The larger stove weighs 5.5 kilogram and the smaller stove weighs 3.5 kilogram. Both stoves have round bodies, circular pot supports, and are mounted on four legs on a circular base. The stoves are stable, particularly the larger stove.

Each stove has a detachable ethanol fuel tank made of a 2 litre drinking water bottle, normally of polyethylene terephthalate (PET) plastic, which is inverted and supported in a metal tripod stand separate from the stove. Ethanol is conveyed to the burner through a clear plastic tube. This is hospital grade disposable tubing probably made of polyvinyl chloride. The tube is primed by squeezing a small charging chamber at the base of the bottle. Once the tube is full of ethanol and the ethanol begins to flow, the flow continues until it is shut off by a simple squeeze valve (flow rate regulator) at the end of the tube adjacent to the stove (Figure 5.6).

Figure 5.4: Top view of a single stove burner

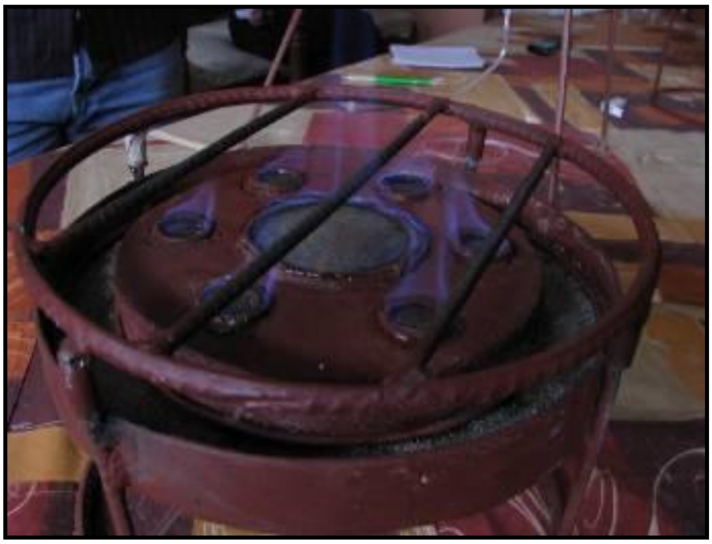


Figure 5.5: Top view of multiple burner stove

This squeeze valve can restrict the flow rate and thus regulate the amount of ethanol coming to the stove. The ethanol is conveyed by a tube into the 'burner core' made of metal oxide, which is a rigid, porous, lightweight, white or light-coloured material that has a large surface area, such as pumice stone. The ethanol is charged into this material and adsorbs onto its surfaces. Both stoves have a concentric overflow trough around the burner, and about 25% of the alcohol/water mixture that entered the burner core, finds its way into the overflow trough and is discharged through a bleed hole and was collected by a rag placed below the bleed hole during the tests (Figure 5.7).

Figure 5.6: Regulating the fuel flow to the stove

Figure 5.7: The single and multiple burner stoves during the water boiling tests

- **CleanCook Stove (CCS)**

The CleanCook stove is designed to burn liquid ethanol. The CleanCook stove is third generation technology based on the ORIGO® stove designed by ORIGO of Sweden, later acquired by the Electrolux Corporation and now manufactured by its successor company, Dometic AB of Sweden, and adapted by Dometic for Africa. The ORIGO stove was first commercialized in Europe and the U.S. in the 1970s and gained commercial dominance in the boating and RV or 'leisure appliance' markets. It is not used for camping because it is neither small nor lightweight like camping stoves. It has been used by the Swedish Army as a field stove.

Figure 5.8 (left): CleanCook stove during CCT

Figure 5.9 (above): Filling the fuel canister for the CCT

Figure 5.10: CleanCook stove during Usability Tests in Vatomandry

The CleanCook is a non-pressurized alcohol stove that retains its liquid fuel in a removable, refillable fuel canister (Figures 5.8 & 5.10). The fuel canister contains a porous, ceramic refractory material that absorbs the alcohol onto a large surface area and makes it available by capillary action to an evaporative surface at the top of the fuel canister (Figure 5.9). The ethanol evaporates into a combustion chimney where air mixing occurs, with the burning ethanol moving up the combustion chimney to a burner. Because the ethanol is held in an open, non-pressurized container adsorbed onto the refractory material contained within the canister, the ethanol fuel does not leak or spill from the stove and will not flare up or explode, as it is not held under pressure, which are important safety attributes of the stove. The company recommends hydrous or azeotrope ethanol or methanol (another low-carbon alcohol) or any combination of these two, since they are miscible in any proportion. The team experimented with higher water concentrations of ethanol, but conducted the CCT with the hydrous ethanol, according to the manufacturer's recommendations. It should be noted that a version of the CleanCook stove is being engineered for production in Ethiopia, using locally available materials, a different stove body design, and different pot supports to hold round-bottomed pots, which could be relevant of Madagascar.

- **Institut Supérieur en Polytechnique de Madagascar (ISPM) stove:**

The ISPM stove (Figures 5.11 & 5.12) resembles, and works in a similar fashion, to the Proimpex stove, but uses different construction materials for the stove, the burner, the fuel feed hose and the detached fuel tank. Like the Proimpex, the ISPM relies on a hose to convey the fuel from the tank, by gravity, to the burner, but uses a different hose material with standard hose clamps to attach the hose to the bottom of the fuel tank and to the stove. The fuel tank is made from sheet metal, while the stove body is made of clay and cement and is heavy and stable, weighing about 12kg. The stove has a single round burner opening, approximately 4 cm in diameter. In the burner cavity, the ISPM stove uses loose coarse sand (possibly from a riverbed), with small rounded stones, unlike the hard clinker used in the Proimpex.

The ethanol is conveyed by the tube from the fuel tank into the burner cavity and fills the cavity because of the gravitational pressure due to the tank being higher than the burner, being absorbed by the sand. The burner cavity will overflow if the fuel flow is not correctly regulated, and if it overflows, it drains into a concentric trough or valley, just as with the Proimpex, but this trough is wider, deeper and holds more fuel, which gives an extra measure of safety. The trough can also collect watery ethanol left behind as the fuel burns, and a bleed tube can drain the trough, which must be collected in a bowl or onto a rag.

Figure 5.11: Front view of the ISPM Stove

Figure 5.12: ISPM technicians teaching the CCT cooks how to use the stove

To light the stove, the fuel supply valve on the tube is opened, allowing the burner to become saturated, with the valve being closed before lighting. The stove is lit by touching a match to the pooled ethanol. The ethanol is slow to ignite but once lit, the flame grows over a few seconds.

Figure 5.13 *(Left)*: A CCT cook regulates the fuel flow on the ISPM stove

Once the stove is burning, the fuel supply valve is opened again and adjusted to provide a feed rate equal to the rate of ethanol combustion (Figure 5.13 – 5.14), through a series of fine adjustments, until the operator is satisfied with how the stove is burning.


Figure 5.14 *(left)*: Burner showing coarse sand and small stones and ample well around burner. (right): Ethanol in the burner and the well on fire. The cooks used the stove with burner and well (trough) lit. This resulted in a higher rate of fuel consumption

- **Modified charcoal stove (MCS):**

The modified charcoal stove (MCS) uses a clay grate/thermal liner to increase its efficiency over that of a basic charcoal stove. Its diameter is approximately 20 cm and it weighs around 5kg. Charcoal is placed in the middle of the ceramic liner and lit with paper or wood, taking around 10-12 minutes. Combustion air enters via an air door at the base of the stove.


Figure 5.15 *(left)*: The MCS is lit with wood or paper and takes 10 to 12 minutes to kindle.

Figure 5.16 *(right)*: The cook is fanning the MCS to give it more air to burn

Figure 5.17 (left): The MCS used in the Controlled Cooking Tests

Figure 5.18 (above): Placing CO tube near stove

A second improved (modified) charcoal stove became available late during the CCTs (pictured below). It was compared to the other modified charcoal stove but was not used in the CCTs because it was not available at the beginning of the testing (Figure 5.20).

Figure 5.19: Alternative charcoal stove

- **Traditional charcoal stove (TCS):**

The traditional charcoal stove (Figures 5.21& 5.22) is a basic charcoal stove without a clay liner. Its diameter is approximately 20 cm and it weighs around 5kg. Charcoal is placed in the middle of the metal liner and lit with paper or wood; the starting process takes around 5-10 minutes. It is somewhat easier to light than the MCS, with combustion air entering via an air door on the base of the stove.

Figure 5.20 *(far left)*: Front view of the traditional charcoal stove (TCS)

Figure 5.21 *(left)*: Cooking sauce on the TCS

Figure 5.22: Lighting the traditional charcoal stove.

Figure 5.23: Swinging the stove to fan the flames

- **Modified wood stove (MWS)**

This modified wood stove is referred to as a fatana pipa stove (Figure 5.23-Figure 5.27), and is made of fired clay sheathed in sheet metal. The fired clay provides heat insulation and promotes energy efficiency, and the hearth door and general workmanship of the stove are of high quality. The stove is designed for use with specific aluminium pots, which sit on an insulated well, increasing the retention of heat in the pots and probably heat transfer from the stove. The potential for burning a range of fuels and crop residues is said to exist with this stove, including fir cone, corn ear, bean pod, dried leaves etc, however the testing team and CCT cooks only used eucalyptus wood for the tests.

Figures 5.24 to 5.25: The modified wood stove, or fatana pipa stove

When used inside, the fatana pipa is connected to a chimney.

- **Three stone fire (STWS):**

This traditional and widely used fire arrangement, as shown in Figures 5.27 & 5.28, was tested as a baseline for the improved stoves.


Figures 5.26 and 5.27: Three stone fire or STWS

5.6.5 Results of the Controlled Cooking Test (CCT)

Of the improved or modified stoves, four ethanol stoves, a wood stove and a charcoal stove were tested, with each stove being tested at least three times. A summary of test results is shown below.

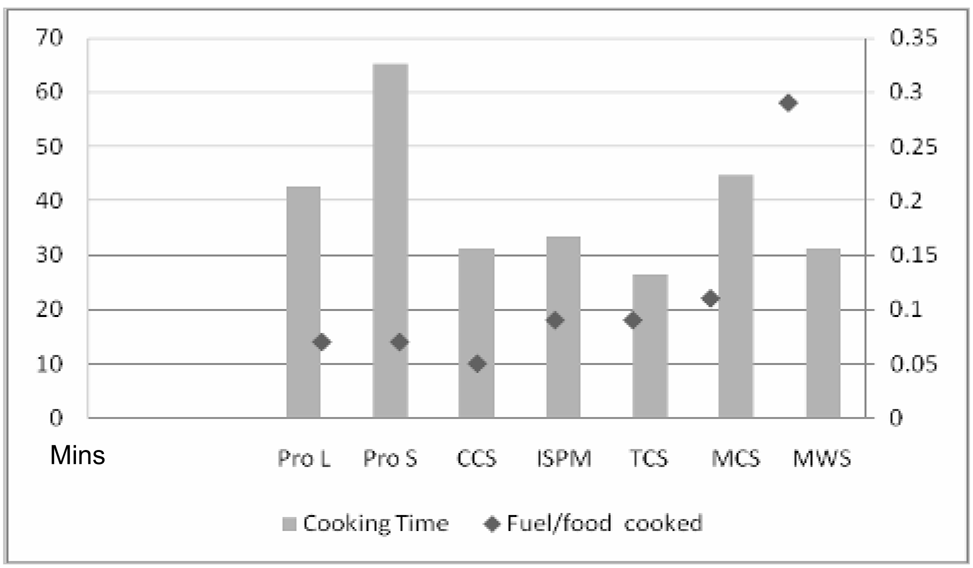
Table 5.5: Controlled Cooking Test Overall Results

Stove	Ignition Time	Cooking Time	Ratio Fuel/food cooked	Energy output	Efficiency	Power Output
	(Min)	(Min)		(KJ)	(%)	(KW)
Pro L	1.92	42.67	0.07	912	23.11	0.34
Pro S	0.46	65.29	0.07	815	20.09	0.21
CCS	0.39	31.24	0.05	1315	48.38	0.68
ISPM	0.81	33.51	0.09	1066	20.77	0.52
TCS	9.49	26.38	0.09	1075	20.80	0.51
MCS	12.81	44.69	0.11	1225	19.80	0.37
MWS	2.41	31.25	0.29	1580	15.84	0.82

Specific fuel consumption is helpful for evaluating stoves that burn the same type of fuel, and the tables presents the specific fuel consumption rather than as total mass of fuel used for the cooking task. For the solid fuel stoves, the measure of specific fuel consumption is grams of dry fuel used per litre of cooked food produced, while for the liquid fuel stoves the measure is grams of liquid fuel consumed, corrected for percent of alcohol content, as determined by a specific gravity reading taken with an alcohol hydrometer. Specific consumption is the preferred way of reporting as it has been corrected for the moisture content in the fuel and the amount of water boiled off during cooking.

Figure 5.29 presents the fuel use results and cooking time based on the average of the three local cooks using local foods for each of the stoves. To compare stoves that use different types of fuels, as we do here, the evaluation parameter should be energy input per weight of cooked food.

Figure 5.28: Controlled cooking tests - time to cook local meal



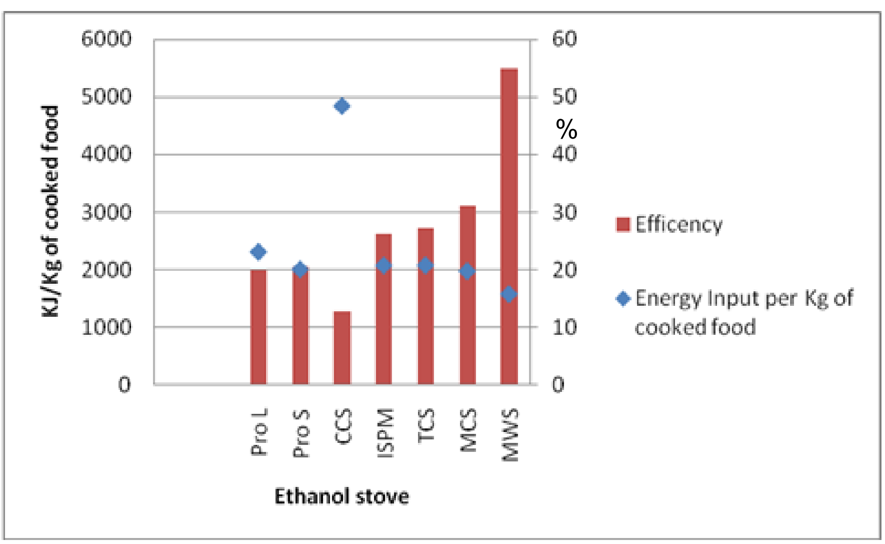
From Figure 5.28, it is evident that the ethanol based stoves use less fuel (in energy terms) for the amount of food cooked than the improved stoves for charcoal and firewood, although the time needed is dependent on the particular stove. Based on this CCT result, the CleanCook stove is the most *energy efficient* stove, followed by Proimpex L/S. The ISPM uses similar amount of energy to the traditional stove, and not much below the charcoal and wood stoves. The relative savings and comparison of stoves among those tested is shown in the Table 5.6. In this table, each stove can be compared to each other stove, by looking at the vertical and horizontal axes. Negative values indicate that consumption is lower for the stove on the horizontal axis by the indicated percentage. For example, the ISPM, on the horizontal axis, uses 21% more energy than the ProImpex S, but it uses 10% less energy than the modified charcoal stove.

Table 5.6: Controlled cooking tests: Percentage difference in energy input per gram of cooked food

Stove Type	Proimpex L	Proimpex S	ISPM	CleanCook	Traditional charcoal	Modified charcoal	Modified wood
	ProL	ProS	ISPM	CCS	TCS	MCS	SMWS
Proimpex L		-4%	-32%	36%	-37%	-57%	-178%
Proimpex S	4%		-27%	38%	-32%	-51%	-167%
ISPM	24%	21%		51%	-4%	-19%	-110%
CleanCook	-56%	-62%	-105%		-114%	-144%	-332%
Trad. charcoal	24%	24%	4%	53%		-14%	-102%
Mod. charcoal	36%	34%	16%	59%	12%		-77%
Modified wood	64%	63%	52%	77%	51%	44%	

Among the ethanol stoves, the CleanCook stove exhibits the greatest saving over the charcoal and wood stoves (Figure 5.29 & 5.30). Compared to the CleanCook stove, the Proimpex S and Proimpex L stoves consume 38% and 36% more fuel respectively. The Proimpex L stove consumes 32% less fuel than the ISPM stove; or, the ISPM stove consumes 24% more fuel than the Proimpex L stove. The Proimpex L stove consumes 178% less fuel than the improved or modified wood stove; or, the improved wood stove consumes 64% more fuel than the Proimpex L stove.

Figure 5.29: Controlled cooking tests: Energy input / kilogram of food cooked



5.6.6. User satisfaction indicators

In addition to efficiency or economy, other characteristics (or indicators) that interest households when cooking are ease of lighting (or heating-up time of stove) and cooking time, which determine the convenience or ease of use of a stove. Lighting time is relatively short for some stoves and longer for others, with charcoal and wood stoves taking up to 10 to 15 minutes, and requiring constant attention, depending on fuel moisture content. The eucalyptus firewood used during this CCT was quite dry, so lighting time for the woodfuel stoves was under two minutes.

The Proimpex and ISPM stoves need to warm up before putting on the pot, and lighting is generally easy during the day, but a little more difficult in the morning, either because of cooler temperatures or because the ethanol/water mixture present in the stoves was too dilute (less alcohol in the water), having been open to the air and subject to evaporation. The small, circumferential burners of the large Proimpex were especially difficult to light in the morning. Once the Proimpex and ISPM stoves were lit, they needed to heat up for about five minutes, probably because the stove heated the alcohol-water mixture, promoting increased evaporation of alcohol, thus making it more available for combustion.

Generally the cooking time is very important for the cook, and a comparison of cooking times among the tested stoves is shown in Table 5.7, which uses a similar comparative table. The fastest cooking time was seen with the Traditional Charcoal Stove, and the Modified Wood Stove and CleanCook were second fastest with similar times. The CleanCook stove required less cooking time compared to the other ethanol stoves and did not require any heat up time.

Table 5.7: Controlled cooking tests: Time differences to cook local meal

Percentage difference between stoves in Cooking Time							
Stove Type	Proimpex L	Proimpex S	ISPM	CleanCook	Traditional Charcoal	Modified Charcoal	Modified Wood
Proimpex L		-53%	21%	27%	38%	-5%	27%
Proimpex S	35%		49%	52%	-32%	32%	52%
ISPM	-27%	-95%		7%	21%	-33%	7%
CleanCook	-37%	-109%	-7%		16%	-43%	-0.02%
Trad.Charcoal	-148%	-148%	-27%	-18%		-69%	-18%
Mod.Charcoal	5%	-46%	25%	30%	41%		30%
Mod.Wood	-37%	-109%	-7%	0%	16%	-43%	
Negative values indicate that time required to cook is longer by the indicated percentage Values are referenced to the stove at the top of the column							

In order to gain more feedback from project households a Rapid Usability Study was conducted at one of the project sites to test the acceptability of the ethanol stoves with the cooks. Vatomandry was chosen for the study as the CCT conducted in Antananarivo more closely resembled cooking conditions in Ambositra, and focused on the less urban and coastal areas. The three CCT cooks in Antananarivo were interviewed after the CCT study to collect the same usability preferences data on as in Vatomandry, with the results show in Table 5.8.

Table 5.8: How easy was it to cook on the stove?

	Clean Cook	Proimpex Small	Proimpex Large	ISPM	Trad. charcoal	Mod. char	Mod. wood
Very easy	✓ ✓ ✓			✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓
Easy		✓		✓		✓	✓
OK							
A bit difficult		✓ ✓	✓ ✓ ✓				
Very difficult							

N.B. The preference of each cook is represented by a tick (✓), so the number of ticks represents the number of cooks who chose each option.

The cooks were asked how confident they felt in using each of the stoves, and the results are show in Table 5.9, below.

Table 5.9: Confidence to cook with the stove?

	CleanCook	Proimpex Small	Proimpex Large	ISPM	Trad. charcoal	Mod. char	Mod. wood
Very confident	✓ ✓ ✓			✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓
Confident		✓ ✓		✓ ✓			
OK			✓				
A bit worried		✓	✓ ✓				
Very worried							

The response from the cooks regarding their stove likes and dislikes is shown in Table 5.10, below.

Table 5.10: Cooks' stove preferences

	CleanCook	Proimpex Small	Proimpex Large	ISPM	Trad charcoal	Mod char	Mod wood
Which did you like best?						✓	✓ ✓
Which did you like least?		✓ ✓	✓				
Which was fastest?				✓	✓		✓

Which was the slowest?		✔ ✔ ✔					
Which was cleanest?	✔ ✔ ✔						
Are there any stoves that you would not wish to use?		✔	✔				

Two of the cooks selected the modified wood stove as the stove they liked the best, and one selected the modified charcoal stove, the ISMP, traditional charcoal and modified woodstove were recognised as the fastest stove. Only the ProImpex stoves were identified as stoves the cook would not wish to use, particularly the small ProImpex, which was slow to use. The CleanCook was identified as the cleanest stove by all three women.

Figure 5.30: The three CCT cooks in the Tany Meva Kitchen at the conclusion of the tests

Before the CCTs began, the Proimpex and ISPM Stove factory teams both provided demonstrations of, and instruction on, the use of their stoves. The CCT managers provided instruction on the modified wood and the CleanCook stoves. Two of the cooks had difficulty learning to use the multiple burner Proimpex stove, whilst the third cook worried about her ability to use the single burner Proimpex, and at the end of the study, the cooks' feelings had not changed.

Table 5.19 records the reactions of the three cooks to questions about how their experiences of cooking with the test stoves compared with their normal cooking experiences at home.

Table 5.11: Comparison of stoves with stove used at home

	CleanCook	Proimpex Small	Proimpex Large	ISPM	Trad charcoal	Mod char	Mod wood
Much better	✔			✔		✔	✔ ✔
Better	✔ ✔	✔		✔ ✔	✔ ✔ ✔		
About the same		✔					
A bit worse		✔	✔ ✔ ✔			✔ ✔	✔

Much worse							

Table 5.20 reports the opinions of the cook on the time required to cook. All test stoves were considered to offer quicker cooking than the stoves the test cooks use at home, except the Proimpex Large and Proimpex Small stoves which were mainly considered to be slower or much slower.

Table 5.12: Time required to cook compared with stove used at home

	CleanCook	Proimpex Small	Proimpex Large	ISPM	Trad charcoal	Mod char	Mod wood
Much quicker	✔					✔	✔ ✔
A bit quicker	✔ ✔			✔ ✔ ✔	✔ ✔ ✔	✔ ✔	✔
About the same		✔					
A bit slower		✔	✔ ✔ ✔				
Much slower		✔					

Findings in brief

- One cook liked the modified charcoal stove best, and two the modified woodstove
- One cook selected the ISPM, one the Traditional Charcoal and one the Modified Wood stove as fastest
- All three cooks said that the CleanCook was the cleanest stove.
- The CCS was the most efficient stove.
- All three cooks agreed that the small Proimpex was the slowest stove and most difficult to operate because of the fuel and flame control. Two of the cooks liked the small Proimpex least and one cook liked the large Proimpex least. All three cooks experienced problems with the small Proimpex stove at high power.
- One of the cooks found it difficult to light the stoves easily in the morning, with the stoves being easier to start during the day when it was warm.
- All three cooks said the power of the small Proimpex stove was not enough to cook rice and sauce, and when they operated the stove at maximum capacity the fuel consumption was high and they worried about the fire because, they said, the regulator and the fuel container are made of plastic.
- The ISPM stove cooked faster than either Proimpex stove*

**The cooks operated the ISPM stove with the central burner and the well or trough lit (see Figure 15). This is not the intended mode of use as it increases the rate of fuel consumption substantially.*

5.7 Usability Study in Vatomandry

5.7.1 Study Design

A field test was conducted in Vatomandry to test the 'usability' of the ethanol stoves. This sub-study was not originally planned into the original project objectives, but was carried out due to the concerns about the usability and safety of the proposed stoves in households putting other parts of the project, in particular the Component A household surveys, in jeopardy. The Tany Meva Foundation and its local partner organization assisted with this study.

A total of eight households were selected for the Usability Study, and to avoid biasing any future results, the study team selected households with similar profiles to survey households from Component A, but which were not actually taking part in the surveys. The selected households were briefed on the project and made aware of safety and privacy issues, and a training session was held on stove operation and to allow the participants to practice using their assigned stoves.

For three days, each household was given a daily sheet on which to record fuel use, cooking times and other information (Figure 5.38). The CleanCook Stove, Proimpex Small, Proimpex Large and ISPM stoves were tested in the field usability study, and households were supplied with a stove and pre-measured fuel during the first day meeting.

Figure 5.31: Usability Study participant with a stove to take home

The enumerators visited each household every day to check for any problems, collect data sheets and to ask a series of qualitative and quantitative questions to gauge users' opinions and habits. The questionnaire was developed to tease out issues of acceptability, preference, safety, and ease of use relating to each stove in particular as well as the ethanol fuel in general (see Annex 1 for the full questionnaire text).

5.7.2 Vatomandry Usability Survey Results

The results obtained for the 4 stoves subjected to usability testing are presented in Table 5.13.

Table 5.13: Usability and safety survey results

How easy is it to cook on the stove?						
	Very easy	Easy	A bit difficult			Total
ProImpex small	0	3	0			3
ProImpex large	0	0	1			1
CleanCook	2	0	0			2
ISPM	1	1	0			2
After training, how confident were you in using the stove?						
	Very confident	Fairly confident	OK	A bit worried		Total
ProImpex small	0	1	1	1		3
ProImpex large	0	1	0	0		1
CleanCook	2	0	0	0		2
ISPM	0	2	0	0		2
How much of the cooking did you do on this stove?						
	All	Most cooking	About half the cooking	A bit of the cooking		Total
ProImpex small	0	1	1	1		3
ProImpex large	0	0	1	0		1
CleanCook	1	1	0	0		2
ISPM	0	2	0	0		2
Did you use other stove / stoves as well?						
	Not at all	Occasionally	About half the cooking	Most cooking		Total
ProImpex small	0	1	1	1		3
ProImpex large	0	0	1	0		1
CleanCook	1	1	0	0		2

ISPM	0	1	1	0		2
How did this stove compare to your usual cooking?						
	Much better	A bit better	About the same	A bit worse		Total
ProImpex small	0	0	1	2		3
ProImpex large	0	0	1	0		1
CleanCook	2	0	0	0		2
ISPM	0	1	1	0		2
If you could afford it, would you buy this stove?						
	Definitely	Probably	Probably not	Definitely not		Total
ProImpex small	0	0	2	1		3
ProImpex large	0	0	0	1		1
CleanCook	2	0	0	0		2
ISPM	1	1	0	0		2
About how much do you think this stove would cost to buy? (Ar)						
	5,000	10,000	14,000	25,000	30,000	Total
ProImpex small	2	1	0	0	0	3
ProImpex large	0	0	1	0	0	1
CleanCook	0	0	0	1	1	2
ISPM	1	1	0	0	0	2
Would you consider using credit to buy the stove, if available?						
	Definitely	Maybe	Probably not	Definitely not		Total
ProImpex small	0	1	0	2		3
ProImpex large	0	0	1	0		1
CleanCook	1	1	0	0		2
ISPM	1	0	0	1		2
Is the stove the right size for cooking meals?						
	OK	Too small				Total
ProImpex small	1	2				3

ProImpex large	1	0				1
CleanCook	2	0				2
ISPM	2	0				2

How long did it take to prepare food compared to usual?

	I saved between 10 and 30 minutes	About the same	It took between 10 and 30 minutes more	It took at least 30 minutes more		Total
ProImpex small	0	1	0	2		3
ProImpex large	0	1	0	0		1
CleanCook	1	1	0	0		2
ISPM	1	0	1	0		2

Did you save any time in other ways compared to usual? (e.g. cleaning pots, gathering firewood)

	Saved a lot of time	Saved a bit of time	Had a bit less time	Had much less time		Total
ProImpex small	0	1	1	1		3
ProImpex large	0	0	1	0		1
CleanCook	1	1	0	0		2
ISPM	0	2	0	0		2

Please say in what ways you saved time

	No answer	Didn't need minding, could continue to work	Free to do other things	in lighting the fire	no need to stay next to the fire, doesn't need to clean pot	some time in lighting	Total
ProImpex small	2	0	1	0	0	0	3
ProImpex large	1	0	0	0	0	0	1
CleanCook	0	0	0	1	1	0	2
ISPM	0	1	0	0	0	1	2

Did you have any problems using the stove? - if so, please describe them

	No answer	had smell, took too long to cook	little problem to regulate	regulating problem	regulating the stove	Total
ProImpex small	1	1	0	0	1	3

ProImpex large	0	0	0	1	0	1
CleanCook	2	0	0	0	0	2
ISPM	1	0	1	0	0	2
Did anything on the stove break? If so, please describe						
	No answer	Leakage				Total
ProImpex small	2	1				3
ProImpex large	1	0				1
CleanCook	2	0				2
ISPM	2	0				2
About how much fuel did you use in total (litres)						
	1.5	3	9	10	13	Total
ProImpex small	0	0	1	0	0	1
ProImpex large	0	0	0	1	0	1
CleanCook	0	2	0	0	0	2
ISPM	1	0	0	0	1	2
About how much would you pay for ethanol per litre? - Ar						
	400	500	600	1,000	10,000	Total
ProImpex small	1	0	0	1	1	3
ProImpex large	0	1	0	0	0	1
CleanCook	0	0	0	1	1	2
ISPM	1	0	1	0	0	2
If any fuel was wasted, how did this happen? (write 'none wasted' if OK)						
	No answer	none wasted	outlet	pouring the fuel in	pouring the fuel in the container	Total
ProImpex small	2	1	0	0	0	3
ProImpex large	1	0	0	0	0	1
CleanCook	0	0	0	1	1	2
ISPM	1	0	1	0	0	2
Did you have any problems using ethanol? - if so, please describe						
	No answer	bad smell	bad smell from the outlet of the	no problem		Total

			stove			
ProImpex small	1	0	1	1		3
ProImpex large	0	1	0	0		1
CleanCook	2	0	0	0		2
ISPM	2	0	0	0		2

SAFETY

Did you feel the stove and fuel was safe to use?						
	Safe	OK	Not safe	Very unsafe		Total
ProImpex small	0	1	1	1		3
ProImpex large	0	0	1	0		1
CleanCook	2	0	0	0		2
ISPM	1	1	0	0		2

Please say why you feel that the stove safe / unsafe								
	No answer	If kids play in the kitchen it is dangerous	I'm too afraid for my kids	Kid wanted to drink alcohol	No - the same as LPG; easy to turn off	Protects from burning	The ethanol isn't very easy to burn	Total
ProImpex small	1	0	1	1	0	0	0	3
ProImpex large	0	1	0	0	0	0	0	1
CleanCook	1	0	0	0	0	0	1	2
ISPM	0	0	0	0	1	1	0	2

*** Did you feel the ethanol fuel was safe to use?**						
	Very safe	Safe	OK	Not safe		Total
ProImpex small	0	0	1	2		3
ProImpex large	1	0	0	0		1
CleanCook	0	2	0	0		2
ISPM	0	1	1	0		2

*Note: There were no burns or scalds recorded during this survey using any of the stoves

The feedback results have a number of dimensions but in general can be seen to show that both the Proimpex Small and Proimpex Large stoves consistently scored lowest of the 4 stoves on ease of use, confidence in using, proportion of use in practice, comparison with normal cooking and time taken to cook compared with normal.

Of importance for the Component A study, 2 out of 3 of the respondents stated that the Small Proimpex was too small for cooking. The main problem cited with using the Proimpex was fuel regulation. Perhaps most crucially, the Proimpex Small and large stoves were scored as unsafe or very unsafe in 4 out of 5 responses, citing issues mainly to do with children playing in the kitchen knocking over or drinking the ethanol bottle. Concerning likely demand for the stove, a telling response was that 4 trial users did not think they would purchase the stove if they could afford it, and that only one of the four would maybe consider taking credit to purchase the stove while the others would not, or definitely would not.

The ISPM stove scored moderately well in most categories, generally better than the Proimpex in terms of usability, confidence in use, comparison with existing cooking experience, perceived safety and desire to purchase. Opinion was however divided on whether credit would be taken to purchase the stove and the actual use of the stove varied widely from one user only using 1.5 litres while the other used 13 litres in the period.

The CleanCook generally received the most positive reaction from the 2 users who trialled it with the main concern appearing to be wasted fuel in refilling the container. The expected cost (or perceived value) of the stove was high, although both users stated their openness to taking credit to purchase a stove if it was available.

The overall reaction of the users to using ethanol is not very clear with the relatively small sample size; respondents reported a few problems including a bad smell (two cases) and filling the canister (the two CleanCook users). The price people were willing to pay for ethanol varied widely and a more focussed survey with a wider sample group at different income levels is likely to be needed to establish real ability and willingness to pay more accurately. It should also be noted that with a total sample size of 8 and a relatively short period of working with the stoves (3 days), that the results of this usability test cannot be considered conclusive and that a wider survey in other towns with a wider cross-section of populations would yield more robust results. However, within the limitations of time and survey size the results presented are notably consistent in the key areas of user preference (purchase intent) and safety.

5.7.3 Verbal Feedback from Focus Group Discussions (FGDs)

The enumerators visited households on a regular basis to check on safety and gather data. At the end of the field test a focus group discussion was held, where users gave their more general views (Figure 5.39). At all times communication was in Malagasy, the main language in Madagascar, and no payments were made as part of this research with users

Figure 5.32: The Focus Group Discussion (FGD) in Vatomandry evaluating the various stoves

receiving only free ethanol fuel for four days.

Table 5.21 shows the stove user's feedback during these focus group discussions.

Table 5.14: Focus Group Discussion findings

Overall result All eight users were shown the four stoves in the FGD and asked to rank them in order of preference. All the households liked the CleanCook stove best, the Proimpex least, and the ISPM the intermediate choice.		
Good things about the stove	**Problems user had with the stove**	**Suggestions**
CleanCook Stove - Users Feedback		
- No smoke - Clean - Able to save time - Above all: it protects the environment and keeps people healthy	- No major problem, but just concerned about the price of the ethanol, will it be affordable	- Should have bigger size for bigger pot - Should have 2 burners
ISPM Stove - Users Feedback		

- Clean - Safe - Easy to light - Easy to turn off	- When the food is boiling, water falls down on the burner and turns off the flame - High consumption of ethanol fuel - Doesn't support heavy cooking pot - Not appropriate for windy areas	- Stove stands should be stronger to hold big pots - It will be better if the ethanol's smell wasn't so bad
Proimpex Stove - Users Feedback		
- Clean - Easy to use - Movable	- Bad smell of ethanol - Needs permanent control - High fuel consumption - Flame turns off by itself - Too slow	- Better if the tank is under the burner itself - Need to find ways to decrease fuel consumption - Better to improve the design of the stove (appearance) - The raw material for the stove shouldn't be metal because it's too easily rusted; especially near the coast

5.8 Preliminary Impact on Indoor Air Pollution (IAP)

Although the most accurate, replicable and comparable emissions data will come from laboratory testing by Aprovecho and field testing, with a wider sample of indoor air quality results coming from the Component A monitoring, it was considered valuable to add an element of room monitoring to the CCT, as a preliminary guide and cross-reference to the future data, and to pick up any unexpected variations in the environment between the laboratory and the users kitchen.

Carbon Monoxide (CO) was chosen as the indoor air pollutant to be measured since it is consistently associated with negative health impacts, and serves as a useful indicator of the small lung-damaging particles associated with respiratory and cardiovascular health effects; as well as being associated with poorly functioning ethanol stoves. The equipment deployed during the CCTs, to measure the CO concentration in the kitchens, was the HOBO CO logger.

5.8.1 Testing Methods

Gaining standard results in a kitchen environment is difficult, given the different stove and kitchen geometries and materials. Particularly important is standardizing the height of the IAP samplers, because air pollutants are vertically stratified inside a house (for CO, which is lighter than air, concentrations increase with increasing height in a room). The following standard procedures were used for measurements taken within Tany Meva's kitchen:

The room concentration was measured in a total of five tests with the CleanCook stove (CC), the Proimpex Large, the Proimpex Small, the improved charcoal stove, and the traditional charcoal stove. The HOBO CO logger was set to record CO-concentration every minute, with the meal being cooked represented an average lunch for a family of four, and sampling times varying from 25 to 75 minutes, depending on the stove.

During the IAP testing the stove position in the room was not changed and the monitoring instrument was placed in the same location for each stove test, in accordance with the standard placement protocols given by University of California – Berkeley; the requirements (highlighted in Figure 5.34) being:

1. 100 cm from the edge of the stove (combustion zone)
2. 140 cm above the floor
3. 150 cm from any openable door or window (where possible)

An IAP measuring device was placed for a two hour period in accordance with the above requirements on each test day, and over the duration of the study, measurements were taken in the same kitchen with equipment installed in same position, to ensure that stove comparison was not affected by inconsistent factors. Although comparisons may be influenced by time-varying characteristics, the effects of these on air pollution levels were considered to be minimal over the duration of the study. The picture below shows the standard IAP equipment installation.

Before starting measurements, a co-location calibration check was performed to test whether or not the HOBO logger was working properly. The HOBO logger was tested against a 'Gold Standard' HOBO logger (which is only used for calibration). This calibration was followed after each of the devices was used six times.

Figure 5.33: IAP monitoring installation

5.8.2 IAP Testing Results

The baseline level in parts-per-million (ppm) was reasonably low during the CO sampling period, with baseline readings of the HOBO being in the range of 0.2ppm to 3.7 ppm. The graph revealed the pattern of peaks and lows which signifies a clean data set. Figure 5.41 shows mean values of Carbon Monoxide (CO) concentrations associated with each stove, with the lines representing the values of the HOBO CO logger every minute. The time required to conduct each CCT depended on lighting (heat-up) time and cooking time taken by the stoves and so varied with each stove.

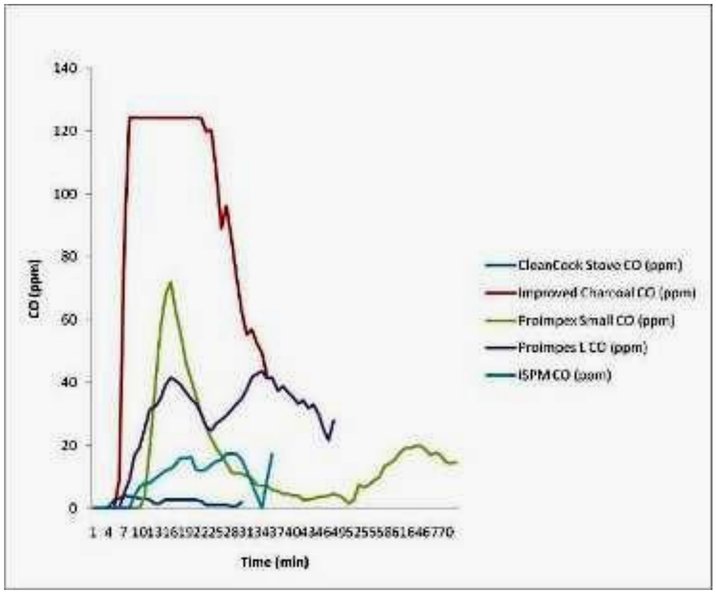


Figure 5.34: Time series values of CO emissions from stoves tested

Monitoring equipment was placed and began collecting data 20 minutes before any material was cooked. Background CO was measured before and after each cooking event, with the averages of these background measurements being subtracted from the concentrations measured during the cooking event (the CO contribution from human respiration was estimated to be negligible).

- The highest CO level was observed while cooking with the improved charcoal stove, possible due to the cook placing small pieces of paper to light the charcoal which produces sooty smoke.
- The next highest CO level was for the Proimpex stove. Carbon monoxide levels were relatively high when cooking with both the large and small Proimpex stove. Reduction of CO levels compared with charcoal is also evident with all ethanol fuels
- The maximum reduction was obtained with the CleanCook stove, due in part to the reduced exposure time due to faster cooking. Average and maximum CO concentrations are illustrated in Figure 5.42 for each of the ethanol stoves.

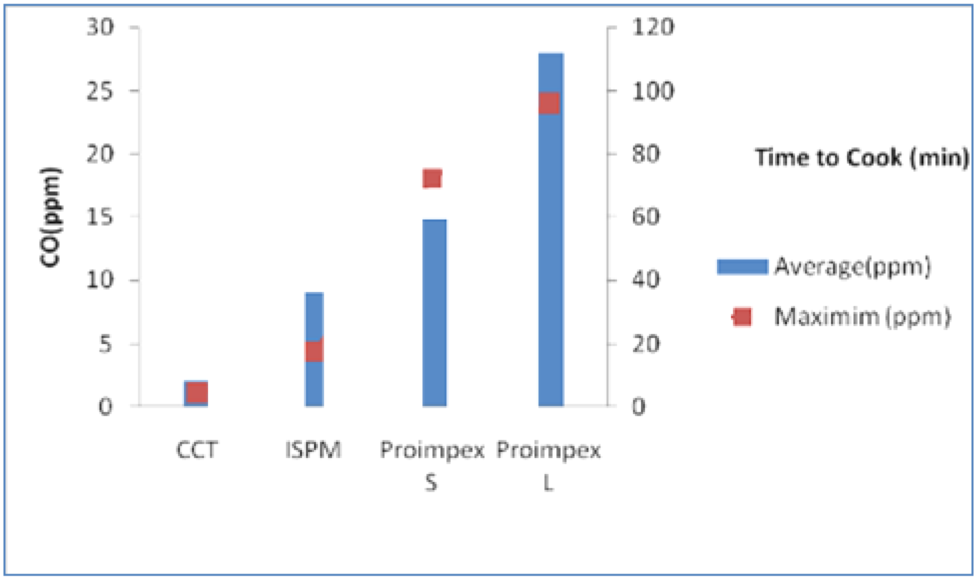


Figure 5.35: Ethanol stove time to cook and CO

5.8.3 Comparison to International Standards

The World Health Organization (WHO) sets air pollution guidelines to offer guidance in reducing the health impact of air pollution (both indoor and outdoor) based on current scientific evidence. WHO recently set new Air Quality Guidelines (AQG) for PM2.5, ozone, nitrogen dioxide, and sulfur dioxide, along with interim targets that are intended as incremental steps in a progressive reduction of air pollution in more polluted areas (WHO, 2005). The guideline for carbon monoxide was set in 2000 (WHO, 2000) and is currently being revised.

The results of the preliminary emissions testing are compared to WHO's AQG and interim target-1 (WHO, 2005) in the Table 5.22., with the CO concentrations, recorded in parts per million (ppm), being converted to μg/m^3 to match the unit used by WHO. It can be seen that even when reported at the highest concentration occurring during any eight hour period (i.e during cooking), the CleanCook stove is well below WHO 8-hour standard and the concentrations associated with the ISPM stove are very close to it. No conclusions can be drawn about the ProImpex stoves, as over the cooking period they were well over the WHO guidelines, whilst averaged over eight hours they would be below the standard, provided no other cooking event took place during this period.

Table 5.15: Comparison of kitchen concentrations to WHO guidelines

	CC	ISPM	Proimpex S	Proimpex L	WHO AQG
CO (μg/m3)	2.36	10.38	17.01	32.02	10 μg/m3
Time (min)	29	34	73	47	8hr

Note: WHO AQG is averaged over a time-span of 8 hours.

5.9 Laboratory testing

Laboratory tests were conducted at the internationally recognised Aprovecho Research Center in Oregon, USA, where they operate a state of the art laboratory facility for testing stoves. Testing and reports on fuel use, carbon monoxide, particulate matter, and greenhouse gas emissions from a variety of improved cook stoves are available to projects. Aprovecho conducted standard laboratory testing to determine the relative performance, including fuel use and emissions, of the five ethanol stoves, at various ethanol water contents. Emissions of carbon dioxide, carbon monoxide, particulate matter, and methane were measured, as well as an evaluation of the safety of the stoves.

5.9.1 Testing protocol

The ethanol stoves were tested using the 2003 UCB Water Boiling Test (WBT). The first phase of each test consists of a high-power analysis in which 2.5 or 5 litres of water are brought to a boil in standard 3 or 7 litre pots. In this case, only the 95% fuel burnt in the CleanCook stove produced a high enough firepower to reliably boil the 5 litres, so the other test series were conducted using 2.5 L of water. Each high power test was performed twice with the stove body starting cold and then again when hot. In the low power phase of the test, the 2.5 or 5 litres of water was simmered at about 3 degrees centigrade below the boiling temperature for 45 minutes. However is should be noted that the WBT is not intended to necessarily predict field performance of the stove, as real-world conditions are highly variable.

The Aprovecho gas chromatograph (GC) was used to measure the emissions of carbon dioxide, carbon monoxide, and methane. An integrated Tedlar bag sample was taken from the exit of the emissions collection hood throughout the duration of the test, which was then analyzed within 24 hours using the gas chromatograph. A calibration standard was run daily to ensure accurate readings from the GC.

5.9.2 Monitoring emissions

The stove was tested using Aprovecho's commercially-available Portable Emissions Measurement System, in which real-time emissions of carbon dioxide (CO2), carbon monoxide (CO) and particulate matter (PMTSP) were recorded (Figure 5.42). The system also measured the flow rate of the diluted exhaust gases, enabling mass-based calculations of the emissions.

Although the Aprovecho test protocol suggests that each stove/fuel combination be tested three times for statistical confidence, in this test series, the pure fuel was tested three times as required, but the varying fuel/water content levels were tested only once each. This allows a trend to be observed, but may not account for possible variability.

Figure 5.36: Aprovecho Testing Rig

5.10 Calculations

5.10.1 Heat transfer calculations

Fuel use was calculated in accordance with the standard methods in the Shell Foundation/UCB Water Boiling Test. The prime indicator is that of specific consumption, corrected for:

- starting temperature of the water
- moisture content of the fuel
- mass of water remaining in the pot

This provides a measure of fuel used to boil (or simmer) one litre of water. Fuel used to complete the WBT is reported as the average specific consumption (and emissions) of cold and hot start plus simmer, multiplied by 5 Litres.

5.10.2 Combustion calculations

Emissions are monitored in real time throughout the duration of the test, with the emissions equipment measuring the concentration of each gas and the volumetric flow rate through the system each second. Then the mass of each pollutant emitted during each test phase is calculated. Because the GC is not real-time, it provides an integrated sample over the duration of the test, with the average concentration of the bag sample being applied to each second of the real-time flow data. This total mass is then normalized and reported as specific emissions to complete the WBT, corrected for starting temperature of the water, moisture content of the fuel, and mass of water remaining in the pot.

5.10.3 Fuels and water content

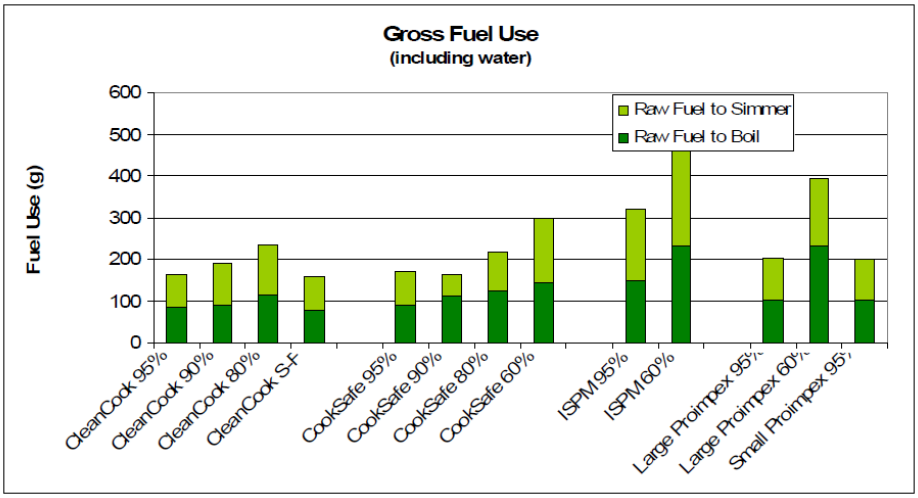
The main base fuel was 95% (190 proof) pure grain alcohol by volume, with 5% assumed water content. An additional test on the CleanCook was run using a fuel designated 'Soot Free' fuel used by the boating fraternity. It was assumed that the purity of this sample was also 95% with the remainder being water. A standard value of 29.7 MJ/kg was taken for pure ethanol and the stoves were tested with varying water contents, including 95% ethanol, 90%, 80%, and 60% by volume.

5.11 Results

Fuel is usually purchased on a per volume basis, irrespective of actual ethanol content. However, since water does not provide energy to the pot but rather requires energy to be evaporated, actual ethanol used to heat the pot needs to be investigated. In these reported results, it should be noted that they may be skewed slightly due to the following:

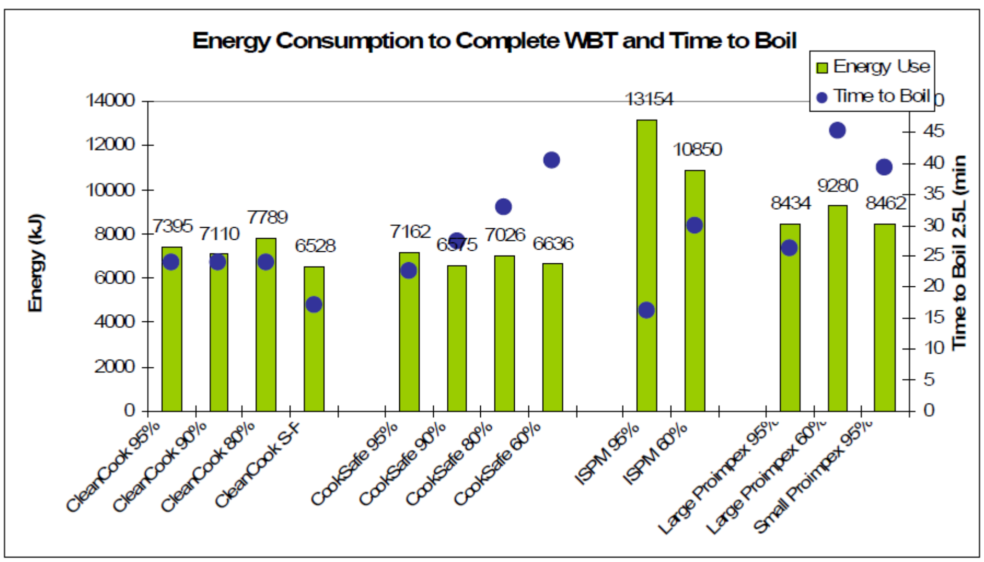
- The CookSafe stove run on 60% fuel was not able to boil the 2.5 litres of water. The test was run until the maximum temperature of 96ºC was reached and held for 5 minutes without any further increase
- The Proimpex with 60% fuel reached a maximum temperature of 98ºC for cold start and only 94ºC on hot start, simmering at only 92ºC as opposed to the ideal 96ºC
- The small Proimpex with 60% fuel was not able to boil the water and the test was abandoned
- Gross fuel consumption, (uncorrected for fuel water content, starting temperature, or water remaining) is shown in Figure 5.43
- The mass of total fuel increased when increasing water content in all stoves. The use of the special 'soot-free' fuel in the CleanCook was similar to that of the 95% ethanol spirits, suggesting similar calorific values for the two fuels.

Figure 5.37: Gross fuel consumption by stove and fuel concentration



Specific consumption is used to describe the fuel minus the water and energy required to evaporate the water in the fuel divided by the litres of water heated, and provides a measure of fuel use per useful task completed. The same 'specific' calculation was used for the reported emissions. The data is then presented as if each stove had been tested with 5 litres of water, albeit based on tests that used 2.5 litres for all but the CleanCook stove.

Figure 5.38: Time to boil, and energy consumption by stove and fuel concentration



The tests illustrated in Figure 5.44 record the 'Specific energy', or the burning rate of actual ethanol, decreasing with increasing water content at high power. This is, as expected, due to the increased time required to boil with increasing water content suggesting slower burning of the ethanol fuel. Firepower at simmer seemed to follow an opposite trend.

On average, the CleanCook used 254 g (7206 kJ) of dry ethanol to complete the WBT, while the CookSafe used 242 g (6878 kJ), or 5% less – albeit it was not able to provide enough energy to achieve complete boiling and using 2.5 litres of water (adjusted). The ISPM used 423g (12002 kJ), about 70% more than the CleanCook/CookSafe while the Proimpex used 307g (8725 kJ), or 24% more than the first two stoves.

5.11.1 Total emissions

Real-time carbon monoxide (CO) emissions were not constant for any of the stoves. Emissions in the CleanCook and CookSafe stoves were dependent on how much fuel was in the canister and how long the stove had been burning. When corrected for the amount of fuel required to evaporate the water in the fuel, total CO emissions are shown in Figure 5.45. The Soot-Free fuel (S-F) emitted high amounts of CO when operated at low power in the CleanCook stove, although emissions are similar to the pure fuel at high power. The CookSafe stove had quite high CO emissions, while the ISPM was fairly clean burning, and the Proimpex stoves emissions being in the middle. Overall, the water content in the fuel did not seem to have a significant effect on combustion in terms of the total CO production.

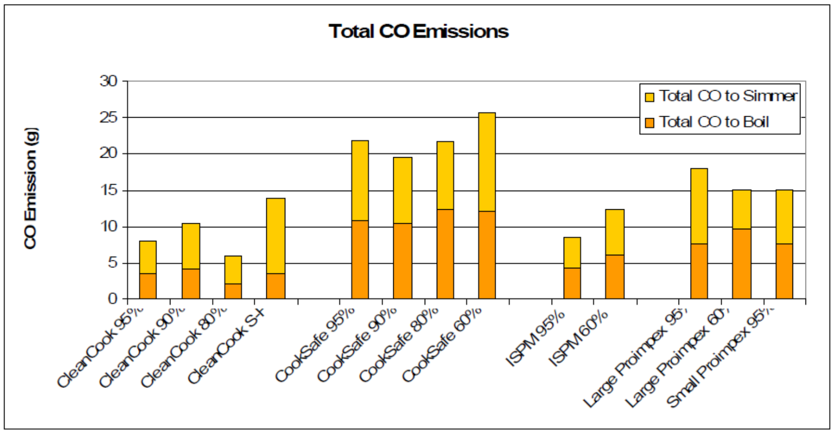


Figure 5.39: Total CO emissions by stove and fuel concentration

When corrected for the emissions produced while evaporating the water in the fuel, and comparing emissions to complete the 5L WBT, with the Shell Foundation/ Aprovecho CO benchmark of 20 grams to complete the WBT, the CleanCook and ISPM stoves met this benchmark with all fuels. The CookSafe emitted too much CO to meet the benchmark, regardless of fuel water content. The Proimpex stoves did not meet the CO benchmark with the higher-purity fuels, but did meet the benchmark when the 60% fuel was used. Thus, for the CookSafe, ISPM and Proimpex stoves, corrected CO decreases with the increased water content, suggesting that the water in the fuel seems to improve the completeness of combustion, reducing CO emissions, albeit slowing down the cooking process substantially.

The CO/CO_2 ratio measures the amount of pollutant CO given out for the total completely combusted fuel – indicated by CO_2. The CleanCook stove showed an average CO/CO_2 ratio of 4% at high power and 5% at low power in the spirit-based fuel tests. The CookSafe ratios were almost three times higher, showing 13% at high and 12% at low power. The ISPM was similar to the CleanCook, at 3%-5%, and the Proimpex was slightly better than the CookSafe at 5% to 13%; as shown in Figure 5.46.

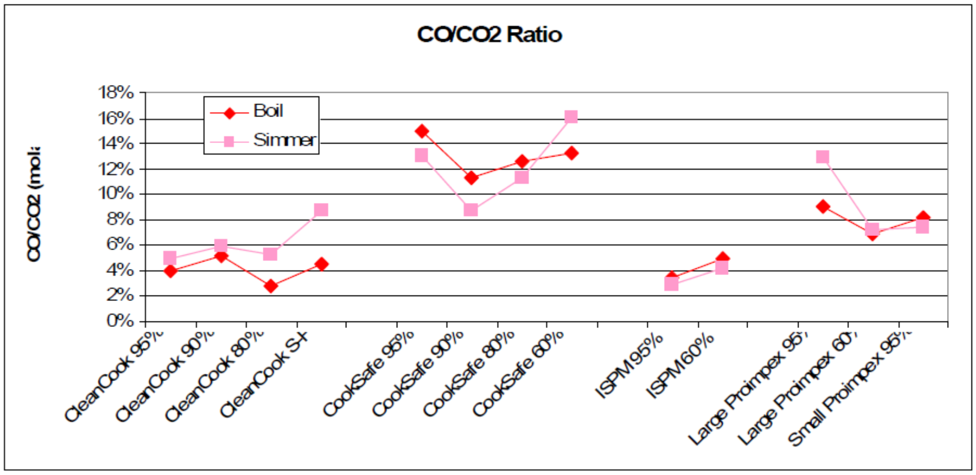


Figure 5.40: CO/CO_2 ratio by stove and fuel concentration

Note: Particulate Matter (PM2.5) emissions were negligible in all tests.

Safety

The stoves were evaluated for safety, with each stove being given a safety score out of a possible 40 points, based on the protocol developed by Nathan Johnson of Iowa State University. The protocol includes an evaluation on a scale of 1-4 (with 4 being highly safe) in ten different areas. Table 5.22 shows the ratings given for each stove (not that this methodology is still under development, and was adjusted from the protocol adopted for biomass stoves).

Table 5.16: Stove safety ratings

Stove	Score (out of 40)
CleanCook	39
Cooksafe	37
ISPM	36
ProImpex	35

5.12 Conclusions and Recommendations

The CCT, Usability and pilot IAP tests described in this report have assessed the leading International ethanol stove, available Madagascan ethanol stoves and traditional and modified/improved fuelwood and charcoal stoves. Due to time and budget limitations it should be noted that not all possible ethanol stoves were tested with CCTs and Usability, with perhaps the most notable exception being the CookSafe stove from South Africa, which was however tested in Aprovecho laboratory testing.

The testing presented in this section of the report has largely addressed issues of stove safety, usability, performance, design, efficiency, preferences of cooks/households and initial indoor air pollution. The testing has not substantially addressed wider issues of commercialisation; fuel cost, quality and supply; stove manufacturing, cost and supply chain issues; or local socio-political context etc. This sub-study has also drawn feedback mainly from a small sample group of cooks in Antananarivo and households in the project location of Vatomandry. As such, while this sub-study can act as an indicator of likely acceptability, and any corresponding stove development needs, it cannot at this stage be presented as a full assessment of the viability of the stoves in the long term and as part of a commercial scale up. The authors believe that this sub-study only offers a view of which of the stoves, in their current state, are likely to be accepted, used and offer substantial IAP improvements in households under the Component A surveys of the project. This can act as a proving step for ethanol fuel in the country while further stove development continues in Madagascar and internationally.

5.12.1 Ethanol as a household fuel

Feedback from the three CCT cooks stating that of all the stoves, the ones they liked best were the modified wood and the modified charcoal (Table 8) should act as a warning to promoters of ethanol stoves in Madagascar. In order to enter the household cooking market, ethanol and ethanol stoves will have a substantial challenge in order to overcome existing patterns of preference, low cost and familiarity. Where concerns were raised about the fuel in usability tests, they related to safety concerns of children knocking over or drinking the fuel, and to the smell of the fuel in some cases. Pricing feedback on what people would be prepared to pay for ethanol varied widely and no conclusive feedback on this crucial question can be presented in this report. However positive feedback on ethanol was also noted for all ethanol stoves in the Focus Group Discussion feedback on their cleanliness (Table 10) and perceived environmental benefits.

It should be noted from the reactions to ethanol from the Usability survey that the stove in which the ethanol is used has an impact on the perception of the fuel, particularly in terms of safety, usability and smell. The success of ethanol introduction will therefore be a function of both the fuel and stove, as well as linked fuel issues of price, local availability, quality, purchase volume options and bottle/tank options as well as ethanol specific requirements like denaturing.

5.12.2 The Proimpex Stove

The Proimpex stove in its current form does not appear to represent a viable alternative to charcoal or compare favourably with other ethanol stoves available in Madagascar. Tests at Aprovecho showed promising performance for the larger version, and some further experimentation to optimise the geometry of the stove for efficient combustion and greater usability, and improve its safety experiments and tuning were recommended for both the ProImpex stove and the ISPM to improve both fuel use and emissions. It was advised that changing variables such as the height of the pot supports could make a significant improvement. The smaller ProImpex tests were abandoned as the stove did not have the power to heat up even the lower volume (2.5 litres) of water to boiling point.

Aprovecho noted that in safety terms, the Proimpex functions in a similar way to the ISPM. However, the separate fuel holder poses an additional danger, as the long fuel supply tubing may be tripped on, or pulled, which could knock over the stove and pot or possible spill the fuel all over. It would be preferable to have the fuel source very close to the stove itself.

The reflected fears expressed by three out of four usability participants described the stove as unsafe or very unsafe (Table 9), while the screening evaluation rated it lower than all the other ethanol stoves and the modified wood and charcoal stoves. The stove also generated IAP levels higher than the competing ethanol stoves in the preliminary testing conducted which will be cross-checked at Aprovecho. In terms of convenience, responses from CCTs and Usability tests revealed long cooking times, difficulties in lighting and difficulties/attention required in fuel regulation (Tables 5 and 9). Two out of three of the users of the smaller Proimpex stove considered it too small for cooking typical meals and with an average cooking time of over 65 minutes for a standard meal (Table 7) it took more than twice the time taken by the other ethanol stoves and the traditional and modified wood stoves.

The key potential advantages of the Proimpex stove are not evaluated in this study, but they include local ownership, local manufacturing capacity, low cost and use of low grade ethanol which can be produced by small-scale producers with basic technology (although elevation of percentage ethanol from typical 45% up to 60% minimum for use in the stove is required). However, in spite of these possible advantages in scale-up, the stove is unlikely to be adopted widely (and was not used in the Component A study on safety grounds) while the usability, safety and convenience issues which have been found in this testing series remain. It is therefore recommended that further design work be conducted on the following issues before introduction at scale is considered:

- Modification of the bottle stand and feed system for increased safety (eliminating access potential for drinking and knocking over by children) and usability (removing the need for constant attention by the cook in adjusting the ethanol feed).
- Improving the firepower of the stove so as to reduce cooking times to levels comparable with other available ethanol, charcoal and wood burning stoves. This may involve burning higher grade ethanol or modifying ethanol feed or burner geometry and materials.
- Making the stove look more attractive to users

Recommendations from Aprovecho include:

- The fuel flow is very difficult to control with the present hardware. There seems to be too much or too little flow, no matter where the controller is placed.
- The construction of fuel flow lines was poor, as fuel was leaking out of several connections in the tubing.
- The small Proimpex seems too underpowered to be useful, especially when there is water in the fuel.

- The pot supports could be lower, placing the pot closer to the flames. This might decrease fuel use, but needs to be tested.

5.12.3 The ISPM Stove

The ISPM stove performed consistently better than the Proimpex stove (large and small) on most measures including evaluation screening (Table 3), CCTs (Table 5), CCT cooks preferences (Table 8 and Figure 36), Usability feedback (Table 9) and IAP (Table 12). With scores on a par with the other stoves in consideration (third of eight in the screening, cooking time within 2 minutes of the CleanCook etc), the ISPM stove deserves further consideration for possible introduction and commercialisation. It shares many of the potential advantages cited for the Proimpex in the previous section in terms of local ownership and initiation, but without several of the drawbacks described above in the feedback on the Proimpex stoves. Given the relatively similar basic design concept of the ISPM to the Proimpex it implies that with some optimisation of the design of the low-grade ethanol/separate fuel supply stove type results on usability, safety and performance can be improved.

It is recommended that the ISPM be undergoes further development and testing where budget additions to accommodate it may be made. Design review should be made by the promoters on the following:

- Considering safety and usability issues around the bottle and feed system and comparing with the Proimpex. Safety feedback on the Proimpex was worse although the systems are fundamentally similar so comparison of strengths and weaknesses in each may help identify optimum design features for such systems.
- Rusting, more evident during the laboratory tests, could be a serious problem in terms of corrosion and leakage of the fuel tank, and blocking of the line between fuel tank and combustion surface.
- Although the stove is able to deliver competitive cooking times with other stoves it appears that this relies on excess feed of ethanol to the stove which lights in the gutter to speed up cooking. This feature should be considered closely since it may have safety implications and increases fuel consumption (and so cooking cost) compared with the Proimpex stove.

Recommendations from Aprovecho include:

- The stove should always be level. When the stove sits at an angle due to uneven feet on the stove, the flames tend to focus toward the higher side of the pot, reducing heat transfer efficiency. For testing, a shim was used under one side of the stove to make it level.
- The nozzle in the flow control clogs easily. After three tests, some rust from the interior of the fuel holder had begun blocking the nozzle. Thus, the only way to clear the line was to disconnect the tube from the stove and blow into the tube, which is dangerous and inconvenient, and only a temporary solution. Perhaps a way to prevent this blockage is to put a filter membrane at the entrance to the tube from the fuel holder. The entrance could be widened, possibly funnel-shaped, to hold this filter.

However, this rust appears to be coming from the body of the fuel tank, and could lead to corrosion and holes in the fuel tank.

- The fuel supply canister would be better if level, as some ethanol always remains inside. Also, the closer to the stove centre the fuel supply can be, the less likely to tip the stove will be.
- Is the outer ring of the burner necessary? Fuel should not be burning there, so it is unclear what the purpose of the rocks there might be. It might be better to simply have an empty trough for draining rather than a rock-filled area which appears as it should be burning.
- The stove is very heavy, and it seems the handles might bend or break. Perhaps stronger handles can be designed.
- Perhaps the pot supports could be lower, placing the pot closer to the flames. This might decrease fuel use, but needs to be tested.

5.12.4 The CleanCook stove

In general the CleanCook stove delivered the best performance of the four ethanol stoves in evaluation screening, CCTs, CCT Cooks feedback, Usability tests and IAP testing. It would be considered therefore as a stove which, if fuel of appropriate quality was made available at a price which people could afford, would be safe, accepted and offer substantial IAP improvements over existing wood and charcoal stoves. Aprovecho stated that there were no apparent improvements to heat transfer or combustion efficiencies for the CleanCook stove.

However, key challenges from a wider perspective with the CleanCook include its imported origin, its up-front cost, and the need for 95% pure ethanol, which may not be as easy to produce in the current local distilleries. The stove could be expected to work well in the current study, providing a means to test ethanol as a fuel in the country while stove development continued on local designs and/or local manufacture of proven ethanol stoves, if ethanol proved successful.

5.12.5 Cooksafe stove

The Cooksafe stove was not available for field testing and seems to no longer be in production at the present time, although laboratory testing was carried out. Though somewhat underpowered, it provided almost enough power to bring the 2.5litres to the boil, and was considered sufficiently safe to pass the Aprovecho standard. However, although there are no apparent improvements to heat transfer or combustion efficiencies for the Cooksafe stoves, Aprovecho reported that the CookSafe stove could benefit from some basic manufacturing improvements to increase durability.

6 Market, Financial and Economic Analysis of Ethanol as a Household Fuel

6.1. Introduction

This section describes the market, financial and economic analysis for ethanol as a household fuel in Madagascar.

- Section 6.2: Market Analysis. The first section analyses the market for ethanol production. It looks at various production scenarios for micro distilleries to determine a range of viable price points for ethanol production. These price points are then used to look at potential household penetration rates for ethanol as compared with other fuels.
- Section 6.3: Financial Analysis. This section presents an assessment of the financial viability of an ethanol stove from a household perspective, and from a micro-distillery perspective.
- Section 6.4: Economic Analysis. The financial analysis looks at the implications of ethanol to the private sector – e.g. a household or a plant operator – whereas the economic analysis incorporates the implications of ethanol as a fuel for the public good, incorporating wider benefits such as decreased deforestation, reduced GHG emissions, and public health consequences.

For both the financial and the economic analysis, the benefits of using ethanol as a fuel were compared with a baseline scenario comprising traditional production/consumption of charcoal as a fuel. The analysis did not compare ethanol against other fuels for the following reasons; LPG and kerosene are more expensive than ethanol, and therefore are not competitive, and; ethanol cannot compete with wood as it is inexpensive (at a minimum there is a time cost during gathering).

A traditional Cost Benefit Analysis (CBA) approach was used for the analysis, discounting net benefits over a specific time horizon, and testing for sensitivities in the analysis. The principal economic indicator applied is the net present value (NPV), which is derived by subtracting the sum of the present value (PV) of a cash flow of costs from the sum of the PV of a cash flow of revenues. The difference between discounted revenues and discounted costs gives the NPV. Generally, an investment is accepted if the NPV is positive at a pre-selected discount rate. The financial analysis of stoves was conducted over a period of 10 years (the lifetime of a stove), while the financial analysis of micro-distilleries and the economic analysis were conducted over a 30-year time horizon, both used a discount rate of 10%.

6.2. Market Analysis

6.2.1. Usage of Household Cooking Fuels in Madagascar

The USAID-funded IRG/Jariala report (2005) estimates that Madagascan families annually consume approximately 9.026 million m^3 of wood as firewood and 8.575 million m^3 as charcoal (IRG Jariala, 2005), as shown in Table 6.1.

Table 6.1: Estimation of annual consumption of various wood products (Jarialy, 2005)

Type of wood	Rural (m^3/pers)	Urban (m^3/pers)	Total (millions m^3)
Fuelwood	0.686	0.134	9.026
Charcoal	0	1.75	8.575
Construction	0.24	0.22	4.127
Total	0.93	1.97	21.728

Figure 6.2 below indicates that a total of 72.4% of the Madagascan population currently uses firewood for household cooking while 25.2% uses charcoal, with only 2.4% of the population using other fuels such as electricity, LPG, kerosene and coal. As ethanol is a very clean burning fuel it will be able to compete with LPG, particularly if it is significantly cheaper, but due to the very low numbers of LPG users' ethanol will only have a significant impact if it can attract users of charcoal and wood that can afford to buy it.

Table 6.2: Summary of Household Cooking Fuel Use in Madagascar

	Housing characteristics								
	Type of cooking fuel								
	Electricity	LPG, natural gas	Biogas	Kerosene	Coal, lignite	Charcoal	Firewood, straw	Dung	Other
Urban	0.9	2.7	0.3	0.2	0.7	59.4	35.5	0.1	0.1
Rural	0.1	0.6	0	0.1	0.2	15.2	83.3	0.3	0
Total	0.3	1.1	0.1	0.1	0.3	25.2	72.4	0.3	0

Reference: Demographic and Health Survey for Madagascar. Measure DHS stat compiler http://www.measuredhs.com

6.2.2. Cost of Household Cooking Fuels in Madagascar

The cost of household cooking fuels in Madagascar varies depending on where they are purchased, with prices in urban areas typically being higher due to the increased demand, fuel scarcity, and the greater transport costs from production to market. In rural areas wood is often collected, while wood is purchased in urban areas. Charcoal is always purchased but its cost is considerably higher in urban areas as it is further from its place of production. The cost of household fuels varies throughout the year with the price of biomass fuels rising in the wet season due to the lack of dry wood as highlighted in Table 6.3, which summarises the amount households spend on household fuels per week, with the annual household cooking fuel costs being given in Table 6.4.

Table 6.3: Weekly spending on fuel by the majority of households (MGA)*

	Wet season		Dry season		% use
	Max	Median	Max	Median	
Charcoal	15,000	2,100	17,000	2,100	81
Wood	14,000	2,800	14,000	2,800	41
Kerosene**	200	200	200	200	0.3
LPG	6,220	4,670	6,220	4,670	1.6
Electricity	9,000	9,000	9,000	9,000	0.9

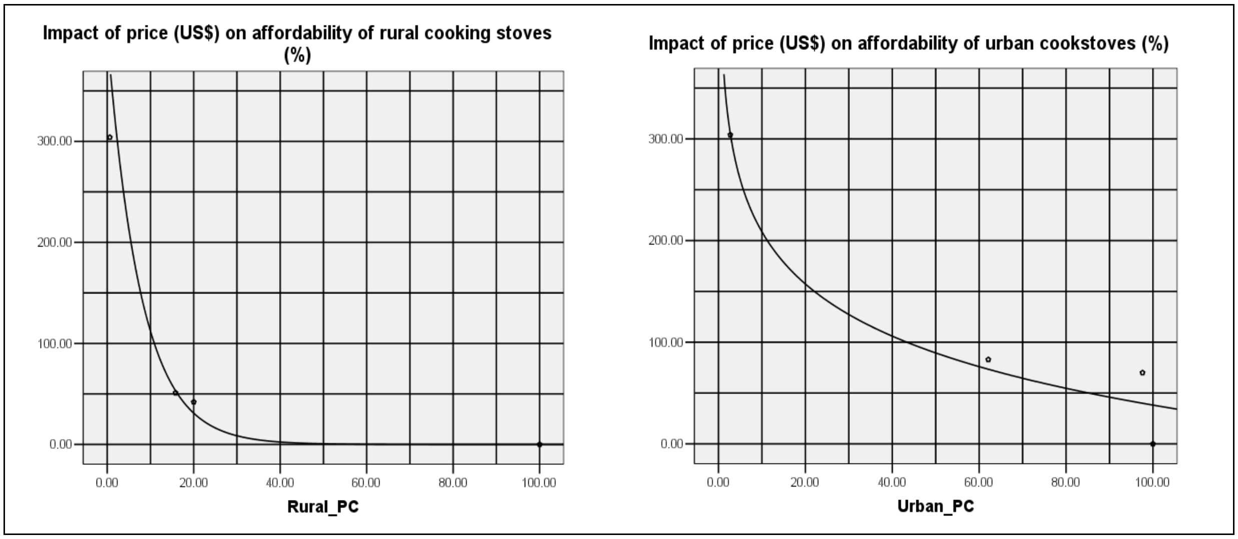
*Households may use more than one fuel, so total % use is >100% **Fuel for lighting

Table 6.4: Annual Costs of Purchasing Household Cooking Fuels/Stoves in Madagascar

Fuel	Annual Cost of Fuel (US$)	Population in Urban Areas (%)	Population in Rural Areas (%)
LPG[1]	294	2.7	0.6
Charcoal – urban	78.13	59.4	n/a
Charcoal – rural	45.96	n/a	15.2
Woodfuel – urban	70	35.5	n/a
Woodfuel - rural	35	n/a	4.165

Only the wealthiest families can afford LPG, while households in urban areas generally tend to preferentially purchase charcoal rather than woodfuel. Conversely rural households tend to preferentially use woodfuel, often being collected rather than purchased, with only the wealthier households being able to purchase charcoal. The graphs in Figure 6.1 are cumulative curves which describe the relationship between the cost of fuel (in dollars per annum, on the vertical axis) against the percentage of the Madagascan population who can afford to pay for a fuel.

Figure 6.1: Impact of Price on the Affordability of Household Cooking Fuels in Urban and Rural Areas of Madagascar



For example, in urban areas for LPG (which costs around US$300 per annum), only 1.6% of the population are able to afford it, whilst for charcoal, the percentage includes the charcoal users and the LPG users – as both can afford charcoal. For woodfuel, the LPG, charcoal and purchased wood household percentages are included – and finally, the gathered fuelwood can be afforded by all. In this analysis, the costs of the fuel and stove are not relevant, with the curves providing data on how much households in Madagascar are currently paying for household cooking energy. The assumption is that people will use one fuel even if they could afford a bit more, until they can afford to take the next step.

It is also assumed that at the same price, households will prefer to use ethanol than charcoal or wood for most (but not all) cooking purposes, due to its cleanliness and ease of use. It is also assumed that households will switch some (but not all) cooking from LPG to ethanol, if ethanol is cheaper. By plotting a best fit curve it is possible to predict the percentage of the population that would be able to afford a household cooking fuel of any price between LPG and free woodfuel, and once the price of ethanol has been determined it is possible to estimate the percentage of Madagascan Households that will be able to afford to purchase ethanol in both urban and rural areas.

6.2.3. Cost of Household Cook Stoves

Although the cost of purchasing a stove is relatively small over its lifetime, because households almost always have to purchase the cost of the stove 'up-front' it is a barrier for households wishing to change to using another fuel. Table 6.5 below summarises the costs of household stoves in Madagascar.

Table 6.5: Summary of Cost of Purchasing Household Stoves in Madagascar

Stoves	Total Cost (US$)	Stove life in years	**Annual Cost (US$)**

No stove	0	-	**0**
Woodstove*	52	5	**5**
Charcoal stove	2.4	1	**4.8**
LPG stove	50	5	**10**[121]
Ethanol Stove	50	10	**5**

*The full price of the improved woodstove used in this study was not used in this analysis, as many households would be using a lower priced stove. A value of $5 per annum was used as a conservative estimate of the stove cost.

The prices of stoves in Antananarivo varies considerably, and as of December 2010, an improved charcoal stove cost Ar 3,000 – 7,000 (US$1.43 – 3.34), a traditional charcoal stove cost Ar1,500 (US$0.72), and an improved wood stove (with a chimney) cost Ar110,000 (US$52.38). These prices, spread over the lifetime of the stove, are included in Table 6.4.

6.2.4. Ethanol Production Scenarios

Madagascar's current ethanol production activities are focused on the development of industrial scale production facilities, attached to the countries major sugar producers (Sirama, Morondava, and Nouvelles Unites), and current expectations are that most of this ethanol will be exported to the more lucrative European ethanol markets, or used for fuel blending in Madagascar, with only 5% of production being allocated to the domestic household cooking fuel market. This study provides information on what is required to allow most of the ethanol for household fuel to come from micro-distilleries such as the working models in Brazil and the USA (highlighted in Chapter 5). These units can produce ethanol of a high enough quality and strength to be used in ethanol stoves (over 92% ethanol), unlike the ethanol produced in artisanal (Toaky Gasy[122]) stills, which produce ethanol at too low a concentration (only around 35-45% ethanol). A further advantage of advanced micro-distilleries is that they do not require the large amounts of woodfuel required by artisanal stills, often obtained from unsustainable sources, and leading to further deforestation.

Micro-distilleries can be constructed in rural settings close to the feedstock sources, and can produce high-grade household fuel ethanol to supply local markets. Although ethanol can be produced from a wide range of feedstocks, this report is mainly focusing on ethanol produced from molasses and from sugar cane. It should be noted, however, that increasing the range of raw feedstocks can increase the number of days each year during which ethanol can be distilled, which has a substantial impact on the cost of ethanol production.

Sugar cane is currently grown throughout rural Madagascar, often illicitly, for Toaky Gasy production. Toaky Gasy has been declared illegal as it is often made without any form of quality control, and can be dangerous to people's health, with occasional police crack-downs doing little to reduce the quantities produced. If ethanol is produced in micro-

[121] Includes sundry items such as tubing, which needs to be replaced on a regular basis

[122] Toaka Gasy is a type of rum for which Madagascar is famous, and which forms part of the 'tourist circuit' but uses large amounts of wood. It does, however, bring in income into the informal economy

distilleries it can be more easily controlled as well as denatured and coloured to ensure it does not enter the illicit drinks market. Table 6.6 summarises a financial model for a 120 litre per day capacity micro-distillery, based on currently operating plants in Brazil and USA, and using both molasses and waste products (including waste from fruit and vegetables).

Table 6.6: Financial model for a 120 litres per day capacity micro distillery

- Equipment costs: $15,380; construction cost $5,000; boiler cost $1,000
- Financing: $21,380 financed over 5 years at 10% interest. Depreciation taken as payment into a cash reserve based on 15 year straight line
- Feedstock Option 1: Crop waste valued at $4 per tonne
- Feedstock Option 2: Sugarcane purchased at $15 per tonne
- Estimated value of co-products:
  Primary co-product – animal feed valued at $0.10/litre
  Secondary co-products - garden crops valued at $0.10/litre
- Ethanol cost is calculated for two scenarios:
  Income earned on primary or secondary co-products
  No income earned on primary or secondary co-products
- Production based on fermentation and distillation of 120 litres per day over 330 days per annum

Five Year Distillery Budget	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Totals**	**Year 6**	**Notes**
Feedstock purchase (Option 1)	2640	2640	2640	2640	2640		2640	Low-cost feedstock ($4 per tonne)
Feedstock purchase (Option 2)	8250	8250	8250	8250	8250		8250	Sugarcane feedstock @ $15/tonne
Operational cost	5476	5476	5476	5476	5476		5476	
Interest	2138	1828	1467	1049	564	7045	0	
Principal	3,104	3,603	4,182	4,855	5,635	21380	0	Loan capital $21,380; 5yr finance
Depreciation (Operating Reserve)	1425	1425	1425	1425	1425		1425	Straightlin e 15 years
Transport costs (5% operational costs)	274	274	274	274	274		274	
Production costs								
Total production costs (Option 1)	15057	15246	15465	15719	16014		9815	
Total production costs (Option 2)	20667	20856	21075	21329	21624		15425	
Production costs per litre with no by-products sold								

Production cost per litre (option 1) - no by-products	0.380	0.385	0.391	0.397	0.404		0.248	
Production cost per litre (option 2) - no by-products	0.522	0.527	0.532	0.539	0.546		0.390	
Valuation of by-products								
Sale of direct co-products (animal feed only)	3960	3960	3960	3960	3960		3960	$0.10 animal feed /litre
Sale of secondary co-products	3960	3960	3960	3960	3960		3960	$0.10 of secondary co-products/litre
Interest on Operating Reserve	114	228	342	456	570		684	Operating Reserve- 8% simple interest
Subtotal	**8034**	**8148**	**8262**	**8376**	**8490**		**8604**	
Production cost per litre with by-products sold								
Production cost per litre (option 1) with by-products	**0.177**	**0.179**	**0.182**	**0.185**	**0.190**		**0.031**	
Production cost per litre (option 2) with by-products	**0.319**	**0.321**	**0.324**	**0.327**	**0.332**		**0.172**	
Returns on investment @ 5%								
Selling price for option 1	0.40	0.40	0.41	0.42	0.42		0.26*	
Selling price for option 2	0.55	0.55	0.56	0.57	0.57		0.41*	
Selling price for option 1 with by-products	0.19	0.19	0.19	0.19	0.20		0.03*	
Selling price for option 2 with by-products	0.33	0.34	0.34	0.34	0.35		0.18*	

**Note that once the capital cost of the distillery has been paid off in year 5, the unit price of ethanol could fall substantially. However, in a growing market, it is more likely that the price of ethanol would stay unchanged, with the increased profit margin going into expansion to supply the growing market*

Total income per annum

Option 1	**15810**	**16008**	**16238**	**16505**	**16814**		**10306**
Option 2	**21700**	**21898**	**22128**	**22395**	**22705**		**16196**
Option 1 with by-products	**15408**	**15600**	**15825**	**16086**	**16390**		**9875**
Option 2 with by-products	**21299**	**21491**	**21715**	**21976**	**22280**		**15766**

Profit margin (Income vs expenditure)

Option 1	**753**	**762**	**773**	**786**	**801**
Option 2	**1033**	**1043**	**1054**	**1066**	**1081**
Option 1 with by-products	**351**	**355**	**360**	**367**	**376**
Option 2 with by-products	**632**	**635**	**641**	**648**	**657**

The operating costs of the micro-distillery are summarised in Table 6.7 and the materials and installation costs of the micro-distillery are summarised in Table 6.8.

Table 6.7 Micro-Distillery Operating Costs (US$)

Operating Cost Budget			
Costs	**Year 1 to 5**	**Year 6**	**Details**
Yeast	$0.00	$0.00	See chemicals
Enzymes	$0.50	$0.50	Necessary for some feedstocks but not others
Chemicals	$1.20	$1.20	Yeast, PH modifiers, testing materials
Energy	$0.60	$0.60	Auxillary biomass purchase for fuel; unnecessary if there is bagasse
Electricity	$0.75	$0.75	For pumps, fans and electronic controls; can be supplied with ethanol from in small generator
Other utilities	$0.00	$0.00	Water -- no charge
Maintenance	$2.50	$5.00	Doubled at year 6
Labour	$8.00	$8.00	Four full-time staff (based on a daily wage of US$2)
Admin	$4.00	$4.00	One part-time manager
Insurance	$0.00	$0.00	Self-insurance
Total	$17.55	$20.05	
Total/litre	$0.15	$0.17	

Table 6.8: Micro-distillery Materials and Installation Costs (US$)

Materials and Installation for Distillery (120 L/d capacity)	
8'3" Copper pipe	$120.00
5' 3'Copper pipe	$60.00
fittings/flanges	$350.00
Copper tubing	$350.00
Brass fittings	$200.00
Packing rings	$200.00
8 sq ft evaporator	$1,000.00
Custom hood	$1,500.00
Pumps and controls	$1,500.00
2"pvc pipe and fittings	$500.00
Auto valve	$400.00
Process tank and equipment	$2,500.00
Plastic Fermentor tanks	$1,000.00
Miscellaneous parts	$700.00
Cane Press and accessories	$2,500.00
Flat-plate Heat Exchanger	$2,500.00
Hardware costs	**$15,380.00**
Brick built-in-place furnace & boiler	$1,000.00
Labour and welding	$5,000.00
Total	**$21,380.00**

Ethanol Micro-Distillery Summary	
Total Equipment Cost	$15,380
Total Construction Cost	$5,000
Total Boiler Cost	$1,000
Daily production	120 litres

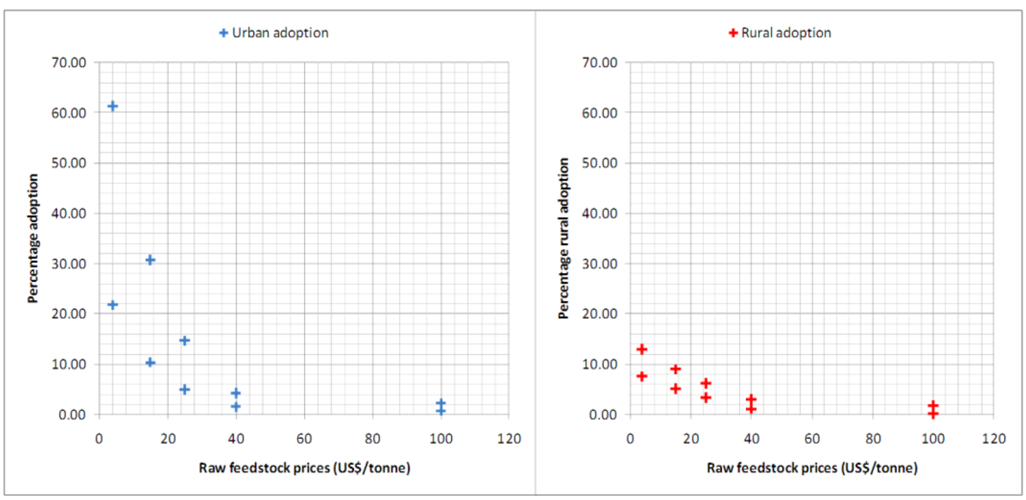
In this financial summary, feedstock costs for sugarcane and for waste materials have been included, but there are a wide range of other materials that are suitable for producing ethanol as shown in Table 6.9 below, and in more detail in Annex 12.

Table 6.9: Feedstock options for Ethanol Production (optimum yields)

Crop	Crop Production (tonnes/hectare)	Ethanol (litres/tonne)	Ethanol Yield (litres/hectare)
Sugar-cane	85	83	7055
Cassava	40	200	8000
Cassava	30	200	6000
Sweet Potato	20	140	2800
Sweet Sorghum	40	55	2200
Corn	10	400	4000

For most of these analyses, the price of raw feedstock of sugar cane is taken as US$15/tonne or US$4/tonne for waste, based on estimates from other countries such as Ethiopia and quoted FAO values. However, since the price of ethanol, and thus the adoption rate of ethanol as a household fuel, is highly dependant on the price of the raw feedstocks, a range of prices (from $4 per tonne to $100 per tonne) was considered, for 330 days per annum production of ethanol in all cases. The resulting price of ethanol, and adoption percentages were calculated where by-products were included and excluded from the analysis, as shown in Figure 6.2. In each case, the lower levels indicate the levels of adoption where the value of by-products is not included.

Figure 6.2: Summary of the Percentage Adoption of Households and Raw Feedstock Price



Production scenarios

Using the same model of micro-distillery as described in Table 6.6, the price of the feedstocks and the impact of the sales of bi-products was analysed to determine to what extent this affects the end cost of ethanol production and thus the effective uptake by households. The 6 production scenarios, below, were analysed and the results are shown in Table 6.10. As sugar cane is typically not available as a feedstock all year round production 3 and 4 highlight mixed crops of sugar cane and other cultivated crops to ensure year round ethanol production.

Production 1 Waste foods (e.g. over-ripe fruits etc.): cost of $4 per tonne with by-products sold
Production 2 Waste foods (e.g. over-ripe fruits etc.): cost of $4 per tonne without by-products sold
Production 3 Mixed-crop of sugar-cane and other cultivated crops (e.g. cassava): cost of $15 per tonne with by-products sold
Production 4 Mixed-crop of sugar-cane and other cultivated crops (e.g. cassava): cost of $15 per tonne without by-products sold
Production 5 Sugar-cane only: cost of $15 per tonne with by-products sold
Production 6 Sugar-cane only: cost of $15 per tonne without by-products sold

Table 6.10: Cost of Ethanol Production using Various Production Scenarios

Ethanol Production Values	**Prod 1**	**Prod 2**	**Prod 3**	**Prod 4**	**Prod 5**	**Prod 6**
Raw material cost (US$ per tonne)	4	4	15	15	15	15
Days of production (per annum)	330	330	330	330	264	264
Ethanol fuel price per day (US$)	**19**	**40**	**33**	**55**	**42**	**63**
Price of ethanol use per annum (US$)	74	151	125	206	158	235
Stove Cost (US$)	50	50	50	50	50	50
Stove Life (years)	10	10	10	10	10	10
Urban population adoption (%)	**61**	**22**	**31**	**10**	**20**	**7**
Rural population adoption (%)	**13**	**8**	**9**	**5**	**7**	**4**

Although it can be seen that the type of feedstock has a significant impact on the cost of ethanol production and its potential adoption, this study will focus on 3 costs scenarios of ethanol production, as summarised in Table 6.11, being 20, 30 and 35c per litre, as well as the adoption levels. These three price points were selected to analyse the changes that variations within a viable affordable market would create. Although at the 'low' end of the price range, it can be seen from Figure 6.1 that if ethanol costs more than around $35cents, the potential adoption rate drops off rapidly.

Table 6.11: Total Potential Adoption of Ethanol as a Household Fuel in Urban and Rural Areas of Madagascar based on 3 prices of ethanol production

	Scenario 1	**Scenario 2**	**Scenario 3**
Fuel/day (cents)	20	30	35
Fuel/annum (US$)	73	110	128
Stove cost (US$)	50	50	50
Stove life (years)	10	10	10
Stove/annum (US$)	5	5	5
Total cost per annum (US$)	78	115	133

Urban adoption (%)	**58**	**36**	**28**
Rural adoption (%)	**13**	**10**	**9**

The Impact of the Raw Feedstock Price

A further analysis was conducted to determine the impact of the price of the raw feedstocks on the price of ethanol and its subsequent impact on household adoption in urban and rural areas. A range of feedstock prices were analysed from the $4 and $15/tonne already analysed, as well as feedstock prices of $25, $40, and $100 per tonne, summarised in Table 6.12. The price of sugarcane in Madagascar was obtained from various sources and ranged from US$15 up to US$100 depending on where it is purchased. FAO currently quotes the cost of raw sugar cane at $17, but the significantly higher prices quoted by other sources could be due to the current scarcity of raw feedstock, or other external factors, such as a one-off quote, without the promise of ongoing commercial demand. All these feedstocks were assumed to be available over the full year, with the number of days of production per year taken as 330. Since sugar-cane is not generally available over this time-frame, there are implications for the agricultural sector on the need to grow suitable 'partner crops', such as sweet sorghum or cassava.

Table 6.12: Impact of the Feedstocks Prices on the Cost of Ethanol Production

	Price of feedstock (US$)	4	15	25	50	100
With by-products sale	**Price of ethanol (US$))/litre**	0.19	0.33	0.48	0.73	0.86
	Cost per annum	74	125	180	271	319
	Urban adoption (%)	**61**	**31**	**15**	**4**	**2**
	Rural adoption (%)	**13**	**9**	**6**	**3**	**2**
Without by-products sale	**Price of ethanol (US$))/**	0.40	0.55	0.70	0.94	1.07
	Cost per annum	151	206	261	348	396
	Urban adoption (%)	**22**	**10**	**5**	**2**	**1**
	Rural adoption (%)	**8**	**5**	**3**	**1**	**0**

It can be seen that the feedstock price has a significant impact on the price of ethanol production, falling from an adoption rate of 61% of urban households with a feedstock price of US$4/tonne, down to an adoption rate of 2% of urban households with a feedstock price of US$100/tonne. For this analysis a feedstock price of US$15 for sugarcane is used, but it should be noted that any increase in feedstock price will result in an increased price of ethanol and a lower household adoption rate.

Household Ethanol Adoption Curves

Figures 6.3 to 6.7 show predicted adoption curves for both urban and rural households based on the typical sale prices of ethanol summarised in Table 6.11. These adoption curves follow s-curves, derived from well-documented real life commercial experiences of the growth of a product[123]. Note that no replacement is included in this formula.

[123] Modelling Market Adoption by Juan Carlos Mendez Garcia.

Based on the four calculated ethanol prices of 20, 30, and 35c per litre, potential adoption curves were produced for the following three growth rates:

- Rapid - 10 years to reach maximum market penetration
- Medium - 20 years to reach maximum market penetration
- Slow - 30 years to reach maximum market penetraion

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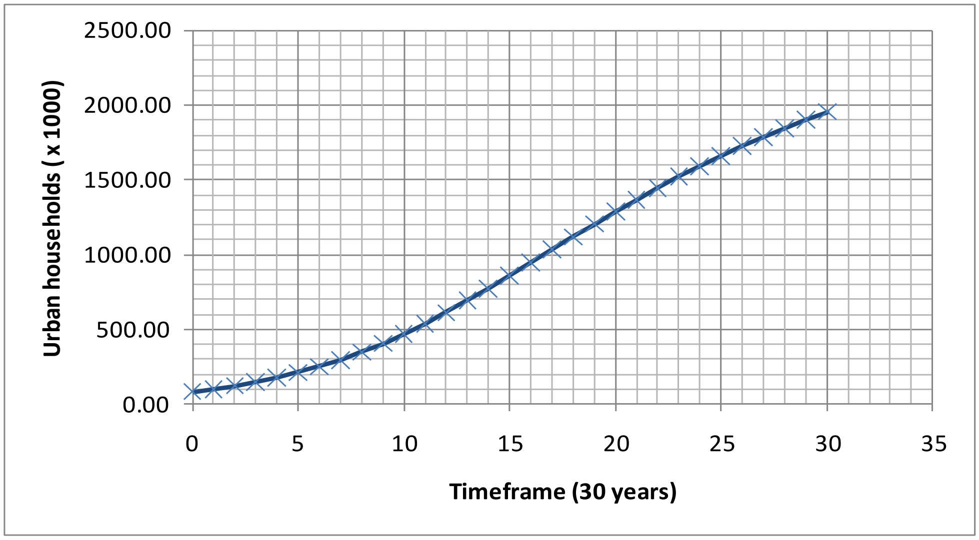
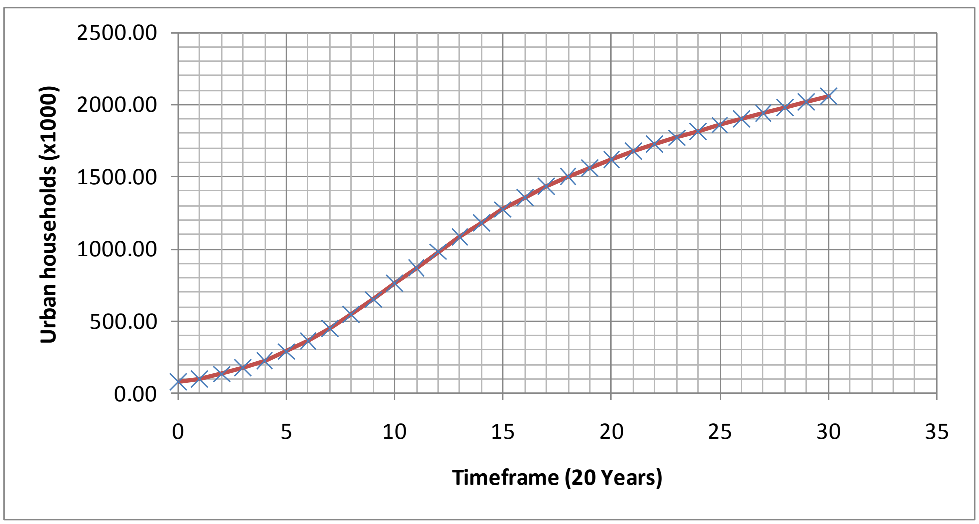
http://8020world.com/jcmendez/2007/04/business/modeling-market-adoption-in-excel-with-a-simplified-s-curve/

Figure 6.3: Potential Adoption Curves over 10, 20 and 30 years for Urban Households Based on an Ethanol Price of US$0.20





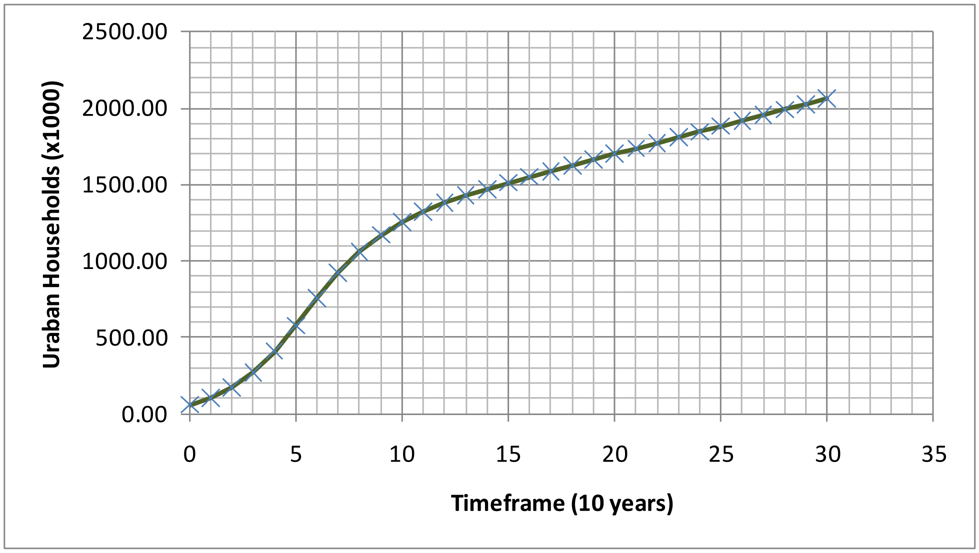
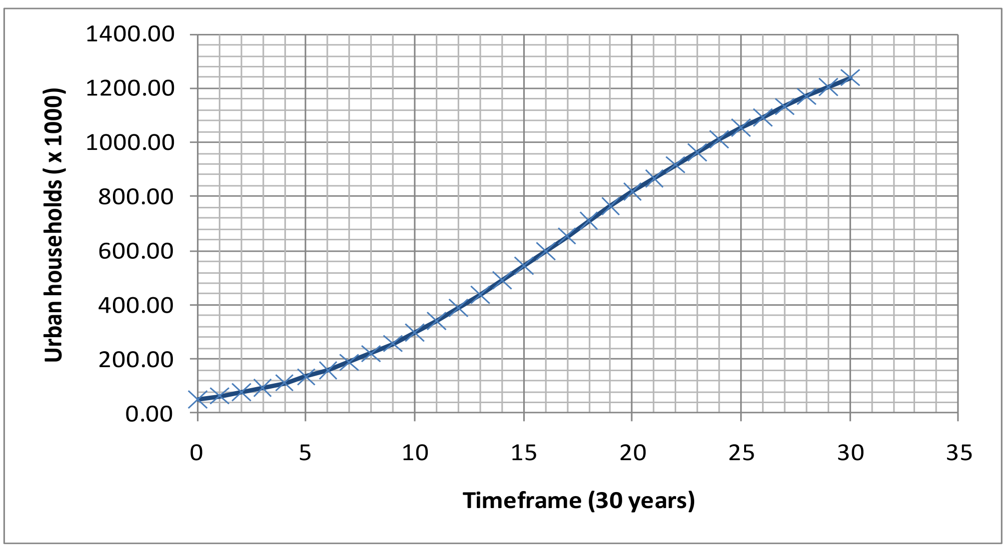
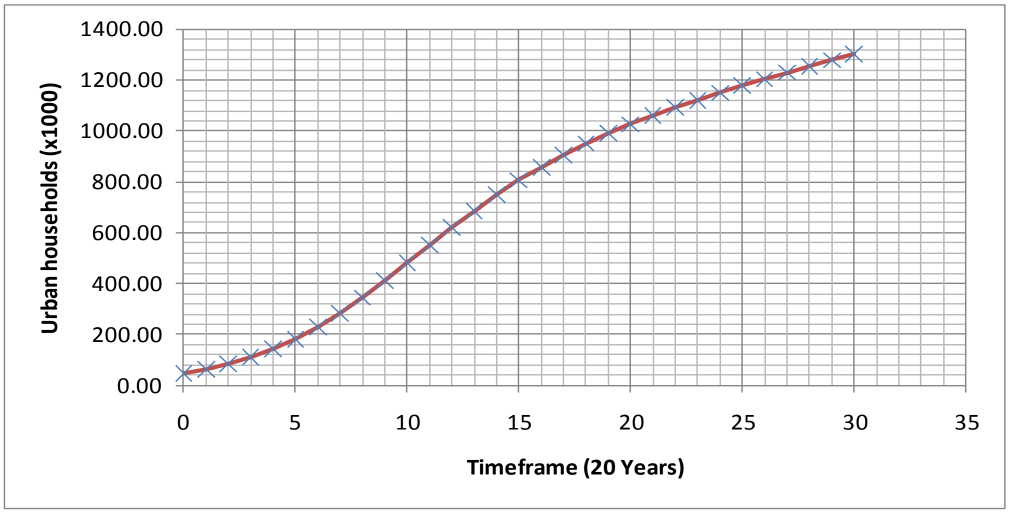


Figure 6.4: Potential Adoption Curves over 10, 20 and 30 years for Urban Households Based on an Ethanol Price of US$0.30




Urban households (x1000)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0
5
10
15
20
25
30
35
Timeframe (20 Years)

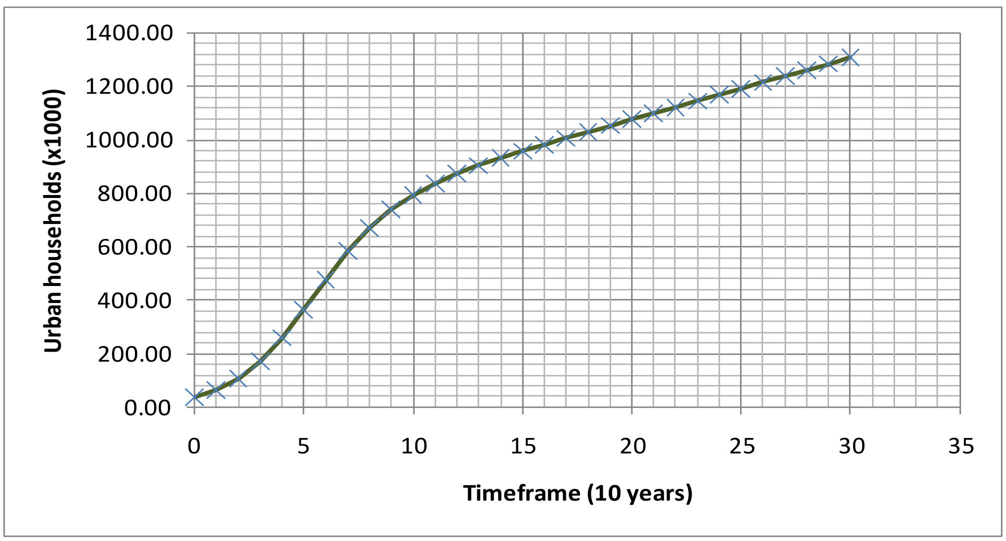
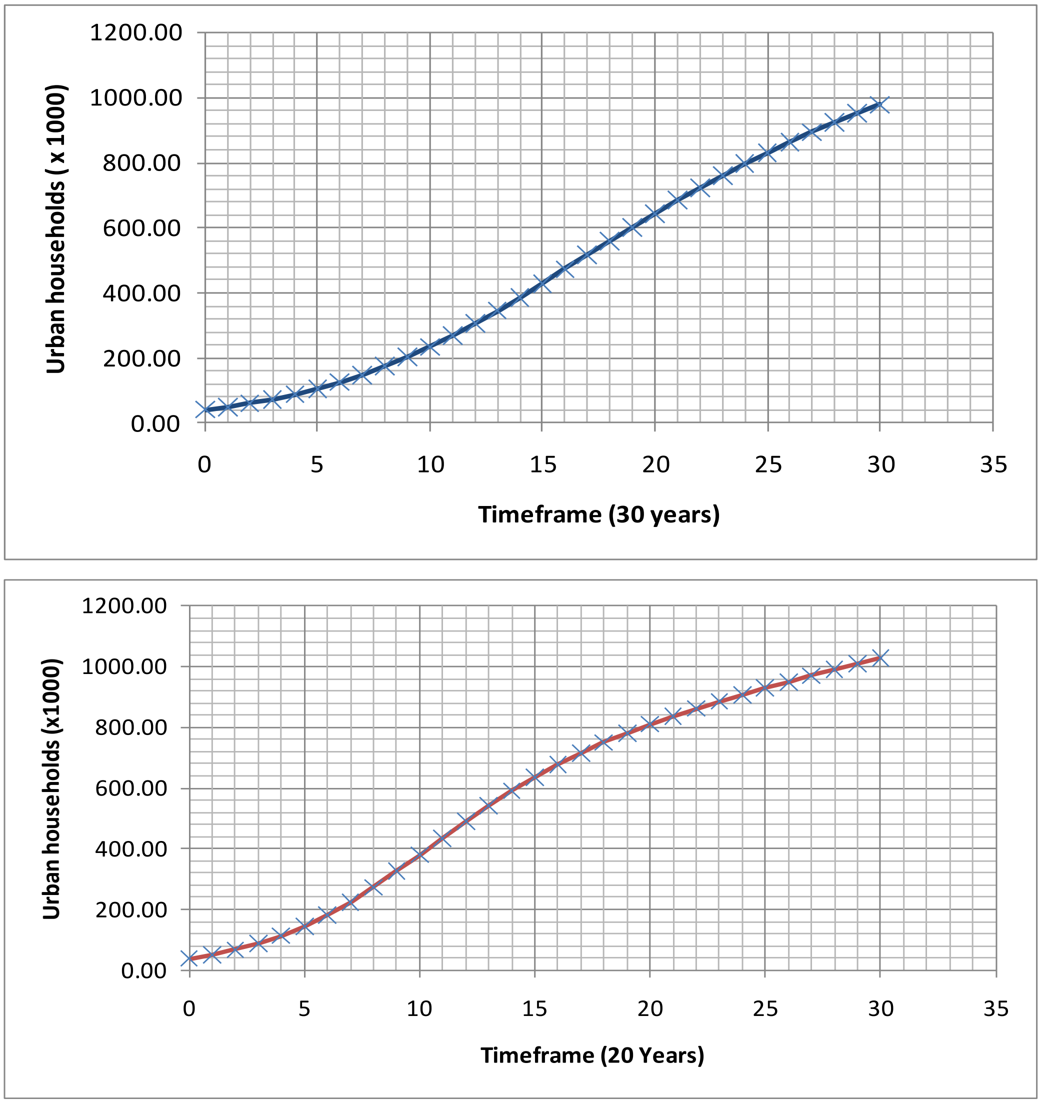

Urban households (x1000)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
0
5
10
15
20
25
30
35
Timeframe (10 years)

Figure 6.5: Potential Adoption Curves over 10, 20 and 30 years for Urban Households Based on an Ethanol Price of US$0.35



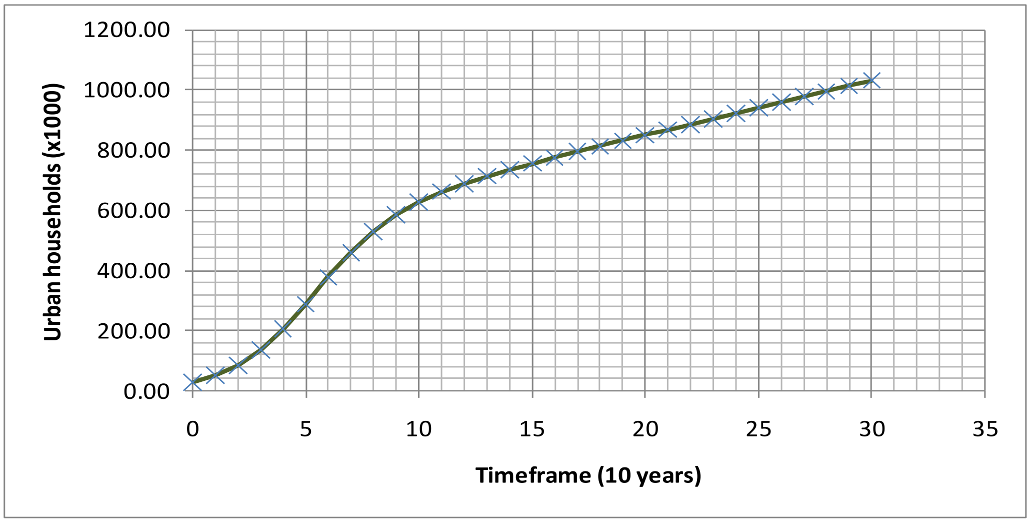
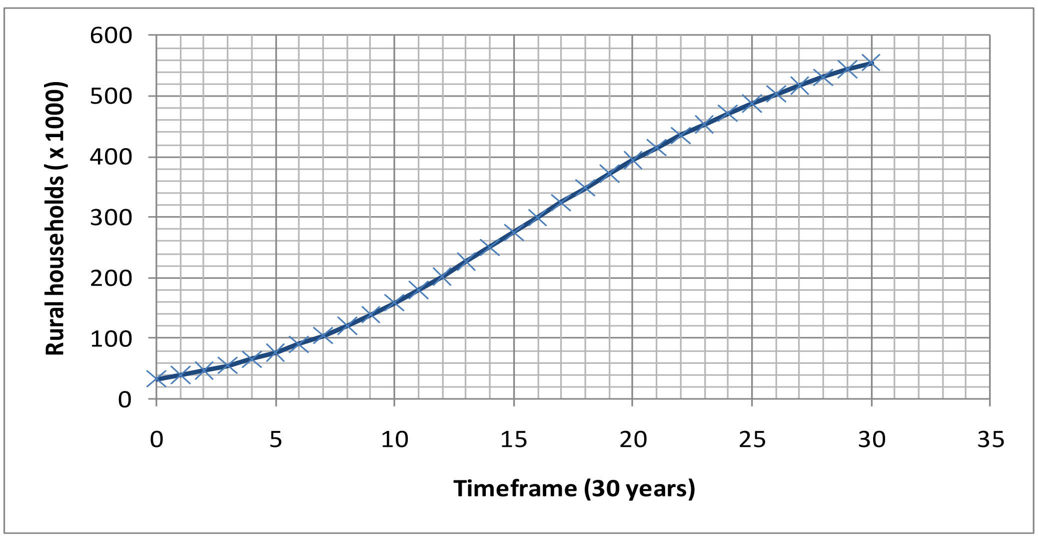
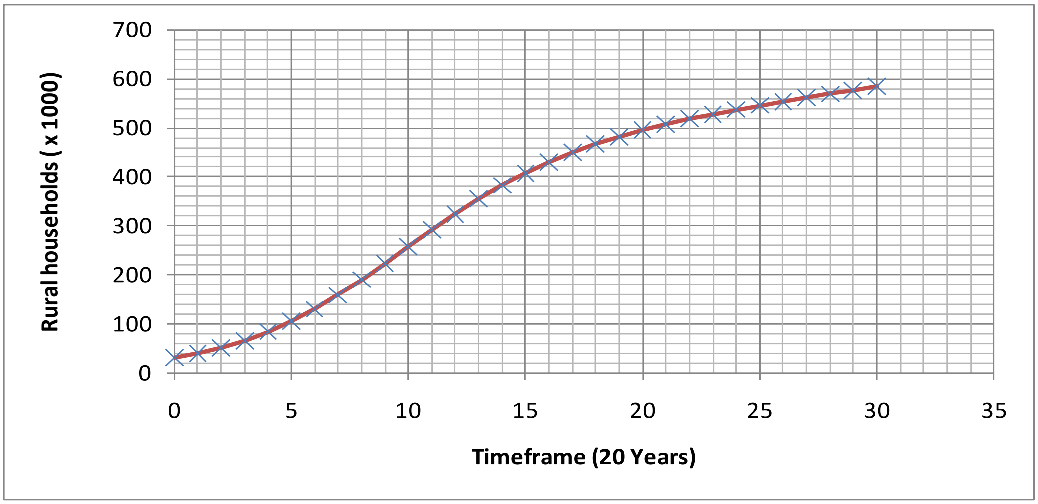


Figure 6.6: Potential Adoption Curves over 10, 20 and 30 years for Rural Households Based on an Ethanol Price of US$0.20




Rural households (x 1000)
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
Timeframe (20 Years)

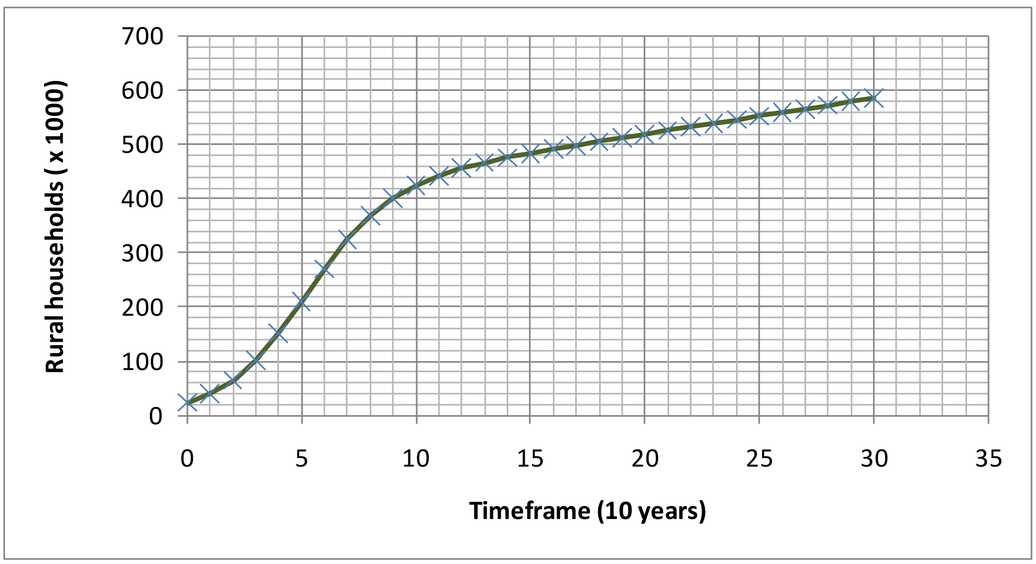
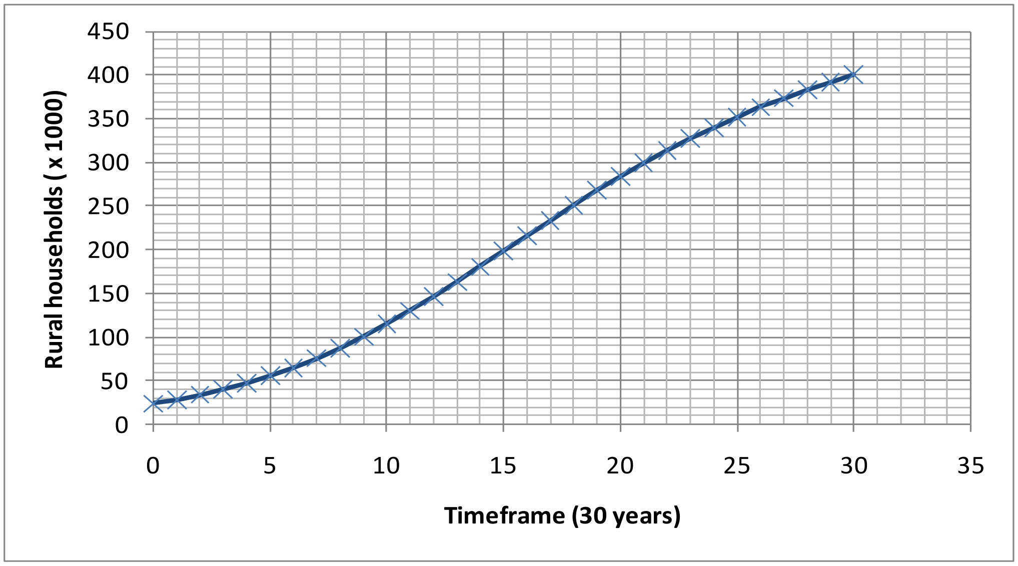
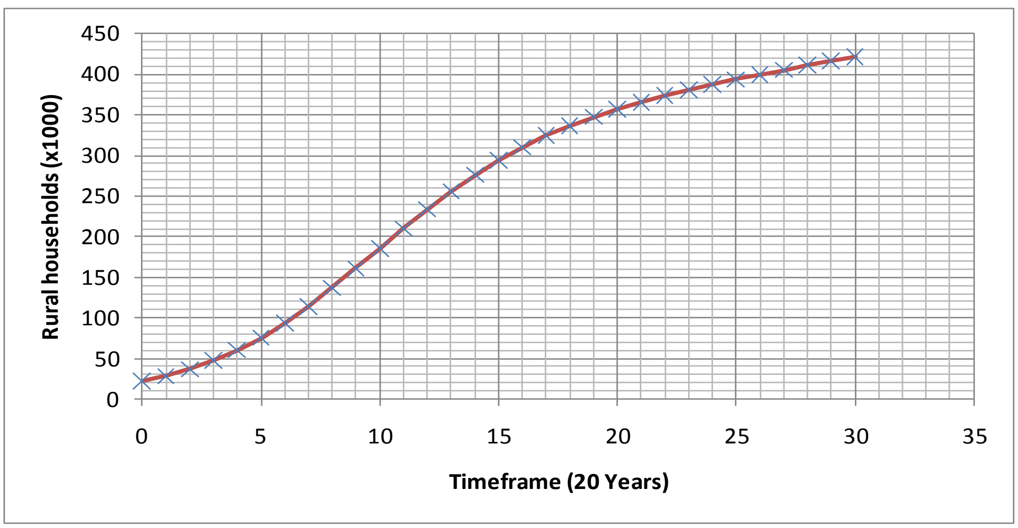

Rural households (x 1000)
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
Timeframe (10 years)

Figure 6.7: Potential Adoption Curves over 10, 20 and 30 years for Rural Households Based on an Ethanol Price of US$0.30





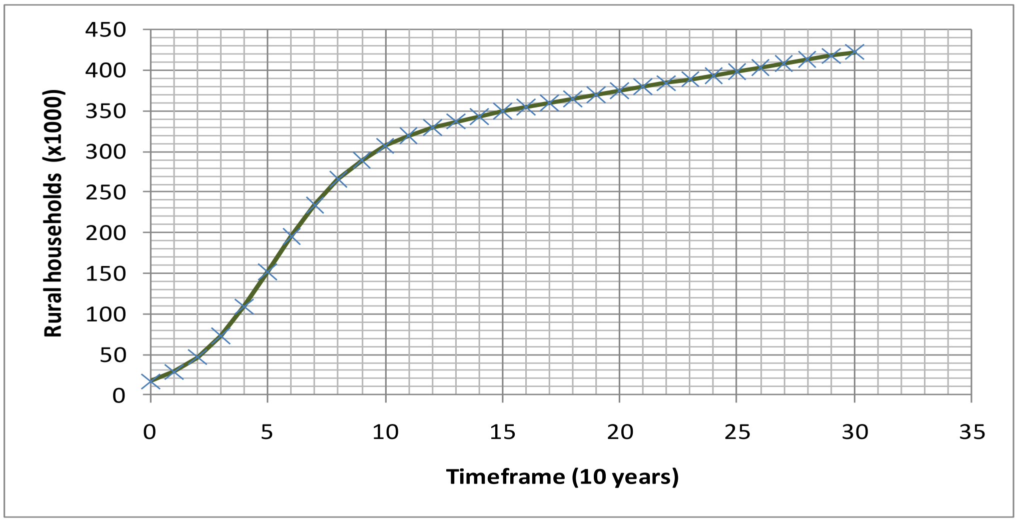
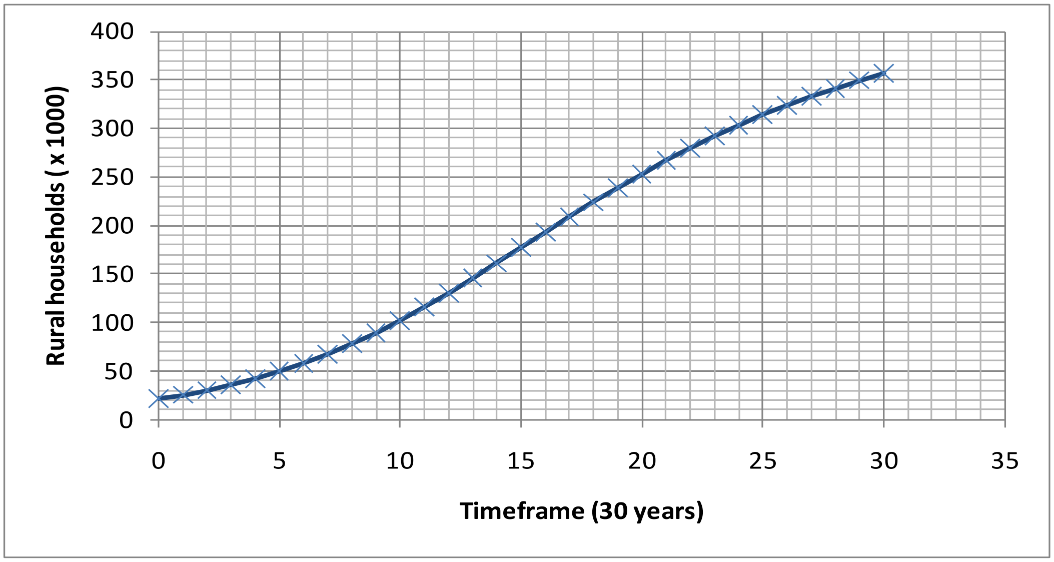
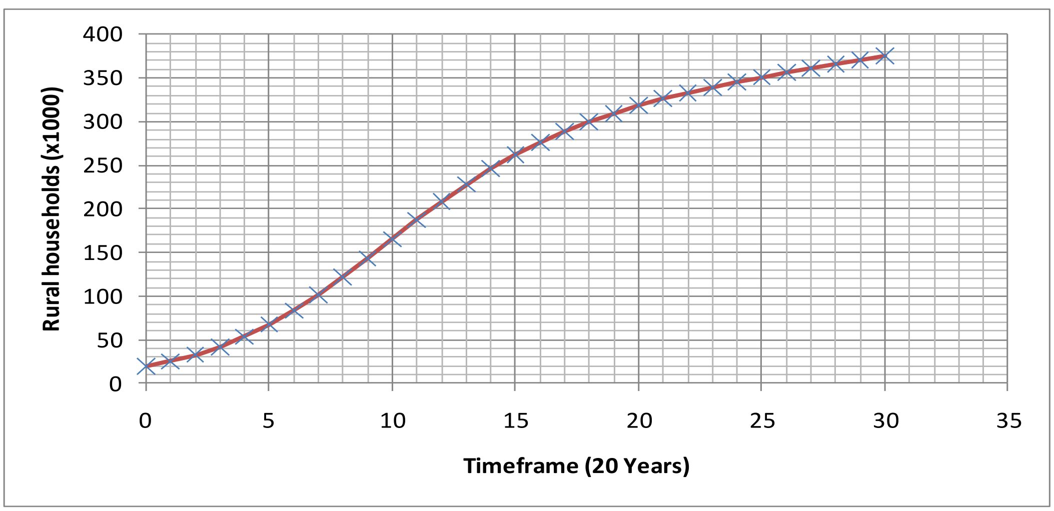

Rural households (x1000)
Timeframe (10 years)
0
50
100
150
200
250
300
350
400
450
0
5
10
15
20
25
30
35

Figure 6.8: Potential Adoption Curves over 10, 20 and 30 years for Rural Households Based on an Ethanol Price of US$0.35





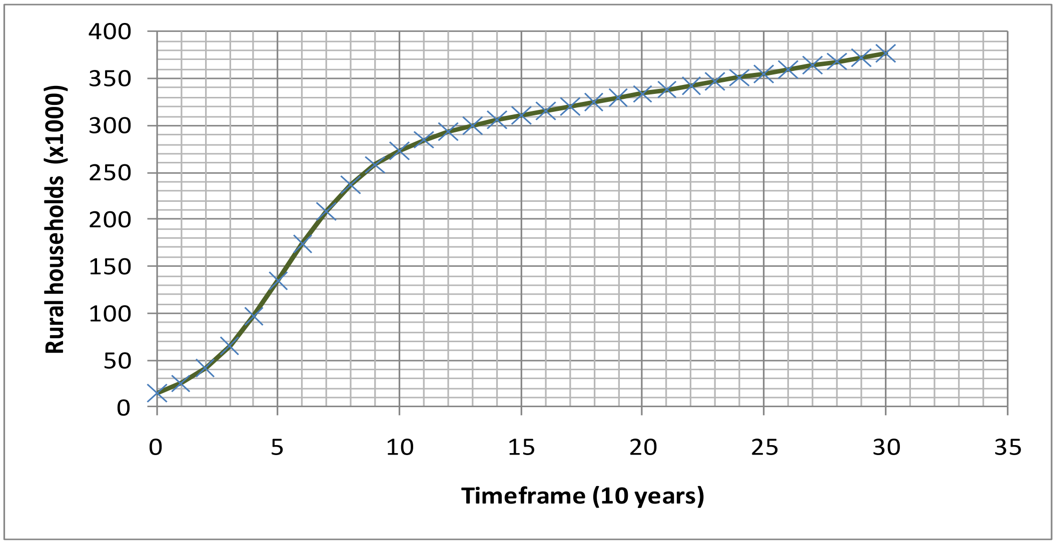


Table 6.13 below summarises these graphs, giving the total number of urban and rural households that might start using ethanol within a 30 year period, based on the selling price of US$0.20, US$0.30, and US$35, for 10, 20, and 30 year adoption periods towards a steady state. These vary from just over 1 million households to over 2.5 million households.

Table 6.13: Potential Total Number of Households Adopting Ethanol in Rural and Urban Areas of Madagascar

Number of Households x 1000	Urban	Rural	Total
Ethanol Price of US$0.20			
Slow Adoption (30 years)	1,957	555	2,512
Medium Adoption (20 years)	2,058	584	2,642
Rapid Adoption (10 years)	2,064	586	2,650
Ethanol Price of US$0.30			
Slow Adoption (30 years)	1,239	401	1,640
Medium Adoption (20 years)	1,303	421	1,724
Rapid Adoption (10 years)	1,307	423	1,730
Ethanol Price of US$0.35			
Slow Adoption (30 years)	978	357	1,335
Medium Adoption (20 years)	1,029	376	1,405
Rapid Adoption (10 years)	1,032	377	1,409

The supply of ethanol must meet this potential demand from the household sector if the numbers of households adopting ethanol stoves over a 30 year period is to be reached. Table 6.14 summarises the total number of litres of ethanol that would be needed to meet this potential annual demand by 2042.

Table 6.14: Total Annual Ethanol required to meet the Potential Demand by 2042

Litres of Ethanol (million)	Urban	Rural	Total
Ethano Production based on an Ethanol Price of US$0.20			
Annual production - 30 yrs to saturation	714	203	917

Annual production - 20 yrs to saturation	751	213	964
Annual Produciton - 10 yrs to saturation	753	214	967
Annual Production based on an Ethanol Price of US$0.30			
Annual production - 30 yrs to saturation	452	146	599
Annual production - 20 yrs to saturation	476	154	629
Annual Produciton - 10 yrs to saturation	477	154	632
Annual Production on based on an Ethanol Price of US$0.35			
Annual production - 30 yrs to saturation	357	130	487
Annual production - 20 yrs to saturation	376	137	513
Annual Production - 10 yrs to saturation	377	138	514

This shows that if these rates of ethanol adoption for household cooking fuel are achieved, between 514 million and 917 million litres of ethanol will be required annually after 30 years.

The Government of Madagascar has developed regulations that require large scale industrial ethanol producers to allocate 5% of their production towards the domestic household fuel market, and these quantities of ethanol are summarized in Table 6.15.

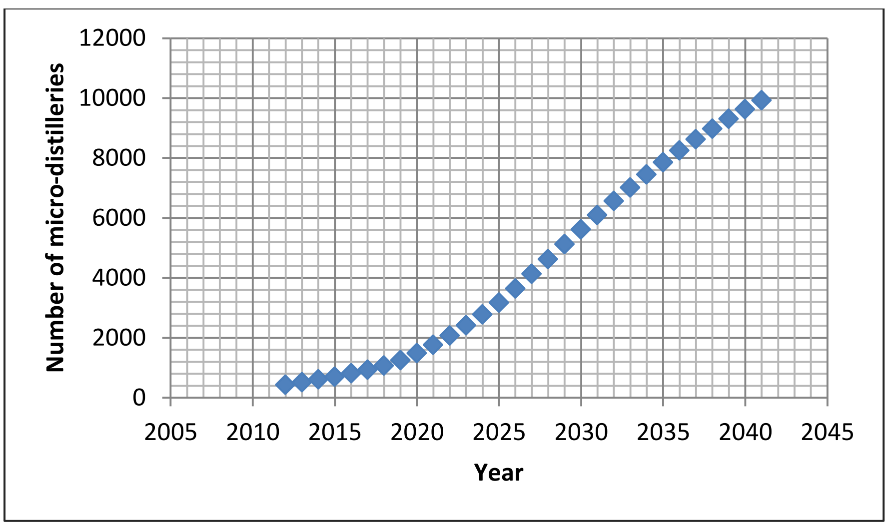
Table 6.15: Total Predicted Annual Production of Ethanol from Industrial Scale Ethanol Plants in Madagascar, household ethanol availability, and scale of micro-distillery ethanol required for the household energy market

Year	Number of Industrial Distilleries	Total Annual Production (litres) – large scale	Large-scale Ethanol Available for Household Fuel (5%)	Number of Households Supplied Annually by large scale	Ethanol adoption over 30 years (HHs x1000)	Households not served by large-scale	Number of 120 litre per day micro-distilleries required
2012	3	81,000,000	4,050,000	11,096	63	51,535	429
2013	4	108,000,000	5,400,000	14,795	76	60,915	508
2014	5	135,000,000	6,750,000	18,493	91	72,694	606
2015	7	189,000,000	9,450,000	25,890	109	83,496	696
2016	9	243,000,000	12,150,000	33,288	131	97,349	811
2017	12	324,000,000	16,200,000	44,384	155	110,876	924
2018	15	405,000,000	20,250,000	55,479	184	128,063	1,067
2019	18	486,000,000	24,300,000	66,575	216	149,144	1,243
2020	20	540,000,000	27,000,000	73,973	252	177,972	1,483
2021	22	594,000,000	29,700,000	81,370	292	210,899	1,757
2022	24	648,000,000	32,400,000	88,767	337	247,847	2,065
2023	26	702,000,000	35,100,000	96,164	385	288,596	2,405
2024	28	756,000,000	37,800,000	103,562	436	332,779	2,773
2025	30	810,000,000	40,500,000	110,959	491	379,893	3,166
2026	30	810,000,000	40,500,000	110,959	548	436,717	3,639
2027	30	810,000,000	40,500,000	110,959	606	495,154	4,126
2028	30	810,000,000	40,500,000	110,959	665	554,466	4,621
2029	30	810,000,000	40,500,000	110,959	725	613,923	5,116
2030	30	810,000,000	40,500,000	110,959	784	672,842	5,607
2031	30	810,000,000	40,500,000	110,959	842	730,626	6,089

2032	30	810,000,000	40,500,000	110,959	898	786,779	6,556
2033	30	810,000,000	40,500,000	110,959	952	840,928	7,008
2034	30	810,000,000	40,500,000	110,959	1,004	892,814	7,440
2035	30	810,000,000	40,500,000	110,959	1,053	942,291	7,852
2036	30	810,000,000	40,500,000	110,959	1,100	989,305	8,244
2037	30	810,000,000	40,500,000	110,959	1,145	1033,883	8,616
2038	30	810,000,000	40,500,000	110,959	1,187	1,076,110	8,968
2039	30	810,000,000	40,500,000	110,959	1,227	1,116,118	9,301
2040	30	810,000,000	40,500,000	110,959	1,265	1,154,061	9,617
2041	30	810,000,000	40,500,000	110,959	1,301	1,190,113	9,918

Based on an ethanol production price of 35cents per litre, and supplying both the urban and rural sectors, it is assumed that micro-distilleries will have to make up the annual ethanol shortfall, and if the focus is on building 120-litre per day micro-distilleries, a total of almost 2,000 micro-distilleries will be required after 10 years, over 6,000 after 20 years, and nearly 10,000 micro-distilleries after 30 years. To meet this demand it is assumed that the construction of new micro-distilleries will follow a typical s-curve over a 30 years period, as shown in Figure 6.8 below, with a slow initial uptake by innovators, followed by a more rapid uptake as the technology becomes more mainstream and accepted, and then followed by a gradual slowdown in new micro-distilleries as the industry heads toward capacity.

Figure 6.9: Assumed Construction of new Micro-Distilleries over 30 years



The total cost of these micro-distilleries, calculated on an average cost of $21,380, is shown in Table 6.16 below. It is assumed that as the industry develops it will become increasingly more innovative and production methods will become more efficient with cheaper equipment, and increasingly lower costs. Since the model described has a five year payback period for paying off all capital costs, and it is likely that larger (200 or 500 litre/day) distilleries will be developed, the ethanol producers would be able to expand their businesses within years 10-15.

Table 6.16: Total Cost of New Micro-Distilleries in Madagascar over 30 years*

Year	Number of Micro-Distilleries	Total Cost of Micro-Distilleries @ US$21,380 per distillery
2012	429	9,172,020
2013	508	10,861,040
2014	606	12,956,280
2015	696	14,880,480
2016	811	17,339,180
2017	924	19,755,120
2018	1,067	22,812,460
2019	1,243	26,575,340
2020	1,483	31,706,540
2021	1,757	37,564,660
2022	2,065	44,149,700
2023	2,405	51,418,900
2024	2,773	59,286,740
2025	3,166	67,689,080
2026	3,639	77,801,820
2027	4,126	88,213,880
2028	4,621	98,796,980
2029	5,116	109,380,080
2030	5,607	119,877,660
2031	6,089	130,182,820
2032	6,556	140,167,280
2033	7,008	149,831,040
2034	7,440	159,067,200
2035	7,852	167,875,760
2036	8,244	176,256,720
2037	8,616	184,210,080
2038	8,968	191,735,840
2039	9,301	198,855,380
2040	9,617	205,611,460
2041	9,918	212,046,840

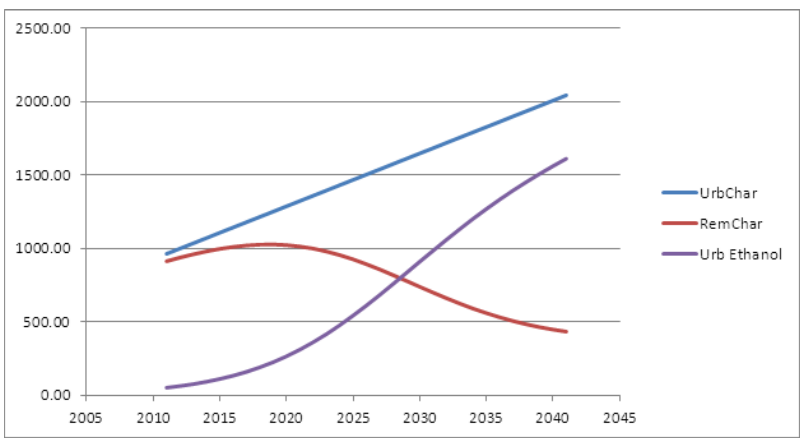
*From Table 6.5 – assuming only 120litre distilleries (worst case)

Land Requirements for Ethanol Production

Each 120 litre/day micro-distillery requires around 1.5 tonnes of feedstock daily, equating to 486 tonnes of feedstock per year. In Madagascar current annual production of sugar cane per hectare is about 50 tonnes, meaning that each micro-distillery can be supplied by 10 hectares of land, assuming the land produces sugarcane annually. To ensure sustainably high yields land often has to be left fallow for some time before replanting, which means that more land might be required. For 2,000 micro-distilleries, this equates to a total land area of 20,000 hectares required for feedstock growth, for 6,000 micro-distilleries a total required land area of 60,000 hectares, and for 10,000 micro-distilleries a total required land area of 100,000 hectares. It should be noted that the current total arable land in Madagascar is around 2.9 million hectares, so this feedstock for household ethanol fuel production would require a significant increase in the amount of cultivable land in Madagascar.

One additional point to be aware of is highlighted in the graph below, Figure 6.9, which shows in blue the predicted growth in charcoal use in urban areas with population growth, in purple the potential increase in ethanol use in urban areas, and in red the corresponding decrease of the size of the charcoal market if ethanol grows at the estimated levels. Previous experience has shown that charcoal producers tend to adjust their price of charcoal to compete with other fuels such as ethanol. Unless greater action is taken to prevent non-sustainable gathering of wood, the prices of charcoal will make ethanol increasingly less competitive, whilst the incentive for illegal charcoal production increases. With charcoal production providing a substantial part of the rural income, a rapid expansion of ethanol (10 years to saturation), even if viable, might be destabilising.

Figure 6.10: Potential Growth in Ethanol Production with Corresponding Decrease in Charcoal Production



6.3. Financial Analysis

6.3.1. Financial impact of ethanol stoves at a household level

As described in the market analysis, households use a range of fuels, including wood, charcoal, LPG, kerosene and ethanol. The financial analysis at a household level looks at the financial impact on a typical household choosing to buy an ethanol stove over other available and affordable stoves. It attempts to balance the cost of the initial investment in the stove, against the benefits (or in some cases the additional costs) of ethanol as a household fuel in comparison to other fuels.

The analysis uses an imported CleanCook Ethanol stove (based on the test results presented in Chapter 5 which concluded that other ethanol stoves currently available in Madagascar were found to be unsafe), priced at US$50 with an expected 10-year lifetime. This is compared with a more inefficient, but less expensive, charcoal stove (priced at approximately US$5). The Net Present Value (NPV) (described as future costs given a value in the present) of the stove is calculated by comparing the initial investment cost, with the difference in fuel costs when compared with charcoal, discounted using a 10% discount rate.

The financial impact of ethanol stoves will be different for urban and rural households, as urban households typically pay more for charcoal, and are therefore more likely to be able to shift to using ethanol as a household fuel.

Rural households

Figure 6.10 shows the Net Present Value (NPV) of an imported ethanol stove across a range of price points of ethanol. It is compared against charcoal, which has been given an average price in rural areas of $0.10/kg (the price of charcoal varies greatly across Madagascar depending on a number of factors including the availability of wood, the efficiency of carbonization, distance to market, the quality of the roads and the seasons, but for the purpose of this analysis an average price has been chosen based on available data). It demonstrates that at a price per litre of $0.20 or less, the ethanol stove is a financially viable option for a rural household, considering the costs and benefits over a full ten years. It must be noted that the initial upfront investment cost of the ethanol stove may be a barrier for allowing some households to adopt ethanol as a household fuel.

Urban households

It has been estimated that urban households typically pay $0.17/kg for charcoal, and Figure 6.11 shows the NPV of an imported stove as compared with this higher price of charcoal. For an urban household, the ethanol stove is financially viable (over a 10 year period) when the price of ethanol is $0.37/litre or less.

Figure 6.11: Price Sensitivity of Stoves to the unit cost of ethanol – Rural

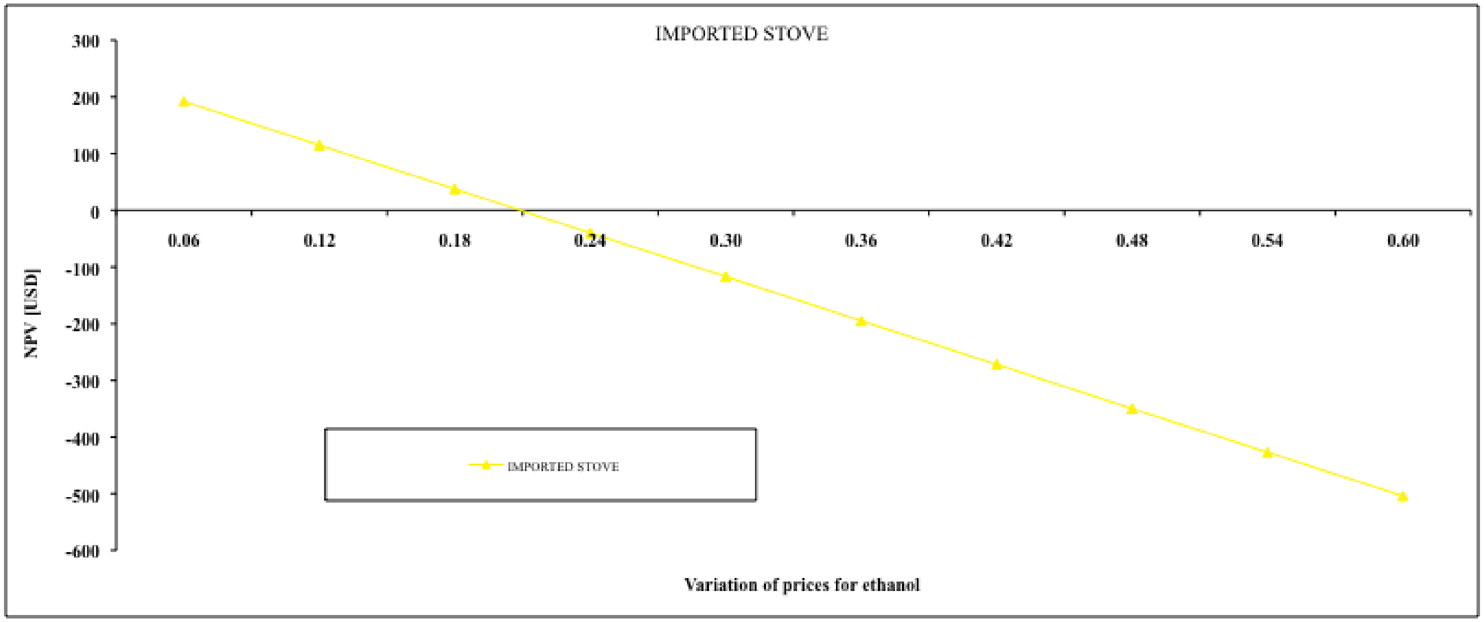


Figure 6.12: Price Sensitivity of Stoves to the unit cost of ethanol – Urban

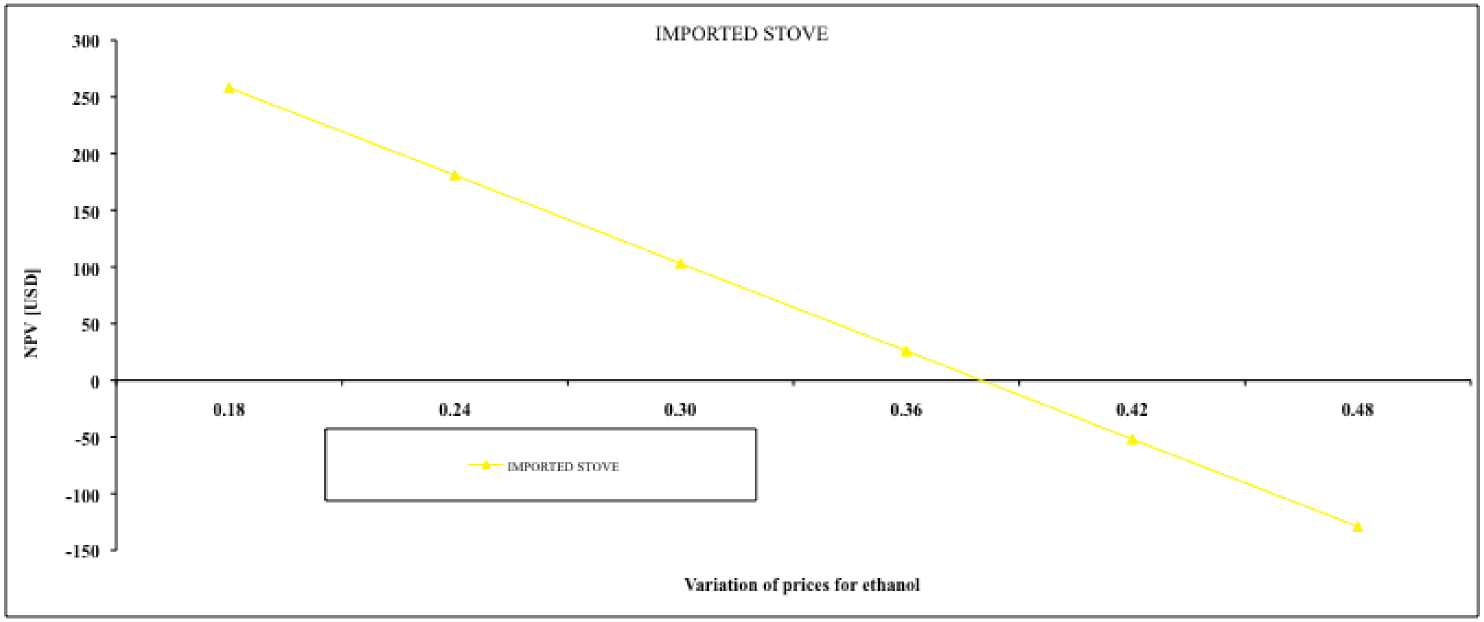
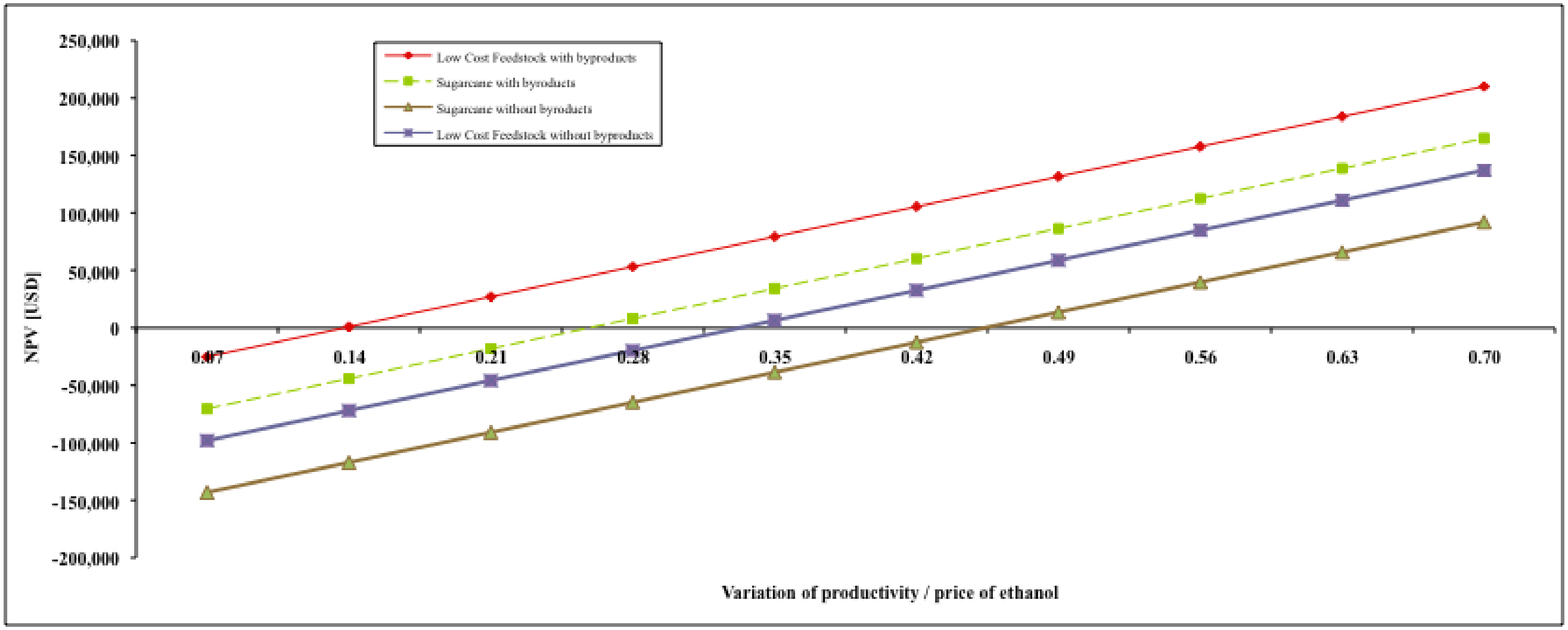


Figure 6.13: Ethanol price sensitivity of micro-distilleries



6.3.2. Financial Analysis of Ethanol Micro-Distilleries

A financial analysis was conducted for an ethanol micro-distillery plant, producing 120 litres per day. The four production scenarios, outlined previously, were used for the financial analysis of ethanol micro-distilleries, as follows:

Scenario 1: Low cost feedstock, with byproducts
Scenario 2: Sugarcane, with byproducts
Scenario 3: Low cost feedstock, without byproducts
Scenario 4: Sugarcane, without byproducts

Low cost feedstock assumes that crop waste is used in production of ethanol. The model assumed that low-cost feedstock is available for $4/tonne, while sugarcane costs $15/tonne (this is partially offset by the fact that sugarcane is a more efficient feedstock, providing more ethanol per unit than the low cost feedstock). The byproducts produced in ethanol production include feed for animals and high-value garden crops (such as tomatoes and mushrooms), and can be sold for approximately $0.10 per litre, creating an additional revenue stream for the micro-distilleries.

The financial analysis was run for the four different scenarios, described above, to identify at what price point of ethanol the distilleries become financially viable (i.e. starts producing a positive NPV), which is summarized in Figure 6.12 and Table 6.17. The model was discounted at a rate of 10% over 30 years to arrive at the NPVs summarized below, as well as the payback periods.

Table 6.17: Break Even Price of Ethanol for Distilleries

Scenario	Price of Ethanol	NPV	Paybac k period
Low cost feedstock, with byproducts	$0.14	$905	10 years
Sugarcane, with byproducts	$0.26	$594	11 years
Low cost feedstock, without byproducts	$0.34	$2,70 5	10 years
Sugarcane, without byproducts	$0.46	$2,39 4	10 years

6.4. Economic Analysis

6.4.1. Components of the Analysis

The financial analysis presented above assessed the impacts of ethanol at an individual household and distillery level. This chapter expands on this analysis to look at the economic impacts of ethanol as a household fuel. In other words, the analysis addresses the costs and the benefits at an economy-wide level, aggregating the impacts of ethanol across the full number of households and distilleries engaged in ethanol use. Importantly, this analysis also accounts for the full scale of monetary benefits that can be associated with ethanol use, including avoided GHGs from deforestation, health benefits and time savings.

This analysis focuses on one scenario – namely production of ethanol using sugarcane micro-distilleries with the sale of byproducts, over a 30-year penetration period, and based on an ethanol price of $0.35/litre. In Table 6.17, the lowest price at which an ethanol distillery has a positive NPV is $0.26. However, it is assumed that most operators will not wish to run at margin, and there should also be some flexibility to accommodate fluctuations in the sale of/market for byproducts. Therefore, to be conservative, a price of $0.35/l of ethanol over a 30-year penetration period was used for the analysis. Unless otherwise indicated, this scenario is used for the presentation of all findings from the economic analysis below, using a 30-year operating period, and a discount rate of 10%.

The specific costs included in the analysis are:

- The cost of producing ethanol;
- Transportation/distribution costs;
- The investment cost of stoves (borne by households); and
- The stove dissemination costs.

The economic benefits included in the analysis are:

- Sales of ethanol, and its byproducts (where appropriate);
- Fuel savings to the household (sometimes a cost depending on the price of ethanol);
- Avoided deforestation as a result of reduced demand for wood and charcoal;
- Avoided reforestation costs;
- CO2 emissions reductions as a result of new stoves;
- Time savings from cooking; and
- Avoided mortality and morbidity due to avoided health effects of charcoal/wood stoves

6.4.2. Parameters used for estimation of economic benefits

Economic analysis typically assigns values to benefits that are not necessarily traded on the open market, and therefore proxy values are required to monetize these impacts. The following assumptions were used to calculate the economic benefits.

Health impacts

As the study could not, within the time-scale and resources available, study the direct impact on the major health outcomes associated with exposure to HAP, which are child acute lower respiratory infections (ALRI), chronic obstructive pulmonary disease (COPD) and ischaemic heart disease (IHD), these were modelled using methods of the Comparative Risk Assessment (CRA) of the Global burden of Disease Project, using the following two scenarios for the period 2010 to 2019:

- Scenario 1: AGECC Universal Clean Energy Access - at the rate required to meet the target for universal access to clean, modern household energy by 2030 that has been proposed by the UN Secretary General's Advisory Group on Energy and Climate Change (AGECC)124. Thus, over the first 10 years of this period, the rate of adoption among current solid fuel using homes is set at that needed to halve the current proportion of households reliant on traditional solid fuels and stoves. For this scenario, a constant yearly adoption rate has been assumed.

- Scenario 2: Adoption of ethanol stoves by 17% of the Madagascan population over 10 years - this scenario examines health impacts of adoption at a rate required to achieve 17% adoption by 2020, this being the level seen after the first ten years of the projections based on an ethanol price of 35 cents/litre125 and 20 year adoption. The year-on-year rates of adoption are based on the same curve as proposed for the market development at this price over 20 years, but only the first 10 years are used here.

These two scenario models for the period 2010 to 2019 give some impression of the health benefits that would result from very substantial reductions in IAP exposure with clean fuels. The first, based on the ambitious AGECC target for 2030, emphasizes the very large impact that elimination of exposure to household air pollution can be expected to have, particularly for childhood pneumonia and COPD. Ethanol can contribute to achieving this target, but does not need to be seen as the only option: other clean fuels and advanced biomass burning stoves (e.g. fan-assisted gasifiers) also hold the promise of delivering very low emissions of health damaging pollutants. The second scenario, based on projections for market growth for ethanol cooking only, still offers valuable benefits that can be seen to increase over time with growth in the total number of clean stoves in use. In interpreting these estimated health benefits, however, it is important to keep in mind the multiple sources of imprecision in estimates of all of the parameters that contribute to the models, and the various assumptions that have been made.

In summary, the more ambitious Scenario 1 (AGECC target) would, in the year 2019, lead to the prevention of around 17%, 16% and 5% respectively of total national deaths and DALYs126 for child ALRI, adult COPD and IHD. Scenario 2, based on market growth with an ethanol price of 35 cents/litre, would in the year 2019, result in prevention of around 3%, 2.5% and 1% respectively of total national deaths and DALY's for child ALRI, adult COPD and IHD. This does however also assume that all homes in this market projection are using solid fuels at the start of the period. Note that homes switching from LPG to ethanol would not gain any health benefit through reduction of indoor air pollution.

Exposure-Response Functions

The exposure-response functions required to directly predict the health benefits given the

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[124] The AGECC targets for universal energy access by 2030 form a key part of the UN International Year of Sustainable Energy for All (2012)

[125] This is a conservative estimate of predicted price of ethanol based on several variables including the cost of feedstock's and co-products and taking into consideration the fact that there is currently no large-scale micro-distillery operation in Madagascar. For further information on the calculation of this figure please refer to: Madagascar: Ethanol as a Household Fuel: Approach for Market, Financial and Economic Analysis – March 2011

[126] DALY: Disability adjusted life year. See main report for further explanation

measured exposure reductions observed for ethanol in this study, are not yet available. For this reason, large (>90%) reductions that accord with the available evidence on risk of exposure have been used for the modelling. Preliminary results from the RESPIRE study in Guatemala indicate that a 50% reduction in exposure resulted in an approximate 15-20% reduction in pneumonia incidence127. This compares with a 56% reduction in exposure, derived from CRA modelling from this study, reporting on a comparison of solid fuel use with clean fuel or other indictors of very low or absent exposure. The implication of this on the health impacts of ethanol stove users in Madagascar based on Scenario 2 is that the reduction of pneumonia incidence cases will be reduced by about one-third. We have argued above, however, that with widespread use of clean fuels, adequate supply and affordability, the exposure reductions with ethanol should in practice, and over time, be larger than those observed in the current study.

Based on the more limited evidence on the impact of the improved wood stove in Vatomandry, a similar effect could be expected, that is, around one third of the modelled health impacts. Unlike ethanol, however, which burns very cleanly and has low emissions of pollutants, the wood stoves achieve exposure reductions mainly by venting the smoke outside of the home. One important consequence of this is that we would not expect community outdoor levels of air pollution to be reduced, and consequently, reductions in personal exposures will never be as great as should be achievable with a low emission stove such as the ethanol Cleancook. For households continuing to use biomass, attention should be focused on low emission stoves, such as those using fans and/or gasification.

Not included in these estimates of deaths and DALYs averted are other health outcomes which have not yet been formally included in the CRA, but for which there is growing evidence of a link with IAP exposure. These outcomes include low birth weight, TB, cataract, and possibly also lung cancer where biomass fuel is used (as opposed to coal which is already confirmed and included). The update of the CRA/GBD project will be published later in 2011, and will provide evidence summaries and risk estimates for any additional health outcomes that can in future be included in burden of disease assessment for IAP. Finally, other health issues which were included in the study, notably burns/scalds, and symptoms of eye irritation, headache, etc., are also not formally included in these calculations as suitable summary estimates of risk (in the case of burns) or impact on health (eye irritation, headache) are not available. The importance of these outcomes for health and quality of life should however also be taken into consideration in assessing the benefits of the Ethanol (and other) interventions.

Health benefits were estimated by valuing avoided DALYs associated with the programme. Avoided DALYs were estimated at 0.03 per household per year. This figure was then scaled up by the total number of households using ethanol stoves each year, and multiplied by the Gross National Income per capita ($484 per year). The analysis was not able to take account of avoided treatment costs associated with disease, due to lack of relevant data. However, a WHO global study on the economic benefits of alternative fuels found that, in the WHO subregion for Madagascar, the health care savings as a proportion of overall

[127] Smith KR et al. Impact of a chimney wood stove on risk of pneumonia in children aged less than 18 months in rural Guatemala: results from a randomized controlled trial Epidemiology 2006;17:S45 (Abstract)

economic benefits were very small (<1%).[128]

These calculations result in a total of 442k DALYs saved over the 30-year period, equivalent to a total discounted value of $34m.

There are a number of reasons why it is not feasible to match health modelling to the economic modelling and proposed marked growth. With current levels of knowledge, the constraints to accurate determination include:

- Only having accurate 10 year population and health (disease/death rate) projections for Madagascar
- Analysis tools are not yet available to deal with the 'partial' reductions in exposure, so it is not possible to model accurately the impact of reductions from wood (high) to observed ethanol (low/medium), or from high/medium (charcoal) to ethanol (low/medium). Since it is recognised that most of the solid fuel users adopting ethanol are charcoal users, this limitation will tend to exaggerate the benefits to some extent.
- Since health data (e.g. pneumonia incidence and death rates) differentiating urban and rural populations are not available separately, all adopters have to be analysed together.

Because of these constraints, health impacts should not be over-interpreted, as there are many assumptions and sources of error. From prior economic analyses, the valuation of health impacts through clean fuel is quite small in terms of overall economic benefits, and a high level of precision is neither feasible nor appropriate.

Avoided deforestation

Valuation using CO2 as a proxy

If a large scale ethanol production scenario was to be developed this would have significant impact on the forests of Madagascar due to reduction in the use of wood and charcoal for household cooking. Currently it is estimated that 90% of wood obtained for household cooking (either as wood or by conversion to charcoal) is obtained from unmanaged sources that leads to some form of forest degradation. This is based on a 2006 USAID reference that states that in 2006 there were 150,000 ha of plantations/managed forests with a productivity of 8 to 10 m3/ha/yr. Based on this plantations in Madagascar only provide about 1.3-1.6% of all charcoal, with an estimation of a further 8% coming from forests managed by local farmers but not included in these national figures, and not considered to be permitted by law. This equates to approximately 10% of charcoal and wood demand coming from managed sources where the carbon benefits may not be so relevant.

The value of avoided deforestation was calculated by taking the equivalent amount of charcoal that would be required to produce the same energy as under the ethanol program

[128] Hutton, g. et al (2006). "Evaluation of the Costs and Benefits of Household Energy and Health Interventions at Global and Regional Levels." World Health Organization.

described in this analysis, assuming that a traditional charcoal stove consumes 513 kg of charcoal per household per year. The avoided charcoal consumption was then converted into its equivalent in wood, assuming a wood density of 0.70 tons/m3, and operation losses of 15%. This was then further converted into an estimate for reduction in loss of forests, using an average measure of standing wood volume of natural forests of 80 m3/ha.

If ethanol can be produced to meet the potential household fuel market demands described previously then it can be estimated that 127 million m3 of wood obtained from all forests, 90% of which is from unmanaged forests, can be avoided, over a 30 year period. This equates to the avoided degradation of roughly 1.4 million hectares of unmanaged forests, equivalent to approximately 10% of Madagascar's forest[129].

For the purposes of assigning an economic value to the avoided deforestation, the reduction in degraded forests was converted into avoided CO2 emissions, using a factor of 418 tons/ha CO2 fixation capacity of natural forests130 and this was valued using the market value for a ton of carbon (using a value of $3.39, the average price reflected by the voluntary carbon market). As it has already been stated that only 10% of wood (and charcoal) is obtained from managed sources, which will result in a neutral CO2 balance, it is assumed that the remaining 90% will result in the net increase in greenhouse gases (GHG). Based on standard calculations of GHG released from wood it is possible to estimate that our 30 year/$0.35/litre scenario would result in the reduction of 663 million tonnes of CO2 equivalent as a result of avoided forest degradation. Discounted at 10% over 30 years, this equates to a total economic benefit of $324 million.

Alternative Valuation using reforestation costs as a proxy
An alternative approach to valuing the economic benefit of avoided deforestation is to apply the avoided reforestation costs. The World Bank estimates that the cost of reforesting 1 hectare of degraded land in Madagascar is $800[131]. On this basis, the total value of avoided reforestation costs over 30 years, discounted at 10%, is estimated at $203 million.

Time savings from cooking

Ethanol stoves require less time for cooking, cleaning, and fuel collection when wood is being used as a fuel source. However, because this analysis assumes that ethanol is substituting for charcoal, the benefits of saved time are estimated for cooking and cleaning only.

Field interviews with women during the HAP tests in Ambositra and Vatomandry in Madagascar, which were conducted as part of this project, suggest that, on average, households save approximately 1.8 hours each day in cooking and cleaning time through the use of an ethanol stove, which can be valued according to a rural average wage rate of $1.92 per day.

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[129] FAO 2005 gives forest area of 12.8m ha
[130] Moura Costa, P. (1996): Tropical forestry practices for carbon sequestration. In: SCHULTE, A. & SCHÖNE, D. (eds.): Dipterocarp forest ecosystems. World Scientific: Singapore: 308-334
[131] Bienvenu Rajaonson, World Bank, Madagascar (2010), Personal communication

The estimated time saved by the households since installation of the ethanol stove is based on an average of two variables:

- The difference in time that stove was alight during the 24-hour monitoring periods at baseline and round 3
- The perceived reduction in time spent cooking and cooking related cleaning since the start of the project.

Each variable provides an estimate that has limitations. The perceived time reductions are based on recall over 5 months and possibly under estimate the actual amount of time saved whereas the time fire alight does not necessarily reflect the time actively cooking at the stove and may in fact over estimate the time savings. Therefore to present an estimate that takes into account these limitations an average of each measure from each study site has been calculated as follows.

The average alight time of ethanol stove is, on average, 2.17 hours per day less in Ambositra and 2.64 hours per day less in Vatomandry than for household's traditional cooking stoves (a mean of 2.4 hours). The average time saved cooking plus cleaning of pots for ethanol stove users is 8.5 hours per week in Ambositra (1.2 hours per day) and 8.2 hours per week in Vatomadry (1.2 hours per day). For the purpose of the economic analysis it has been decided to use an average time saving of 1.8 hours per day for a household switching to using an ethanol stove from a charcoal stove.

Poverty Reduction through Employment and Reduced Household Labour

A large scale ethanol household fuel program would have significant poverty reduction benefits if managed in the correct way, mainly through the decentralisation of energy production and the increased use of a very clean household cooking fuel. Although an ethanol household fuel programme will have significant employment opportunities, both in the growing of the feedstocks, the construction and maintenance of the micro-distilleries, the production of the ethanol, and its distribution, this will be offset in part by the reduction in employment within the woodfuel and charcoal industry. It is possible to estimate that the net increase in employment of an ethanol household fuel programme is 571,000 additional jobs over a 30 year period. This figure is based on the total estimated litres of ethanol produced over 30 years, multiplied by an estimated 0.05 man days per litre of ethanol. This figure is based on an estimate of the labour required to produce the sugarcane feedstock, estimated at 400 man days per year[132], and labour required to produce the ethanol and transport it to market (analysis of other micro-distilleries from Brasil and the US allow an estimation of 4.5 full-time staff required per micro-distillery). The number of jobs that would have been sustained in an equivalent amount of charcoal production, based on an estimate of 10.6 man days per tonne of charcoal[133], is then deducted from the ethanol jobs to give a net employment figure. Approximately 25% of these jobs would be in the production of feedstock, and the remaining 75% in employment at the micro distillery, and these jobs would be predominantly in rural areas. This is close to estimates of existing unemployment in Madagascar, and therefore must be viewed within the context of labour supply, as well as

[132] http://journeytoforever.org/farm_library/srimanual.pdf
[133] RWEDP, 1997

demand. Job creation associated with ethanol production was not monetized for inclusion in the economic model presented here.

Availability of Land

Although a large scale ethanol household fuel program would have significant benefits the potential environmental damage must also be determined and reduced as much as possible. A large amount of land would be required to grow the feedstocks to produce the ethanol, as well as water resources, for irrigating the feedstock crops and for use within the micro-distilleries themselves. Each 120 litre/day micro-distillery requires around 1.5 tonnes of feedstock daily, equating to 495 tonnes of sugarcane feedstock per year (the figure is higher, 660 tonnes, in the case of low cost feedstock). In Madagascar current annual production of sugar cane per hectare is about 50 tonnes, meaning that each micro-distillery can be supplied through 10 hectares of land, assuming the land produces sugarcane annually. To ensure sustainably high yields land often has to be left fallow for some time before replanting, which means that more land might well be required.

For 2,000 micro-distilleries, this equates to a total land area of 20,000 hectares required for feedstock growth, for 6,000 micro-distilleries a total required land area of 60,000 hectares, and for 10,000 micro-distilleries a total required land area of 100,000 hectares. It should be noted that the current total arable land and permanent crop area in Madagascar is around 3.5 million hectares134, so feedstock for household ethanol fuel production would require expansion of this area by about 3.5%. It should be noted that some of the land that has recently been deforested for charcoal production might well be suitable for growing suitable ethanol feedstocks and it is recommended that a full bioenergy mapping study be carried out to identify suitable land for feedstocks.

6.4.3. Results of Economic Analysis

The findings of the economic analysis are positive across all scenarios (ethanol prices, plant scenarios, and penetration periods), and range from US$454 million (using sugarcane feedstock without the sale of by-products, an ethanol price of US$0.35/litre and over a penetration period of 30 years) to US$2.7 billion (using a low cost feedstock with the sale of by-products, an ethanol price of US$0.20/litre and over a 10 year penetration period). The estimates are using the avoided deforestation valued in CO2 emissions described above. If reforestation costs are used as a proxy for the value of avoided deforestation, the NPVs range from $357 million to $2.7 billion.

Table 6.18 below presents the range of NPVs of the Economic Analysis, using an ethanol price of $0.35 per litre, over a 30 year penetration period, discounted at 10% over a 30 year operating period, for each of the four plant scenarios. The NPV uses avoided deforestation valued in CO2 emissions.

[134] FAO 2005

Table 6.18: Summary of Economic Analysis NPVs

Stove type	NPV (US$)
Low Cost Feedstock with by-products	708 million
Sugarcane with by-products	626 million
Low Cost Feedstock without by-products	536 million
Sugarcane without by-products	454 million

Using this same scenario, the costs and benefits that contribute to the overall economic analysis, can be broken down by category, to give a sense of how they are contributing to the overall total. Table 4.2 reports the total economic benefits over 30 years, discounted at 10%, and includes benefits to households (which in this case are actually negative – see below for further discussion) and benefits to distillery operators. The model also includes estimates for ethanol transportation/distribution, and stove dissemination costs. The calculation of the net benefits to micro-distillery operators includes the production costs of ethanol, as well as the sales of ethanol and related co-products.

Table 6.19: Breakdown of Economic Benefits of an Ethanol Programme in Madagascar

Economic Benefit	Net Present Value of Net Benefits over 30 years (US$ million)
Net benefits to households	139
Net benefits to micro-distillery operators	74
Avoided deforestation (the range depends on the valuation approach)	203-324
Avoided DALYs	34
Time Savings	1,308

In summary it must be stated that there is a net cost to households of using ethanol stoves – the higher investment cost for the stove itself, as well as the higher cost of the fuel, even when adjusted for greater efficiency. For rural households, where charcoal costs approximately $0.10/kg, ethanol fuel prices need to less than $0.21/litre in order for the investment in ethanol to be competitive with charcoal. In urban households, where charcoal is more expensive ($0.17/kg), the ethanol stove is financially viable when the price of ethanol is $0.37/litre or less. However, this financial investment is offset by the very high returns that can be gained by individual households, through both time savings, as well as avoided medical costs, which also can have direct financial impacts on their household.

6.5. Conclusions from Financial and Market Analysis

The analysis demonstrates a wide variety of factors that influence the financial viability of ethanol as a fuel – the type of feedstock used, the price of charcoal, the penetration rate/uptake by households, and the sale of by-products all have a significant effect on the analysis. Nonetheless, the financial analysis of supply and demand suggests that there is some convergence. On the one hand, demand for ethanol stoves is viable for households at a price of ethanol less than $0.20/litre for rural households and $0.37/litre for urban households. On the supply side, assuming a 30-year penetration rate (a conservative scenario), an ethanol micro-distillery is viable at prices upwards of $0.14/litre depending on the scenario.

The economic analysis shows that when the financial aspects of ethanol consumption and production – the values that affect decision making at the private plant or household level – are combined with the wider economic impacts on society as a whole, there is a very clear and strong argument for support to wider use of ethanol stoves. For example, government support to increase dissemination of stoves, particularly given that the upfront cost of buying a stove may be too high for a household to incur in one year, may be justified through the savings stoves bring to public finances through reduced health burdens.

7. Conclusions and Recommendations

Ethanol Production

Due to a number of issues, including high oil prices, international awareness of global warming and concerns about energy security world production of ethanol is rising. For producer countries ethanol offers a range of opportunities, both for domestic energy supply and for export, such as the example of Brazil, the only developing country to have so far gone to scale with ethanol production. Although Africa's ethanol base is less developed than those in Latin and North America, several countries are increasing production and there is significant potential for the African biofuels industry to expand. Despite recent growth however, the global market for biofuels is still in its relative infancy.

The dominant current consumption of ethanol is for transport fuel-blending, but there is also significant demand and use of ethanol in the industrial sector. However, in developing country contexts where household energy accounts for 75-90%,[135] ethanol has also been shown to have potential as a cleaner and healthier household fuel. Developing a stable domestic ethanol household fuel market is considered to have potential to offer substantial economic, health and environmental multiplier benefits at local, national and international levels. This potential has been partially demonstrated in Africa (eg. Ethiopia), but also setbacks have been observed linked to poor stove technologies (eg Malawi), fuel forms (eg. South Africa) and policy inconsistency (eg Ethiopia). If ethanol to achieve it's potential as a household fuel then these lessons must be learned in developing new sectors in countries such as Madagascar.

Ethanol can be produced from any biomass containing significant amounts of starch or sugar. Production scales can be categorised as: large scale, microdistilleries and artisanal scale. Artisanal production is very accessible to poor rural producers due to low capital costs enabling local level benefit distribution, however low ethanol quality and strength at poor conversion efficiencies (implying more fuelwood use per litre of ethanol), creating a higher cost product make it non-viable for a widespread household ethanol programme. The close association of this type of production with drinking, the higher market price per litre for this application, and the difficulties of policing production at this scale appear to preclude its serious consideration for household ethanol market creation.

Large scale production is relatively well known internationally and is the typical scale of production in Brazil and other large ethanol producing economies, offering good efficiencies, quality, strength and low cost per litre. However centralised plants will not necessarily promote maximum benefit distribution along the supply chain and high capital barriers exclude local people from direct participation, other than as waged labour or raw material suppliers. As suchm, the structuring of agreements with outgrower sugarcane suppliers for example, can have a strong influence on inclusivity and development impacts. Micro-distillation is a relatively new scale of production but it appears from international experience to offer many of the energy efficiency and ethanol quality benefits of large-scale production, but with increased levels of decentralisation of production and corresponding dispersal of opportunities and benefits. Although a detailed analysis of costs of production is needed for

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[135] WHO, 2006. Stockholm Environment Institute Policy Brief, June 2009.

each new installation, available micro-distillation technologies internationally appear to also be capital cost competitive per litre of ethanol produced compared with large scale installations. The lower total cost per installation also allows production to be dispersed closer to cane production and household ethanol consumers, and lowers the capital barriers to market entry.

International experience however shows ethanol markets to be strongly dependent on government policy. Particularly given the volatility of international fuel markets and the multiple potential applications of ethanol at different price points – stable and progressive government policies will be important if the ethanol household fuel market is to develop sustainably. In initial stages it may be necessary to ring-fence and prioritise sufficient ethanol fuel for the household energy market to ensure that a failure in the supply chain for ethanol (perhaps linked to international price fluctuations or a fuel blending mandate) does not destroy the burgeoning market for stoves which would also be created. Ethanol fuel pricing is very vulnerable to commodity prices of existing fuels, for example charcoal, fuelwood and fossil fuels, particularly kerosene - and if multiplier benefits of ethanol to health, the environment, rural incomes and balance of payments are to be realised – then government policy must mediate price fluctuation to some extent, especially in initial stages.

In order to succeed, the Malagasy household ethanol programme must learn from the international experiences described in this chapter, and put in place measures to overcome challenges encountered elsewhere, and replicate successes.

Ethanol Supply in Madagascar

Approximately one-half of Madagascar is potentially cultivable, but little more than 5% of the land is currently under crops Taken together cropland and crop/natural vegetation mosaic accounts for 13% of land cover, with approximately 21% of the total land area is covered by forests and 63% by shrubland, grassland and savanna. However the demand for cultivatable land is on the increase, and is not being matched with an increase in land allocated for agricultural use. Any expansion of sugarcane production needs to ensure it does not encroach on sensitive ecosystems and land required for agriculture and food production, and that sugar cane production does not result in food price rises and decrease food security. Madagascar has problems of land ownership, land tenuring and land taxation, all of which are unlikely to stimulate farmers to invest in small-scale sugar cane production.

Madagascar also has a recent history of land degradation and any increase in sugar cane production must be sure to not result in forest clearance or increased land degradation. In general the agriculture system in Madagascar is underperforming, and requires significant investment in improved techniques and technologies to improve soil quality and production. The use of land for sugar cane to produce sugar and ethanol has the great potential to reduce poverty if managed effectively, but requires a strategic and large scale investment to ensure high yields can be achieved sustainably. Producer cooperatives and associations might be an avenue for increasing productivity and ensuring the local farmers derive the most benefits. The extent to which foreign investment is sought to increase sugar cane production needs to be carefully assessed to ensure that benefits to local farmers are maximised and the household ethanol fuel market is not ignored. To ensure that the potential benefits of sugar cane production to increase ethanol supply, it needs to be fully integrated into the national agricultural planning.

Madagascar is very susceptible to increases in oil price rises and so local production of fuels such as ethanol would be of great benefit to the country. The use of ethanol as a household fuel would create a large sustainable market local that would result in a number of significant benefits to the country. Currently Madagascar's sugar cane production is quite low and there is significant potential to increase its production through just efficiencies and technology. Small-scale sugar cane production is also widespread, but generally with very low yields, and almost exclusively used to produce toaka gasy, the locally manufacturer rum for human consumption. The supply of ethanol in Madagascar is set to increase steadily over the next 5 years, which could be directed towards use as a household cooking fuel. It has been suggested that artisanal toaska gasy production could be improved, to be used as a fuel instead, but it is unlikely that ethanol of a high enough grade can be produced efficiently, sustainably and competitively from such scale of production, and it is recommended that the installation of micro-distilleries be promoted instead of artisanal scale production.

Both wood and charcoal use in Madagascar has been growing steadily, and has directly led to increased deforestation. Electricity is generally not used for cooking, and Kerosene and LPG only accounts for a relatively small sector of the market, compared to both charcoal and wood, particularly in rural areas. Madagascar's forests are some of the most diverse and fragile in the world and increased efforts need to be made to reduce their destruction. This can be carried out through investment in sustainable forest management and more efficient charcoal production, but serious consideration needs to be given to how ethanol production for household fuel can contribute to protecting Madagascar's forests. The transport of household cooking fuels is a big issue in Madagascar, particularly due to the relatively poor road network, which is another reason why micro-distilleries located throughout Madagascar could make a lot of sense for developing a more decentralised sustainable energy production.

Ethanol Demand in Madagascar

It is estimated that 95% of households in Madagascar depend on woody biomass, primarily fuelwood and charcoal, for their household energy (annual consumptions of 9.026 million m^3 of wood as firewood and 8.575 million m^3 as charcoal (IRG Jariala, 2005)). Fuelwood is the predominant fuel for poorest, poorer and middle income quintiles, whilst charcoal predominates for the richer and richest quintiles. Electricity, natural gas and kerosene capture very little of the market even for the richest quintile. Most city households use charcoal rather than wood fuel, while the use of natural gas is recorded as almost 11% of the main cities, but negligible in the small cities.

The household sector in Madagascar is expected to be heavily dependent on wood fuels for some time to come, with the FAO predicting an increase in household wood fuel consumption, with little substitution with electricity or kerosene due to the high costs of the fuels and appliances. Fuelwood may be extracted free of charge provided that it is not commercially traded, but an official permit must be obtained in order to sell wood, however illegal cutting is commonplace, particularly in areas where fuelwood is in short supply.

User preferences for household fuels were investigated, and the major concerns were the speed of cooking, followed by convenience, cleanliness, and costliness of the fuel. Smoke, dirt, suffocation and bad health, were some of the factors that made fuels unfavoured by the surveyed households. Within the project area, spending on fuel was widely distributed in both the wet and dry seasons, with the majority of households spending around MGA 2,500 with more affluent households spending up to MGA 10,000 to MGA 15,000 per week. Ethanol compares favourably in cooking cost comparisons amongst domestic cooking fuels in Madagascar, being significantly cheaper than LPG and kerosene and only marginally costlier than cooking with wood fuel on an open fire. If non-financial measures of fuel-stove combinations are introduced, ethanol cooking with a good quality ethanol stove will be preferable to currently available fuels.

An initial estimation of the potential market of ethanol for household cooking (based on relative cost of fuels and the purchasing capacity of households) indicates that there are at least 180,000 households who might substitute their primary cooking fuels with ethanol (LPG, kerosene and charcoal users). The rate of market penetration for a new technology usually follows a logistic curve, with slow initial take-up, fast growth in the middle and saturation at the end, and it is believed that the market penetration of ethanol stoves will follow such a route over a period of 20-25 years. Following this scenario the associated requirements for household ethanol fuel would be 0.7 million litres in 2011, reaching 105 million litres by 2030.

Cook Stoves

A number of stoves were tested to address issues of stove safety, usability, performance, design, efficiency, preferences of cooks/households and initial indoor air pollution. The study can act as an indicator of likely acceptability, and any corresponding stove development needs, but it cannot be presented as a full assessment of the viability of the stoves in the long term and as part of a commercial scale up. Feedback from the three CCT cooks stating that of all the stoves, the ones they liked best were the modified wood and the modified charcoal should act as a warning to promoters of ethanol stoves in Madagascar. In order to enter the household cooking market, ethanol and ethanol stoves will have a substantial challenge in order to overcome existing patterns of preference, low cost and familiarity.

Positive feedback on ethanol was noted for all ethanol stoves in the Focus Group Discussion feedback on their cleanliness and perceived environmental benefits. It should be noted from the reactions to ethanol from the Usability survey that the stove in which the ethanol is used has an impact on the perception of the fuel, particularly in terms of safety, usability and smell. The success of ethanol introduction will therefore be a function of both the fuel and stove, as well as linked fuel issues of price, local availability, quality, purchase volume options and bottle/tank options as well as ethanol specific requirements like denaturing.

The Proimpex stove in its current form does not appear to represent a viable alternative to charcoal or compare favourably with other ethanol stoves available in Madagascar, due to safety concerns. The stove also generated IAP levels higher than the competing ethanol stoves in the testing. In terms of convenience, responses from CCTs and Usability tests revealed long cooking times, difficulties in lighting and difficulties/attention required in fuel regulation. Two out of three of the users of the smaller Proimpex stove considered it too small for cooking typical meals and with an average cooking time of over 65 minutes for a standard meal it took more than twice the time taken by the other ethanol stoves and the traditional and modified wood stoves.

The ISPM stove performed consistently better than the Proimpex stove (large and small) on most measures. With scores on a par with the other stoves in consideration the ISPM stove deserves further consideration for possible introduction and commercialisation. It shares many of the potential advantages cited for the Proimpex in the previous section in terms of local ownership and initiation, but without several of its drawbacks. It is recommended that the ISPM undergoes further development and testing where budget additions to accommodate it may be made.

In general the CleanCook stove delivered the best performance of the four ethanol stoves in evaluation screening, CCTs, CCT Cooks feedback, Usability tests and IAP testing. It would be considered therefore as a stove which, if fuel of appropriate quality was made available at a price which people could afford, would be safe, accepted and offer substantial IAP improvements over existing wood and charcoal stoves. However, key challenges from a wider perspective with the CleanCook include its imported origin, its up-front cost, and the need for 95% pure ethanol, which may not be as easy to produce in the current local distilleries. The Cooksafe stove was not available for field testing and seems to no longer be in production at the present time.

Financial and Economic Analysis

Financial Analysis

The financial assessment of the three scales of ethanol plants show that the net present value (NPV) is positive for all the 3 types which is an indicator of the financial profitability of the ethanol schemes with however sharp differences according to the scale. Over the 15 year time horizon, the NPV of the large scale distillery plant is estimated at 62.69 million US$, while the NPV of the community and artisanal plants is US$67,459 and US$12,674 respectively, much lower than the large scale ethanol scheme.

A sensitivity analysis carried out with the 2 key parameters of ethanol prices and sugar cane yields, shows that the NPV of the large scale plant becomes negative if the production of the sugar plant is reduced by 35%. For the two other plants, the NPV will become negative if there is a further reduction of the 2 parameters; for the community scheme, the NPV will become negative if there is a 40% decrease of the productivity, while in the case of the artisanal plant the NPV will become negative if there is a decrease of 43% of the productivity with an ethanol price of just US$0.11 per litre.

With respect to the financial analysis of household cooking stoves, the NPV over a 10 year period is negative for the three ethanol stoves. On the other hand, the NPV for the improved and semi improved charcoal stoves is positive with overall savings (energy savings and investment costs) of US$260 and US$202 per stove respectively compared with the traditional charcoal stove. The sensitivity analysis indicates that ethanol stoves are only more profitable than traditional charcoal stoves if ethanol retail prices drop down to between

63 and 84%. Changes with regard to the price of charcoal also have a strong effect on the viability of the ethanol stoves. Nevertheless, even with an increase of 200% the NPV of an improved charcoal stove will still be higher than the NPV of the first ethanol stove.

Economic Analysis

The economic analysis of household cooking stoves demonstrates that from the society's point of view ethanol stoves are more preferable than improved charcoal stoves in the case of non-managed forests. However, the results indicate that improved charcoal stoves also have a high positive impact on the national economy if the charcoal production is based on sustainable forest management system.

The analysis of the entire ethanol programme (including sugar cane production, ethanol distilleries and ethanol stoves), compared with the costs and benefits of traditional charcoal stove and non-sustainable forest management, demonstrates that an ethanol programme based on artisanal scale ethanol production with a subsidised ethanol stove will bring the greatest economic return.

Considering the impact of ethanol stove dissemination on household's income, resulting from fuel and investment savings, there will be a negative impact even in the best scenario. Improved charcoal stoves have the most positive impact on household's income. As far the impact on forest cover is concerned, a penetration rate of 10% over 15 years will allow a substitution of 892,139 tons, saving 187,424 ha assuming the charcoal is produced from non-managed forests combined with traditional charcoal stoves. However the combination of managed forests and improved charcoal stoves can save over 243,000 ha over 15 years, just above the savings of an ethanol programme.

With respect to greenhouse gas emissions, over a period of 15 years, the ethanol programme will allow the avoidance of 7.5 million tons CO_2 equivalent, equating to more than US$27.5 million based on a market price of US$3.5/t of CO2. The dissemination of improved charcoal stove will avoid only 33% of these emissions compared with the base line scenario. However, the impact on greenhouse gas emissions of the sustainable forest management option coupled with the diffusion of improved charcoal stoves will be close to the impact of the ethanol programme (7.2 million tons CO2 equivalent). With regard to the health monetary impact, the ethanol programme will save about US$12million resulting from avoided non-working days due to illness, whereas the introduction of improved charcoal stoves will avoid about US$9million.

From the society's point of view ethanol programs are highly profitable. Compared to traditional household energy production and supply systems - non sustainable wood production in combination with the use of traditional charcoal stoves - ethanol programs at different scales will have a positive impact on forest cover, greenhouse gas emissions and public health. However, the burden of each ethanol program will be the consumer acceptance; in comparison to actual charcoal prices the costs ethanol is still too high.

	LPG (US$)	Ethanol (US$)	Charcoal (US$)
Annual Total Cost	302.82	107.61	63.76

Currently about 2.7% of the urban households (167,000 habitants) are using LPG as a primary type of cooking fuel. Compared to other energy sources, non subsidized LPG is the most expensive source of household energy and both. Based on a financial analysis, ethanol is more profitable than the utilisation of LPG as a cooking fool; stove and fuel are less expensive for ethanol as shown in the table above, and these LPG users could provide a potential market for next years. A higher share in the market can only be obtained if ethanol retail prices fall and the price of charcoal increases.

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Chapter 6 and 7

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Annexes

Annex 1
Small-scale industrial process – USI distillery in Brazil

Usinas Sociais Inteligentes (USI) Modern Micro distillery Technology in Brazil

The USI Bio-refinery is an industrial process that integrates processes and equipment capable of converting sugar-based crops into biofuels, energy and saleable chemicals. This ethanol fuel programme is based on one of the most efficient agricultural technologies for sugar-cane cultivation in the world, uses modern equipment and low cost sugar-cane as feedstock, the residual cane-waste (bagasse) is used to process heat and power, which results in a competitive price and a high energy balance (output energy/input energy).

Because of the higher production capacity, with equipment that produces 400 litres per day or more, the bio-refinery is more suitable for groups of producers. An important factor for the group of producers is the possibility of diversifying crop production, and with it, the recovery of agricultural waste for animal feed, with all the equipment already adapted to the bio-refinery.

USI has made major innovations in the fields of biotechnology and agronomic practices, creating a highly efficient agricultural technology for sugar-cane cultivation. Efforts have been concentrated on increasing the efficiency of inputs and processes to optimize output per hectare of feedstock, and the result has been increase of sugar-cane yields. The following table shows the production of ethanol with different feedstocks.

Table 1. Ethanol production from different feed stokes

Crop	Production (tonnes/hectare)	Alcohol (litres / hectare)	Ethanol Yield (litres / hectare)
Sugar-cane	85	83	7080
Cassava	40	200	8000
Cassava	30	200	6000
Sweet Potato	20	140	2800
Sweet Sorghum	40	55	2200
Corn	10	400	4000

The basic conversion of a sugar crop to ethanol begins with processing the feedstock. In the case of sugar-cane and sweet sorghum, this consists of washing, crushing and filtering to separate the bagasse from the sugar. The sugar is sterilized, concentrated and then fermented, using yeast, to produce alcohol solution, which is subsequently distilled to concentrate the alcohol to about 95%. Carbon dioxide is a by-product of the fermentation process. If the resultant alcohol is to be used as a fuel, a denaturant is added to the mixture to make it unpalatable, and unsuitable for consumption

Crops containing starch, such as cassava, are processed similarly to the basic sugar-to-ethanol process but require additional steps to convert the starch to sugar. This additional stage comprises reducing the size of the tubers, and exposing the starch to the enzymes that convert the starch to sugar in a chemical reaction called hydrolysis. Sucrose extracted from sugar-cane accounts for a little more than 30% of the chemical energy stored in the mature plant; 35% is in the leaves and stem tips, which are left in the fields during harvest, and 35% is in the fibrous material (bagasse) left over from pressing.

One of the main concerns about bioethanol production is the energy balance, the total amount of energy input into the process compared to the energy released by burning the resulting ethanol fuel. This balance considers the full cycle of producing the fuel; cultivation, transportation and production require energy, including the use of oil and fertilizers. A comprehensive life cycle assessment commissioned by the State of São Paulo found that Brazilian sugar-cane-based ethanol has a favourable energy balance, varying from 8.3 for average conditions to 10.2 for best practice production[136]. This means that for average conditions one unit of fossil-fuel energy is required to create 8.3 energy units from the resulting ethanol. The USI distillery produces this sort of output with the same feedstock.

An important by-product of the process is the bagasse or agricultural residue from the initial treatment of sugar-cane or sweet sorghum. This can be burnt in a boiler to produce electricity. The wet residues resulting from fermentation and distillation has value as an animal feed or, with further digestion by bacteria, creates biogas which can be used to power the process itself.

The USI Ethanol Production Process

In a typical process, such as the USI study, cited in the text, the process begins with the grinding of cane, for the extraction of sugar-cane juice. As the cane is crushed, the juice that is extracted is passed through a thin screen, intended to retain some residue of the bagasse, and charged into a settling tank. The juice is sent to a thinner to be standardized; the brix (sugar content) of the juice is adjusted to be 15% by volume, by adding water. This procedure is necessary to prevent the yeast culture that is needed to make alcohol from being poisoned.

The type of yeast used in this process may be ‘wild yeast,’ so called because it is derived from a mixture of corn meal (flour resulting from the milling of corn), the same that is used for baking bread. Fermenting the yeast turns the sugar-cane juice into “beer” or “wine”. During fermentation, carbon dioxide is released, usually as a foaming mix, into the air. It is possible to capture this carbon dioxide and vent it to a greenhouse. A good fermentation lasts between 18 to 24 hours, and releases a pleasant odour.

Distillation involves heating the mixture to a boil, creating steam that, when re-condensed, forms a new liquid, with higher levels of more volatile components in it than were in the original liquid—namely ethanol and trace alcohols. The most basic still consists of a pot, in which the ‘wine’ is heated, the column, which receives the ‘wine’ vapors, and the stretch, linked to the highest part of the column, from which the vapors are cooled until they condense and are collected the lower end, as in liquid.

The boilers shown in Figure 2-8 are used to make either 400 litre/day (left) or 1,000 to 1,500 litres/day in a USI plant. They must meet Brazilian Association of Technical Standards (ABNT) requirements.

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136 J. Azevedo Ramos da Silva, 2004

Efficient tubular steam boilers (photos: Eduardo Mallmann, USI[137])

The process begins with the grinding of cane sugar, for the extraction of sugar-cane juice. Soon after crushing, the juice extracted is passed through a thin screen, intended to retain some residue of the bagasse, and passes through a settling tank. The juice is sent to a thinner to be standardized; the brix (sugar content) of the juice is made up to 15% by volume, by adding water. This procedure is necessary to prevent the yeast needed to make alcohol being poisoned.

The type of yeast used in this process is called ‘wild yeast’ derived from a mixture of corn meal (flour resulting from the milling of corn), that in some cases is used for baking bread. Fermenting the yeast turns the sugar-cane juice into “wine”. During fermentation, a lot of carbon dioxide is released, usually as a foaming mix, into the ambient atmosphere. A good fermentation is between 18 to 24 hours, and has a pleasant odour. Distillation involves heating the mixture to a boil, creating steam that, when re-condensed, forms a new liquid, with higher levels of more volatile components than the original liquid. The still consists of a pot, where you put the ‘wine’ to be heated, the column, which receives the ‘wine’ vapours, and the stretch, linked to the highest part of the column, from which the vapours are cooled until they are collected the lower end, as in liquid.

Equipment Description

Mills

The filtered juice is stored in a dilution tank to lower the brix of the juice to around 15-16% (usually the cane juice from ripe sugar-cane is around 18% to 24% brix). It is important that the dilution tank is installed higher than the fermentation vessels for the broth to feed by gravity.

The use of a mill with a capacity higher than the expected production needs, allows greater durability of the equipment, reducing downtime for breaks and wear of parts. For the manufacture of “wine”, it is

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important that the mills have a roller speed of 10 to 12 revolutions per minute (rpm), depending on the diameter of the wheels. Higher speeds increase the productivity of the equipment (in litres of juice per hour), but compromise the extraction yield (in litres of juice per tonne of cane).

Figure 2.6 Sugar cane mill

Usually around 600 litres of sugar-cane broth of around 21% solution is produced for each tonne of cane processed. About 180 litres of water is needed to correct the brix to 15% solution. This produces around 200 litres of ethanol.

Dilution Tank

The filtered juice is stored in a dilution tank to lower the brix of the juice to around 15% or 16% (usually the cane juice from ripe sugar-cane is around 18% to 24% brix). It is important that the dilution tank is installed higher than the fermentation vessels for the broth to feed by gravity.

Fermentation Tanks

The most common are carbon steel vats or stainless steel, or PVC. Some systems will use water tanks. The best systems comprise a conical bottom, with a removable exhaust pipe to facilitating cleaning. The size is related to the volume of "wine" to be distilled, and the volume of the foot-tub is 20% of total volume of the vat. In Brazil, the fermentation time varies from 18 to 24 hours. The fermentation is adjusted to 28 to 30 °C. The pre-distilled "wine" is about 55% alcohol content.

Alembic

This equipment is usually made of copper, as in the case of cachaça production, or stainless steel. The equipment consists of a pot containing the juice to be heated, the column is located above the pan, which receives the vapors of wine, and the stretch, linked to the highest part of the column, from which the vapors are cooled until they are collected at the lower end.

In this step the ethanol is separated from the wine. Wine, initially with 7º to 10º GL, is decomposed into two streams: phlegm (vapors with 40º to 50º GL) and vinasse (going to the fields as fertilizer with less than 0.03 º GL). This distillation step removes impurities such as aldehydes and esters. In this process, the product pre-distillate reaches an alcohol content of about 55%.

Rectification Column

The rectification step is intended to concentrate the phlegm from the distillation to an alcoholic strength above 90° GL. The distillation column is packed with trays which acts as a simple series of stills stacked within a single column. Each tray works like a still. The process is slow, but is simple and safe because it reduces the risk of contamination, and does not require so much staff training.

Condenser/Cooler

In practice, the condenser is made of a drum, or something similar. The condenser should be connected to the top of the column to rectify, to cool the steam and turn it into liquid. The condenser can also be called a heat exchanger. To prevent accidents due to improper use of boilers, a small easy-to-use device called a vaporizer was designed, which produces steam for the distillation process.

The USI sugar-cane-based distillery is more efficient than the Proimpex distillery described in the next section. USI distillers are able to produce ethanol for 22 cents per litre for high quality ethanol, compared with the 40 cents per litre of rum production in Madagascar. Ethanol costs 80% more in Madagascar than Brazil, although the set-up costs for the USI distillery are likely to be substantially higher.

Conclusion

A purposely constructed micro-distillery can achieve efficiencies and production rates similar to industrial operations. Throughout the process, from juice extraction, to steam generation in a modern boiler, to controlled fermentation to rectification, to distillation, dehydration, heat recovery and reuse, electronic controls and computerized operation, the equipment is designed to function efficiently and reliably; essentially an industrial plant on a micro-scale.

A small, efficient steam boiler that burns bagasse or other residues provides heat to the process without the need to burn wood. With sugar cane and sweet sorghum, there may be a large amount of excess bagasse that must find a use elsewhere. If the micro-distillery is large enough to justify an adequately sized boiler, or if the boiler is sized expressly for the purpose, it may be feasible to produce electricity using a steam turbine.

Less energy is required where starch substrates can be broken down without substantial heating. For some raw materials, pasteurization is a required step but may be unnecessary, especially in processes using sugar substrates, where the fermentation process is carefully controlled. Measuring devices with electronic sensors and digital readouts, linked to computerized control, help to keep control of fermentation, and leave less room for human error, ensuring that fewer batches are spoiled and less downtime experienced as a result of the tighter process control.

Because of the better process control during fermentation, alcohol content in the beer should be at its maximum so that more alcohol can be distilled. Design and function of the distillery columns may resemble what is done in industrial plants, with the interior of the columns fitted with trays or plates, rather than simple packing, making the columns just as efficient in separating alcohol as a large unit.

A micro-distillery may have a dehydration unit using corn-meal where a large industrial unit would use molecular sieve technology. Two dehydrators are operated in tandem. When one has exhausted its absorptive capability the other unit is put into use and the first one is dried out or regenerated. As one dehydrator is regenerated by flash drying with forced hot air, the other one is put into use. Since the largest amount of energy is used in the distillation process to take ethanol from about 90% to 95%, and then again from 95% to 99%, the addition of a dehydration unit in the micro-distillery is an advancement that enables the micro-distillery to keep pace with the industrial distillery in terms of efficiency. Ethanol can be brought up to the range of 90% and then be dehydrated, a less energy consumptive process than distillation.

Annex 2

Bio-refinery Mini-Plant Model USI 1000 Proposal for the Okokhuo Community, Edo State, Nigeria

Prepared for Osa-Efe International Ltd. by Joe Obueh, CEHEEN/PGI, July 2009

Equipment Description

One mini-plant for standard bioethanol production, with capacity of 40 to 44 l/h, based on starch content (25 to 30%) of the raw material used, and operating in a continuous system from cassava starch, utilizing the patented "USI" system where hydrolization, saccharification and fermentation processes occur simultaneously through the use of cold enzymes/yeast (28°C to 32°C).

Distillation unit: 1000 litres per day

Distilling Module

Column "A" (Distilling)

Stainless steel distilling column, with diameter of 250mm and a height of 4m, which presents in its internal part – a set of plates longitudinally aligned and juxtaposed to its internal walls, and in its external part – two temperature control units (thermometers), connected to the control panel.

Column "B" (Drainage and Rectification)

Stainless steel drainage and rectification column, with a diameter of 250mm and height of 5m, which presents in its internal part a set of plates longitudinally aligned and juxtaposed to its internal walls, and its external parts two temperature control units (thermometers), visor and (three) condensers.

Digital control panel for column temperature control and pump activation. Stainless steel monophase 0.5cv pumps.

Column support base, control panel and stainless steel pumps, 2m long and 0.6m wide.

Control Module: Control Instrumentation: Alcoholmeter - % GL °, pH meter: Thermometers, Density meter, Saccharimeter for sugar level.

Cooling Module: Cooling Tower – Mini water cooling tower operating in a cross air flux system. ICV/6P motor, maximum 15m^3 water flow.

Utilities Description

Steam Module: Boiler (ABNT standard)

Mix tubular fire boiler for steam generation

Technical characteristics:

Type: .... Vertical

Steam production: ……………………………………….. 200 kg/h

MPT A: …………………………………………………… 8.0 kgf/cm2

Fuel: ……………………………………………………… Wood

Circulation: ……………………………………………….. Natural

Washing Module

Cassava washer, with washing capacity of 1.000kg/h, made in carbon steel and wood with a 5CV motor.

Milling Module

Motorized Graining Disintegrator powered by a 20HP ethanol engine with 0.8mm sieve and production capacity of 1,000 kg/h.

Power Generator

Power generator, fueled by ethanol, with generation capacity of 10KVA.

Bio-refinery Model USI 1000 Plant Cost Estimates∗

S/No	Brief Description	US$ Rate	Naira Price (₦150 = $1)
1.	**Distilling Module: compound by:** ▪ Column "A" (Distilling) ▪ Column "B" (Drainage and Rectification) ▪ Digital control panel for column temperature control and pump activation ▪ Stainless steel monophase 0.5cv pumps.	U$ 64,000.00	
2.	**Control Module** ▪ Control Instrumentation:	U$ 1,111.25	

	▪ Alcoholmeter- % GL° ▪ PHmeter: PH ▪ Thermometer-temperature ▪ Density meter-density ▪ Saccharimeter-sugar level		
3.	**Cooling Module:** Mini water coling tower, operating in a crass air flux system. ICV/6P motor, maximum 15 m^3 water flow	U$ 2,500.00	
3.a	**Freight**	U$ 5,000.00	
4.	**Utilities and Peripheral Equipment**		
	Steam Module: (a) Boiler (ABNT standard)	U$ 15,000.00	₦ 2.250,000.00
	Washing Module	U$ 6,500.00	₦ 975.000.00
	Milling Module	U$ 4,000.00	₦ 600.000.00
	Power Generator	U$ 6,500.00	₦ 975.000.00
	Total (CIF)	**U$ 104,611.25**	**₦ 15,691,685.50**
5.	Duty Rate	U$ 5,230.00	₦ 784,584.35
	Surcharge on duty	U$ 366.10	₦ 54,921.00
	ETLS	U$ 523.05	₦78,458.00
	CISS	U$ 722.50	₦ 156,917.00
	Vat (5% of CIF, Duty, Surcharge, CISS & ETLS	U$ 5,573.00	₦ 859,576.00
	Customs clearing agent	U$ 1,333.00	₦ 200,000.00
	Total Duty Payable	**U$ 13,748.00**	**₦ 2,134,456.00**
6.	**Grand Total for Equipment and Duties**	**U$ 118,359.25**	**₦ 17,826,143.50**
	Turnkey Service	**U$ 10,000.00**	**₦ 1,500,000.00**
	OTHER PROJECT COST		
	Transportation from port to site	U$ 1,333.00	₦ 200,000.00

	10,000 litres of drums (6)	U$ 8,000.00	₦ 1,200,000.00
	Installation cost	U$ 9,500.00	₦ 1,425.000.00
7.	**Grand Total for Ethanol Refinery**	**U$ 147,192.25**	**₦ 22,151,143.50**

∗ Prices current 6-2010.

Utilities and Operating Costs

Cassava Tubers

- The daily cassava tuber requirement for the production of 1,000 litres of ethanol is approximately 6 tons of fresh cassava tubers.
- The cost of each ton is ₦ 7,000 ($46).

Water

- For each kilogram of cassava, 2.5 litres of clean water need to be added to the milled product for the hydrolization and fermentation. Thus, 15 litres of water will be needed for the production of 1 litre of ethanol.

- During the cooling process, 1,000 litres of water are necessary. The water circulates in a tank in the distillery in order to condense the distilled product. This process requires an average replacement of 200 litres of water daily.

- The total daily water requirement of clean water for the 1,000 litres per day plant is an average 16,200 litres, which will be recycled.

Stargen Enzyme

- For each ton of cassava, given that a ton produces 180 litres of ethanol, 625 grams of enzyme are needed. Therefore 3.5 grams of Stargen Enzyme are required for each litre of ethanol produced.

- The price of the enzyme in Brazil is U$ 10.80 per kilogram, which translates to ₦ 5.8 or $0.038 to produce a litre of ethanol.

- Thus, ₦ 5,800 or $38 will be needed to purchase enzyme for daily production of 1,000 l/d. (₦ 6,760 is used in the table below.)

Yeast

- 500 grams of yeast for each ton of cassava. Thus, 2.8 grams of yeast are required for each litre of ethanol. (A cost total of ₦ 4,820 is shown in the table below.)

Boiler Fuel: (wood and/or dried cassava sticks)

- For a 24 hour working cycle 1.5 m^3 of fuel is required.

Other Costs

Components	Line Items	Consumption	Approx Unit Cost ₦
Off sites	Civil engineering work - Land preparation - Filling - Perimeter fencing - Ground water drilling		1,800,000
	Electrical work and hydraulic intern/ external to the building		800,000
	Administrative building		1,200,000
	Land acquisition		1,500,000
	Safety equipment		120,000
	Laboratory and equipment		450,000
	Loading bay		150,000
Utility	Cassava	3 tons/ day	42,000
	Enzymes (kg/day)	4.167 kg	6,760
	Yeast (kg/ day)	3.333 kg	4,820
	Other chemicals		160.00
	Vehicle		5,000
	Electricity (kW –h/day)	3kW/h	8.23
Contingency			500,000
Total			**₦ 6,578,748 ($43,858)**

Process Description

Product Output

At a capacity of 1,000/ l/day in 24 hour daily operating time the plant will produce, on an annual basis, assuming about 300 days:

1. 300,000 litres of hydrous ethanol (94^o – 96^o GL); producing approximately 40 litres per hour.
2. Approximately 70,000 tonnes of DDGS for animals feed
3. Approximately 40,000 tonnes of stillage

Feedstock Source and Supply

Cassava with 33% starch level that can yield 35-40 ton/ha will be the major source of starch feedstock. The tubers will be obtained through direct purchase from the following suppliers and out-sourcing channels that have been identified.

- Existing cassava farmers in Okokhuo, the project community, and its adjoining communities
- Contract farmers from neighbouring communities
- Abasac Global Ventures Ltd in Odighi, operating a cassava farm with a capacity to supply up to 10 tonnes of fresh cassava tubers per day.
- Several private cassava growers within 150 km radius of the proposed site.

The feedstock will be transported to the site by roads that transverse the Okokhuo community and its adjoining villages.

Water Supply and Management

For each kilogram of cassava, 2.5 litres of clean water is needed for the starch hydrolization and fermentation. This translates to a bit less than 17 litres of clean water for the production of 1 litre of ethanol. Daily water requirement for the production of 1,000 litres of ethanol is thus <17,000. During the cooling process, 1,000 litres of water that are kept circulating in a tank in the distillery so as to condense the distilled product are necessary. This process requires an average replenishment of 200 litres of water daily. The supply of water is of paramount importance for both processing and cleaning activities. The water supply at this rate is available from two main sources, being:

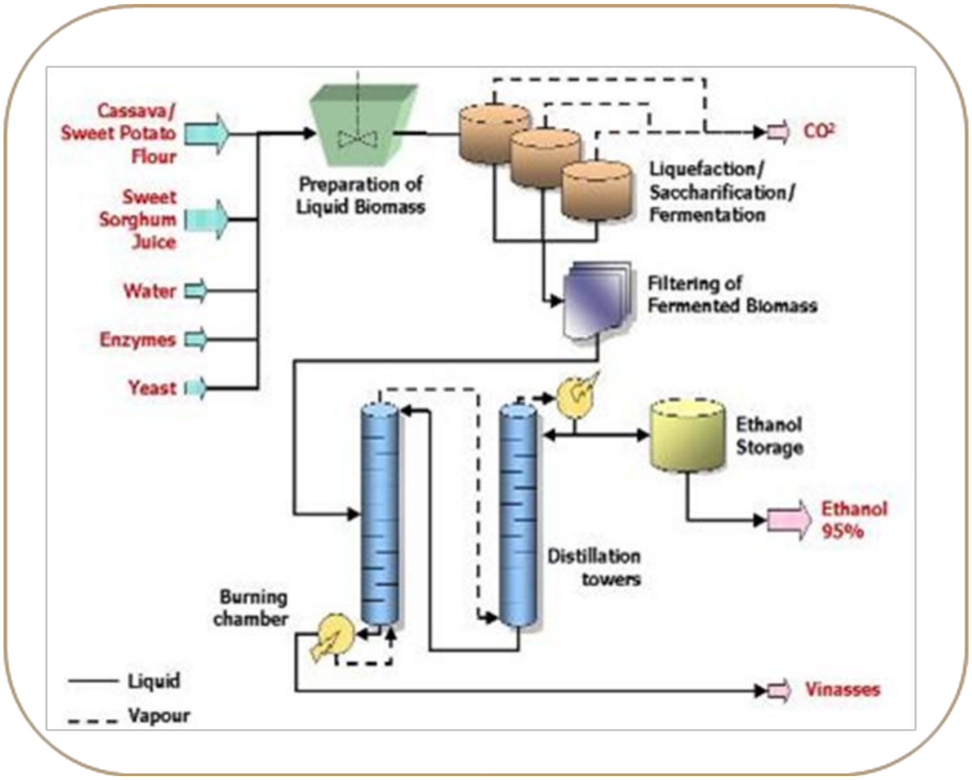
- Groundwater
- An on-site storm water harvesting well

Preliminary investigations to date indicate that the deep groundwater from the aquifer that serves the site is ample to supply the project in quantity and quality.

Process Flow

The ethanol bioerefinery will be operated with the use of cassava tubers. The plant can use cassava chips that are dried and milled. The cassava mash is slurried with water (starch hydrolysis) without the need for jet cooking. Raw Starch Hydrolyzing Enzyme. (stargen™) is added into the slurry tank with pH adjusted to 4.5. Liquefaction and saccarification are done simultaneously by adding yeast (glucoamylase) without cooking. The starch is instantly hydrolyzed to glucose, which is converted to ethanol and CO_2 by the yeast in a single process.

To obtain ethanol from the fermented mash, a distillation step is carried out. Before distillation, the fermented mash is filtered, resulting in a liquid containing about 10-15% ethanol. Then the liquid is distilled by heating it to 78°C and the ethanol is evaporated, captured and condensed, resulting in 95% pure ethanol and liquid waste called vinasse or stillage.



Site Selection and Description

The site for the proposed facility has been selected as the most appropriate site for the proposed ethanol facility for the following reasons:

- It adjoins an existing road access;
- An efficient road network is optimized by the site;
- A stable workforce is handy;
- Lots of feedstock is found within 100 km radius of the proposed site;
- It adjoins existing livestock farms that represent potential markets for the DDGs;
- The communities that adjoin the proposed project location are very peaceful.

Site Description and Layout

The proposed development is located at Okokhuo community about 25km from Ekiadolor in Ovia North East Local Government Area of Edo State. It is situated about a distance of 35km from the Benin-Shagamu Express Road. Okokhuo community is about 50km North East from Benin City. The proposed facility will be established on a site approximately 200m x 300m along Okokhuo-Ekiadolor Road.

The components of the facilities at the proposed site will be:

- A steel reinforced, corrugated zinc-clad process building for the bio-refinery module;
- Cassava storage and processing building;
- A well-equipped laboratory;
- A dried animal feed processing unit and dryer unit;
- An office administrative building containing reception, offices, bathroom facilities, parking lot, first aid room and safety equipment room;
- Maintenance building and workshop;
- Water storage tanks;
- Ethanol storage tanks;
- Security post equipped with a weigh bridge;
- Secured perimeter fencing;
- A building for power generation.

Roads

All roads will be of sufficient width to accommodate articulated trucks and smaller vehicles passing with ease, and all roads will be paved and maintained in excellent condition. Road access to the site is available directly from the dual-carriage Benin-Shagamu Express Road and the Benin – Akure highway which link the by-pass that leads to the Eastern States; South-South, Lagos and Abuja. The site is linked by several road networks that lead to the other communities that adjoin Okokhuo community.

Electricity

There is an existing 3 phase 33 kv power line which runs nearby. The plant requires about 3 kW/hour to produce one litre of ethanol. The plant can rely on electricity from a grid connection, or it can produce its own electricity using some of the ethanol produced in an ethanol-powered generator.

Environmental Considerations

Osa-Efe International Limited will engage an environmental firm to provide a preliminary Environmental Impact Assessment for the construction and operation of the proposed facility.

Environmental Issues to Be Assessed

- Air quality and odour assessment/management
- Water management
- Water pollution control
- Waste treatment
- Noise and vibration

A draft Statement of Commitments will be prepared by Osa-Efe International Ltd to describe how these issues will be managed throughout the implementation of the project.

Economic Considerations—Production Efficiency

The viability of a small-scale ethanol industry requires yield optimization, low energy inputs, and low production and operating cost. The USI plant is examined for process efficiency.

Analysis of ethanol production process using the no-cook enzyme

This analysis is important for the investor to assess whether an energy-saving option of producing ethanol with no-cook enzymes is feasible and practical in terms of cost.

Technical specifications and description of each step in the process (slurry, hydrolysis, liquefaction, saccharification, fermentation, and distillation) are used to examine efficiency, costs and savings.

Basic assumptions

1. The ethanol distillery sized at 1,000 litres/day is selected as the baseline
2. The processing of the ethanol occurs near the feedstock plantation
3. The cost-effectiveness of ethanol can be improved through the co-products obtained during the various production processes
4. Each feedstock provides similar output of valuable residues, ethanol, and CO_2 from the fermentation and distillation columns
5. On a microdistillery scale, CO_2 may not be generated in sufficient quantities to justify the capital cost of processing it into a marketable product, as the recovery technology is expensive
6. The use of crop residues such as cassava peels can be beneficial to the operation cost of the plant. Cassava peels can be carbonized, pelletized and used as boiler fuel to create steam for the hydrolysis step.

Conventional Starch-based Ethanol Production Process—Cooking

Plants naturally store carbohydrates as starch in the form of long chains of glucose molecules. At the end of the cycle, the starch-containing plant matter is harvested and used as feedstock for ethanol production. The starch is enzymatically converted into fermentable sugars for yeast to metabolize to produce ethanol and $CO_{2.}$

In a typical dry milling process that involves the use of starchy feedstock such as dry cassava chips, the chips are first milled and then slurried with water. An alpha-amylase enzyme is added, and the slurry is cooked at high temperatures (105^o – 150^o C or 221 – 302^o F) to gelatinize and liquefy the starch in a process called liquefaction. The high temperature also reduces microbial contaminant levels in the resultant mash.

After liquefaction, the mash is cooled and a secondary enzyme, gluco-amylase, is added to convert the liquefied starch to fermentable sugars known as dextrine in a process called saccharification. At this point, yeast is added to the march to ferment sugars to ethanol and CO_2 in a fermentation process that lasts 2 – 3 days.

Liquefaction and saccharification processes require the starch granules to be extensively pretreated at high temperatures in order to hydrate the starch. This is an energy-intensive process. Special equipment such as heat exchangers, high pressure jet cookers, and cooling tanks are required in both processes. These processes impose technical and physical limits, such as the limitation on concentration of solid loading, which reduce the amount of ethanol that can be produced in a conventional cooking process.

Benefits of the No-cook Process

USI has developed a compact microdistillery that is designed for a "Simultaneous Saccharification and Fermentation" Process (SSF). The technology uses granular starch hydrolyzing enzymes to produce ethanol in a low-energy process that hydrolyzes starch that has not been cooked. The process provides these additional advantages:

- Elimination of jet cooking, saving energy by up to 50 per cent
- Simultaneous saccharification and fermentation steps
- Higher solids processing, increased ethanol yield, resulting in capacity increase
- Reduction of mash viscosity which increases yield
- Use of fewer chemicals
- Less labour, which leads to reduced cost
- Fewer unit operations, meaning process simplification
- Value-added co-products, which have higher protein content
- Versatile—the process can use both sugar and starch feedstock. More than one feedstock can be used at the same plant
- Process is automated
- Homogeneity of product – continuous and sustainable production

The improved process provides benefit in terms of equipment purchase, installation and operation:

- Reduced capital and constructions costs
- Low electricity consumption
- Comes with a press for the formation of blocks of food for livestock
- Safe, automatic compact system
- Produces 1000 l/d of 94/96 GL of ethanol with the no-cook process
- Cost of producing a litre ranges from $ 0.40 (₦60.00) to $0.43 (₦60.50)
- Cost of enzyme per litre is about $0.05 (₦7.65)
- No-cooking process – the starch is rapidly hydrolyzed to glucose, which is converted to ethanol and CO_2 by yeast in a single production step and under the same conditions
- Saves time and energy

<u>Energy-savings – elimination of jet cooking</u>

The heat applied to cooking of the feedstock to aid enzymatic digestion represents a significant portion of the energy cost. The use of energy in the conventional process is always a major cost component with production cost per litre of ethanol in the conventional technology expressed in kW/hour/day at ₦8.23. The use of the cold enzymatic process results in more than 50 per cent energy saving. This is to be compared with the cost of the raw starch hydrolyzing enzyme, which is estimated at $0.05 (₦7.65) per litre of ethanol produced.

Capital savings – elimination of cooking and cooling equipment

In a conventional process, cooking of the mash hydrates gelatinizes the starch and leads to very high viscosity of the slurries. Specially designed jet cooking and cooling equipment is required to handle the resultant high viscosity starch slurries. Because no cooking is necessary for the cool enzymatic process to work efficiently, jet cooking equipment is not needed. This allows for a significant reduction in capital cost for the plant. The cost of a steam-driven jet cooker is high (an Indian-made 100-litre capacity steam jet cooker, excluding the accessories and fittings, supplied by TATA, is priced at $4,800).

Operational cost savings – less labour and lower chemical use

In a no-cooking process, a single pH adjustment step is needed. This simplifies the operation and reduces costs compared with the conventional process, which requires cooking and dual pH adjustment because liquefaction, saccharification and fermentation may be conducted at different pH levels. In addition, a conventional cooking process may require the addition of calcium salts to stabilize the liquefying enzyme at high temperature, which can result in the formation of insoluble salts. Whereas, raw starch hydrolyzing enzymes remain stable at the temperatures employed.

Capacity increase – higher productivity fermentation

Direct conversion of the granular starch using cold enzymes allows high-gravity fermentation of low-soluble solids. This reduces the osmotic stress on the yeast and results in a higher concentration of alcohol in the mash. The use of higher solids concentration of fermentable solids leads to increased processing capacity. This means higher yields at no additional capital cost.

Higher yield of ethanol per unit of sugar

Cooking results in some loss of fermentable sugars. The no cook process increases the efficiency of conversion of starch to glucose.

Robust process – healthier fermentation organisms

With the use of cold, starch hydrolyzing, enzymes, low concentrations of fermentable sugars in the fermenter enhance active yeast population and limit the growth of undesirable contaminating microorganisms. In a conventional process, extra effort has to be taken to maintain sanitation so that the fermentation will not be compromised.

Reduced side-products – lower levels of glycerol and organic acids

Use of the cold, direct starch hydrolyzing enzymes reduces the concentration of soluble solids in the fermenter. This results in the yeasts producing lower levels of wasteful products like glycerol. Reduced glycerol production enables more glucose to be converted to ethanol.

Formation of DDG co-products – higher protein animal ration

By eliminating the cooking step, an increase in carbon conversion efficiency results in higher protein content in the distiller's dried grains (DDG). Further, using cold enzymes results in significantly lower glycerol. This should improve the drying process of the DS.

Water savings – minimal waste and lower cost

Relatively low fermentable solids in most conventional processes result in higher dilution and more water usage. With cold enzymes, more solids can be added to the fermenter, thereby reducing water usage.

Economics of Production

The plant will produce ethanol for the price of energy, feedstock, chemicals, labour, water, taxes, etc. (all inputs considered)

Cost of production per litre of ethanol (₦)	
Wet cassava tubers	38.8
Water	1.50
Chemicals (Enzymes & Yeast	11.50
Labour	2.25
Energy	2.90
Taxes	1.15
O & M	2.12
Total Gross Cost	60.22

Production cost translates to approximately ₦60.50 per litre of ethanol, without consideration of other products. These costs may be spread over the other products as there is an uptake for the animal feed and fertilizer-value residues. There will also be hot water for use or sale. It should be noted that feedstock cost is the largest share of the cost of making ethanol. The cost of the cassava tubers represents about 64% of the cost of making ethanol. For every litre of ethanol produced, about one-quarter ton of spent mash will be available for sale as animal feed.

With a mark-up at each step in the distribution chain, the selling price per litre is estimated at approximately ₦ 80.00, or $0.53, providing sufficient revenue for paying for the cost of the plant, financed over 4 ½ years. This is before revenues are determined on other products, such as animal feed. This price per litre of ethanol is in contrast to the anticipated projected price of kerosene at ₦ 150.00 once full deregulation has taken effect.

Marketing

Awareness creation

Public recognition and acceptance of ethanol fuel and the ethanol CleanCook stove will require a focused public education and promotion campaign through a variety of media and events. We know from our studies that there is a high degree of interest in better cooking appliances, a high dissatisfaction with kerosene stoves and with burning fuelwood, and a clear willingness to try out new stoves. Households will start with little or no information on ethanol fuel, only what they will have heard through the “grapevine.” They will have no information about local production, safety, the fuel or the stove, and its comparative advantages over kerosene stoves.

An early task of Osa-Efe Nigeria Ltd., therefore, is to design and implement a marketing programme for the ethanol stove and its fuel that will have to include a comprehensive public education and awareness campaign.

During the early stage, an awareness campaign should primarily focus on the availability of ethanol fuel, e.g. the reliability of its supply, the price of the fuel, efficiency of both fuel and stove, comparative cooking cost of ethanol fuel compared with its competitors, and health, social, economic and environmental benefits of using ethanol fuel. In order to generate demand and create sales, the following formal and informal marketing media should be considered:

Relevance of the Micro distillery and Stoves to the Millennium Development Goals

The benefits of clean household energy have been well documented by the WHO (Rehfuess, 2006) and the Partners for Clean Indoor Air (PCIA at www.pciaonline.org). The association of the micro distillery to produce ethanol and the CleanCook stove to use it, as well as other small appliances such as generators to produce electricity, creates many opportunities to address local and national development goals, which have also been prioritized in the MDGs.

MDG 1: Eradicate extreme poverty and hunger

- ✓ The distillery creates job opportunities in ethanol production and distribution, stove manufacture, cassava production and cassava product businesses (chips and flour), stove and appliance sales and distribution, and other agricultural businesses, such as animal feed & fertilizer production and sales.
- ✓ The project provides a potentially very inexpensive clean cooking fuel, as ethanol will be less expensive than purchased charcoal and wood, and much less expensive than kerosene. The addition of carbon finance may help to reduce the cost of equipment to produce and use ethanol fuel.
- ✓ Farm animals will be fed with the high protein co-products from ethanol manufacture, providing an affordable source of protein that will enter the human food supply. Organic fertilizer will increase crop yields and thus food supply.
- ✓ Micro distilleries are feasible on the village level and can reach populations otherwise not served with clean fuel, power and the other valuable products of the micro distillery.

MDG 2: Achieve universal primary education

The micro distillery could make it unnecessary for children, especially girls, to spend time collecting firewood far away from home. If girls and women have access to a convenient cooking fuel, their time can go into self-sustaining activities, one of which is schooling for the children.

- ✓ Power for lighting, by which to do schoolwork, becomes a possibility with small, efficient ethanol-powered generators.
- ✓ With reduction of smoke in homes and courtyards, children's health will improve and the likelihood of missing school because of respiratory illness will be reduced.

MDG 3: Promoting gender equality and empowering women

- ✓ Providing clean, safe and affordable cooking stoves and fuel will alleviate drudgery and reduce the social, physical and health dangers of collecting fuelwood. Women will have time to attend to their children, and to engage in economic and social activities that will better their lives and the lives of their children.
- ✓ Owning a non-polluting stove that rivals the quality of an LPG or butane stove raises a woman's prestige and social status.

MDG 4: Reduce child mortality

- ✓ Children under 5 years of age are the most affected by health problems caused by exposure to indoor smoke. Introducing clean-burning stoves will lead to a reduction in the instances and severity of childhood acute lower respiratory infection (ALRI) and a host of other illnesses associated will exposure to smoke.
- ✓ The CleanCook stove greatly reduces the risk of fires and explosions in the home. Moreover, an alcohol fire is extinguished with water. These safety attributes help to ensure that children are protected from being burnt, a significant liability with kerosene stoves.

MDG 5: Improve maternal health

- ✓ The use of ethanol fuel in the home will reduce the risk of Chronic Obstructive Pulmonary Diseases (COPD) and a host of other diseases suffered by women as a result of their daily exposure to smoke.
- ✓ Cooking with a stove that produces very low carbon monoxide may contribute to better pregnancy outcomes. High CO levels in the mother are associated with still births, low birth weight in children and slowed early childhood development.
- ✓ Creating affordable fuel options that can reduce or eliminate the need to gather fuels will benefit women's health, as fuelwood gathering is often physically dangerous and subjects women to injury.

MDG 6: Combat HIV/AIDS, Malaria and other diseases

- ✓ Access to an adequate supply of fuel and a good stove will help to improve family nutrition.
- ✓ Access to clean fuel and a good stove will reduce women's burden of caring for children who have malaria, and those living with HIV/AIDS.
- ✓ Access to a clean fuel and good stove will reduce drudgery and work time for women with HIV/AIDS. As women with AIDS are particularly prone to respiratory infections, maintaining clean air in the home will help to safeguard their health.
- ✓ Access to an adequate supply of fuel and an efficient stove will facilitate provision of hot water, essential for cleaning, general hygiene and caring for the sick.

- ✓ A clean fuel and stove will help to reduce the incidence of ALRI, COPD and a host of diseases resulting from exposure to smoke and harmful emissions in the home and courtyard.

MDG 7: Ensure environmental sustainability

- ✓ Promoting locally-produced ethanol fuel from agriculture will ease pressure on forests. Certain agricultural crops are very efficient converters of the sun's energy to carbohydrates (useful plant material) and produce more rapidly and in greater abundance.
- ✓ Large amounts of abandoned agricultural land are available for cultivation if markets can be produced for the crops that could be grown on these lands.
- ✓ The switch to fuel production from agricultural rather than forests promotes not only sustainability of production but also economic sustainability since crops are harvested and sold once or twice yearly rather than once per coppice rotation or tree harvest (5 to 30 years).
- ✓ Forests already damaged by commercial logging, slash and burn agriculture and city expansion cannot sustain the added pressure of fuelwood harvesting, which grows more acute as settlements reach into the countryside and roads are built. Biodiversity suffers from the impact of fuelwood gathering. It is estimated that about 90% of wood taken from forests in Sub Saharan Africa today is for fuelwood and charcoal use (FAO, 2009).
- ✓ Where forests are allowed to regenerate, their ability to recycle the CO2 in the atmosphere and store carbon is increased, thus helping to reduce the impact of global warming.
- ✓ Pilot studies conducted in Delta State, Nigeria, using a litre per day of alcohol, showed that firewood use was reduced by over 95% in the affected homes.

MDG 8: Develop a global partnership for development

- ✓ The gains to be achieved with alcohol fuels—both for human welfare and for the environment—creates the opportunity for local farmers and small business people to work together with global partnerships, foundations and multinational agencies that are searching for real gains in the MDGs.

Financial Analysis

"The project is profitable and recommended for implementation with the relevant controls put in place to ensure proper monitoring of cash flows."

OSA-EFE INTERNATIONAL LIMITED

RATIO ANALYSIS					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Return on Capital Employed	0.2%	5%	13%	22%	32%
Profit Ratio	20.%	5%	11%	16%	21%
Liquidity Ratio	48:1	-	-	1:1	3:1
Earnings per Share	44k	98k	220k	346k	475k

PROJECT FINANCING

The project will be financed in two forms, that is, equity financing and bank financing. Equity financing is 30% of the total project cost while the bank financing will be 70% as follows. The bank loan shall be at 20% interest rate per annum.

Equity Financing	30% of ₦ 28,671,145	₦ 8,601,343
Bank Loan Financing	70% of ₦ 28,671,145	₦ 20,069,802
Total		**₦ 28,671,145**

PROJECT COST		₦
Land	Land Acquisition	1,500,000
Building & Structures	Administrative Block	1,200,000
	Electrical Work & Hydraulic Intern/External to the Building	800,000
	Civil Engineering Works which include: Land Preparation, Fencing, Perimeter Fencing etc.	1,800,000
Plant & Equipment:	Bio-refinery Plant Safety Equipment	22,151,145 120,000
	Laboratory Equipment	450,000

	Loading Bay	150,000
Contingencies:	Working Capital	500,000
		28,671,145

SALES	Daily Production is 1,000 litres
	Annual Production = 300,000 litres
	Selling Price per litre = ₦ 80.00
	Sales = 300,000 litres ∗ ₦ 80.00
	= **₦ 24,000,000**

PURCHASES	Cassava: 6 tons per day = ₦ 42,000 per day = ₦ 5,550,000
	Enzymes: 4.167 kg per day = ₦ 6,760 per day = ₦ 2,028,000
	Yeast: 3.333 kg per day = ₦ 4,820 per day = ₦ 1,446,000
	Other chemicals: ₦160 per day = ₦ 48,000
	= ₦ 9,072,200

OTHER OVERHEADS

This is estimated at 5% of sales. This will take care of general repairs and maintenance of the equipment, machinery and premises and also for marketing and distribution cost, etc.

SALARIES & WAGES	**₦**
Managing Director	720,000
Business Development Manager	480,000
Plant Operation Manager	480,000
Accountant	480,000
Technicians (2)	600,000
Store Keeper	180,000
Gardeners – (2)	240,000
Security Personnel – (4)	576,000
	3,756,000

ASSUMPTIONS FOR FINANCIAL ANALYSIS

- ✓ Sales are expected to grow at a rate of 5% per annum.

- ✓ No sales revenues for products other than ethanol are figured in this study
- ✓ Payments are expected to grow at a rate of 3.5% per annum.
- ✓ Loan repayment period is 5 years with 6 months moratorium period.
- ✓ Interest on Loan is at 20% per annum.
- ✓ Depreciation is calculated on a straight line basis on the Building and Equipment.
- ✓ No depreciation was made on Land.
- ✓ Depreciation on Plant and Equipment is at 10% per annum.
- ✓ Depreciation on Building and Structures is at 5% per annum.
- ✓ Tax is at 30% of the Net Profit for each year.
- ✓ Tax payment is on preceding year basis.
- ✓ Commission on Turnover (COT) is at ₦5 per mille.

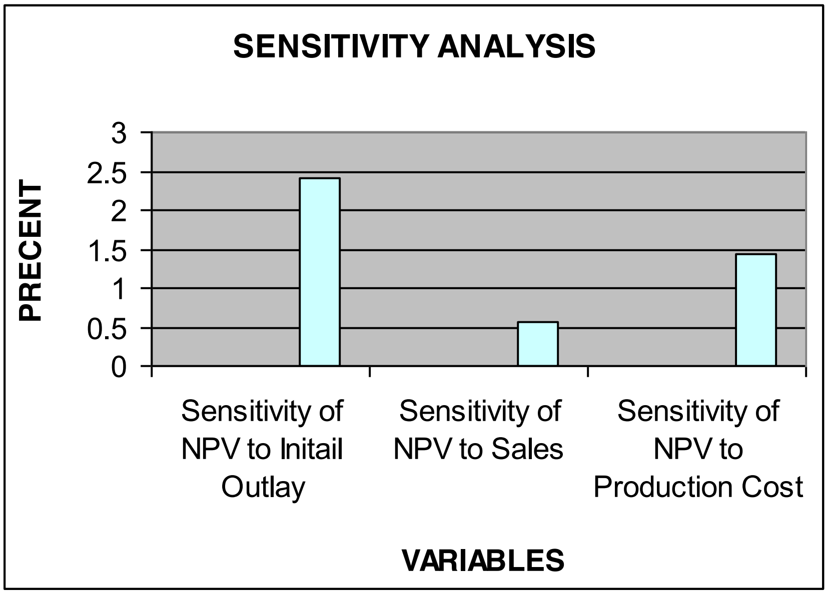
OSA-EFE INTERNATIONAL LTD. SENSITIVITY ANALYSIS

Sensitivity analysis is an investment analysis technique used to test the maximum tolerable unfavourable change in each variable of the project.

The project has a positive Net Present value (NPV) of ₦ 693,772. This shows that the project is viable and is recommended for execution.

Sensitivity of NPV to Selected Variables

Sensitivity of NPV to Initial Outlay	2.42%
Sensitivity of NPV to Sales	0.56%
Sensitivity of NPV to Production Cost	1.43%



Comments

The initial outlay cannot be increased more than 2.42% in order to maintain viability of the project. The sales cannot be decreased more than 0.56% in order to maintain viability of the project. The production cost cannot be increased more than 1.43% in order to maintain viability of the project.

OSA-EFE INTERNATIONAL LIMITED

CASH FLOW PROJECTION					
	Year	**Year**	**Year**	**Year**	**Year**
	1	**2**	**3**	**4**	**5**
Receipts:	**₦**	**₦**	**₦**	**₦**	**₦**
Equity Capital	8,601,343	-	-	-	-
Bank Loan	20,069,802	-	-	-	-
Sales	22,500,000	23,625,000	24,806,250	26,046,563	27,348,891
	51,171,145	**23,625,000**	**24,806,250**	**26,046,563**	**27,348,891**
Payments:					
Fixed Assets Acquisition	28,171,145	-	-	-	-
Principal Loan Payment	2,229,978	4,459,956	4,459,956	4,459,956	4,459,956

Interest on Loan	4,013,960	3,567,965	2,675,974	1,783,982	891,991
Salaries & Wages	3,756,000	3,887,460	4,023,521	4,164,344	4,310,096
Purchase of Materials	9,072,000	9,389,520	9,718,153	10,058,289	10,410,329
Haulage	1,800,000	1,863,000	1,928,205	1,995,692	2,065,541
Electricity	25,200	26,082	26,995	27,940	28,918
Tax Payment	-	16,540	361,687	812,972	1,275,813
Other Overheads	1,050,000	1,086,750	1,124,786	1,164,154	1,204,899
	50,118,283	24,297,273	24,319,277	24,467,328	24,647,544
Commission on Turnover	250,591	121,486	121,596	122,337	123,238
	50,368,875	**24,418,759**	**24,440,873**	**24,589,665**	**24,770,781**
Surplus / Deficit	802,270	(793,759)	365,377	1,456,897	2,578,109
Opening Balance	-	802,270	8,511	373,888	1,830,785
Closing Balance	**802,270**	**8,511**	**373,888**	**1,830,785**	**4,408,895**

LOAN AMORTISATION SCHEDULE				
Year	**Principal Loan**	**Interest on Loan**	**Total Loan**	**Balance on Loan**
	Payment	**Payment**	**Payment**	
	₦	**₦**	**₦**	**₦**
0	-	-	-	20,069,802
1	2,229,978	4,013,960	6,243,938	17,839,824
2	4,459,956	3,567,965	8,027,921	13,379,868
3	4,459,956	2,675,974	7,135,930	8,919,912
4	4,459,956	1,783,982	6,243,938	4,459,956
5	4,459,956	891,991	5,351,947	-
	20,069,802	**12,933,872**	**33,003,674**	

PROJECTED PROFIT AND LOSS

	Year	Year	Year	Year	Year
	1	**2**	**3**	**4**	**5**
	₦	**₦**	**₦**	**₦**	**₦**
Sales:	22,500,000	23,625,000	24,806,250	26,046,563	27,348,891
	22,500,000	**23,625,000**	**24,806,250**	**26,046,563**	**27,348,891**
Payments:					
Interest on Loan	4,013,960	3,567,965	2,675,974	1,783,982	891,991
Salaries & Wages	3,756,000	3,887,460	4,023,521	4,164,344	4,310,096
Purchase of Materials	9,072,000	9,389,520	9,718,153	10,058,289	10,410,329
Haulage	1,800,000	1,863,000	1,928,205	1,995,692	2,065,541
Electricity	25,200	26,082	26,995	27,940	28,918
Other Overheads	1,050,000	1,086,750	1,124,786	1,164,154	1,204,899
Depreciation	2,477,115	2,477,115	2,477,115	2,477,115	2,477,115
Commission on Turnover	250,591	121,486	121,596	122,337	123,238
	22,444,866	**22,419,378**	**22,096,345**	**21,793,852**	**21,512,127**
Net Profit	55,134	1,205,622	2,709,905	4,252,710	5,836,764
Provision For Tax	(16,540)	(361,687)	(812,972)	(1,275,813)	(1,751,029)
Profit after Tax	38,594	843,936	1,896,934	2,976,897	4,085,735
Profit B / F	**-**	38,594	882,529	2,779,463	5,756,360
Profit C / F	38,594	882,529	2,779,463	5,756,360	9,842,095

PROJECTED BALANCE SHEET					
	Year	**Year**	**Year**	**Year**	**Year**
	1	**2**	**3**	**4**	**5**
	₦	**₦**	**₦**	**₦**	**₦**
Fixed Assets:					
Net Book Value	25,694,031	23,216,916	20,739,802	18,262,687	15,785,573

Current Assets:					
Cash & Bank	802,270	8,511	373,888	1,830,785	4,408,895
	26,496,301	23,225,427	21,113,689	20,093,472	20,194,467
Current Liability:					
Taxation	(16,540)	(361,687)	(812,972)	(1,275,813)	(1,751,029)
Net Assets	**26,479,761**	**22,863,740**	**20,300,718**	**18,817,659**	**18,443,438**
Financed By:					
Equity Capital	8,601,343	8,601,343	8,601,343	8,601,343	8,601,343
Bank Loan	17,839,824	13,379,868	8,919,912	4,459,956	-
Profit & Loss Account	38,594	882,529	2,779,463	5,756,360	9,842,095
	26,479,761	**22,863,740**	**20,300,718**	**18,817,659**	**18,443,438**

FIXED ASSETS DEPRECIATION				
	Land	**Building & Structures**	**Machines & Equip**	**Total**
	₦	**₦**	**₦**	**₦**
Year 1 Acquisition	1,500,000	3,800,000	22,871,145	28,171,145
Year 1 Depreciation	-	(190,000)	(2,287,115)	(2,477,115)
Year 1 Net Book Value	1,500,000	3,610,000	20,584,031	25,694,031
Year 2 Depreciation	-	(190,000)	(2,287,115)	(2,477,115)
Year 2 Net Book Value	1,500,000	3,420,000	18,296,916	23,216,916
Year 3 Depreciation	-	(190,000)	(2,287,115)	(2,477,115)
Year 3 Net Book Value	1,500,000	3,230,000	16,009,802	20,739,802
Year 4 Depreciation	-	(190,000)	(2,287,115)	(2,477,115)
Year 4 Net Book Value	1,500,000	3,040,000	13,722,687	18,262,687

Year 5 Depreciation	-	(190,000)	(2,287,115)	(2,477,115)
Year 5 Net Book Value	**1,500,000**	**2,850,000**	**11,435,573**	**15,785,573**

Annex 3
Use of Alternative Bio-Feedstocks

An advantage of micro-distilleries is that they can be constructed near to particular feedstocks, such as a small farm or farmers' co-operative, an operation where co-products or wastes are being generated that can be fermented (such as a fruit processing plant or a city fruit and vegetable market), or even a less formal setting where non-cultivated and wild crops can be gathered, in addition to, or in place of, cultivated crops.

The impact of feedstock cost on the cost of the ethanol produced is clearly evident in the table below provided by Blume Distillation LLC. Fruit cull can be supplied to an operation at a negative charge (in other words, the operation is paid to take it away), which has a significant impact on the cost of the ethanol produced.

Projected per-gallon input costs for a 400-GPD (1,500 l/d) distillation system using alternative feedstocks

Costs	Fruit Cull	Liquid Sugar Waste	Corn
Feedstock	-$0.15	$0.00	$1.44
Enzymes	$0.10	$0.00	$0.06
Other Consumables	$0.04	$0.04	$0.04
Fuel Source	$0.07	$0.07	$0.10
Electricity	$0.01	$0.01	$0.01
Maintenance & Data Subscriptions	$0.02	$0.02	$0.02
Labour	$0.15	$0.15	$0.19
Total Input Cost per gallon	**$0.24**	**$0.29**	**$1.86**
Capital cost per gallon	**$0.27**	**$0.27**	**$0.27**
Total	**$0.51**	**$0.56**	**$2.13**
Total (per litre)	**$0.13**	**$0.15**	**$0.56**

(Blume Distillation LLC Private Placement Memorandum, February 1, 2010)

Some interesting feedstocks that could be gathered and even managed for ethanol production include both dryland species and tropical species, such as, for dryer areas: *Prosopis* or mesquite (yield 341 gal/acre), *Opuntia polycanta*, *Opuntia ficus indica*, or prickly pear cactus (yield 500 to 900 gal/acre cultivated, 200-500 gal/acre wild), *Calotropis procera* or Giant Milkweed, members of the *Cucurbitaceae* family, including Buffalo Gourd (yield 900 gal/acre), and wild melons or *Citrullus* (yield 450 gal/acre). For wetter, coastal, swampy and riparian areas, alternative feedstocks include: cattails (2,500 gal/acre, managed, 1,075 gal/acre, wild), Nipa, Sago and "sugar" palms, *Nipa fructicans, Metroxylon sagus, Arenga pinnata,* etc. (650 gal/acre), and many other plants (Blume, 2007)[138].

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[138] Blume, 2007, and other sources. Ethanol yields are from Blume.

Some dryland species could be made to work effectively together as an integrated energy crop system. A co-planting of mesquite and prickly pear cactus produces a nitrogen fixing shade crop under which cactus can be planted. The micro climate for the cactus is improved by the mesquite and boosts cactus yields. The mesquite provides wood for charcoal or for the distillery boiler fuel, while the mesquite pods, high in sugar and protein, provide a feedstock, along with the cactus, for the distillery. The dewatered stillage may be a potential source not only of animal feed but also food for human consumption (Blume, 2007).

Many tropical fruits are high in sugar or starch and ripen in great quantities in a short space of time. These include papayas, mangos, bananas, plantains, chayotes (the Malagasy name is *saosety*), pineapples, lychee nuts, cashews and so on. Some of these fruits glut the market when they are ready for harvest and thus much fruit is wasted. Some fruits have a limited canning market and are mostly eaten or shipped fresh. Some fruits produce fermentable wastes. The cashew nut grows with a pear-shaped accessory fruit or pseudocarp called the cashew apple and this fruit, usually discarded, is high in sugar and could be available as a feedstock for ethanol (Blume, 2007). It is in fact used in parts of India and southeastern Africa to make an alcohol beverage (FAO, 2004)[139].

Fruit and vegetable markets in cities produce an enormous amount of fermentable wastes. In many cases, these could be gathered and used for producing ethanol, with the residues recycled for animal feed and compost.

[139] Azam-Ali, s. H., 2004, Small-scale cashew nut processing, ITDG - Schumacher Centre for Technology and Development, FAO, 2004. Accessed on the web 6-15-10 at http://www.fao.org/inpho/content/documents/vlibrary/ac306e/ac306e04.htm

PRACTICAL ACTION Consulting

Annex 4

Providers of Small and Micro-scale Distilleries

A web data base for distilleries, plants and distillery networks and associations worldwide may be found at http://www.distill.com/.

1 Brazil

1.1 Usinas Sociais Inteligentes – USI Biorefinarias

Rua Vinte de Setembro, 871 – Centro
São Vicente do Sul – RS – Brazil
Cep: 97 420-000
Fone: +55 55 3277 1244
Fax: +55 55 3277.1245
Email: eduardomallmann@gmail.com and dariopf@usibiorefinarias.com
www.usibiorefinarias.com.br

USI is a micro "biorefinery" that produces ethanol from starch and sucrose, using sugar cane, sweet potatoes, cassava, etc. This plant is installed on a small footprint. An area of only 100 m2 is sufficient for this distillery. In the USI concept, the residues of alcohol production are processed into animal feed, avoiding waste disposal in the environment. The USI plant comes as a shippable package and includes equipment for processing wastes. The distillation unit is automated for easy operation. USI specifies an efficient, small boiler that can be fired with bagasse. It specifies an ethanol-fueled generator for the plant's electricity needs.

USI is the only micro distillery in Brazil certified by the Agencia Nacional de Petroleo, Gas Natural e Biocombustiveis or ANP, of the Federal Republic of Brazil, to provide ethanol into the automobile fuel market. USI's product is also certified by other standards organizations. The plant is known to produce a predictable, high quality product.

The Brazilian Development Bank, BNDES has indicated a willingness to provide financing for these plants (see www.bndes.gov.br)

1.2 Alambiques Santa Efigênia

Rua Santo Antônio, 773
Itaverava - MG – Brazil
Cep: 36.440-000
Fone/Fax: +55 31 3757.1137 / +55 31 3757.1254 / +55 31 3757.1281
Email: alambiquecobre@uol.com.br
www.alambiquessantaefigenia.com.br

1.3 Limana Poliserviços

Rua Julio de Castilho, 2365 – Centro
Jaguairi – RS – Brazil
Cep: 97.760-000
Fone/Fax: +55 55 3255.1778

Email: limana@limana.com.br and denisdelavi.microdestilarias@gmail.com
www.limana.com.br

1.4 Alcompac

Rua Joao Azeredo Coutinho, 100, Jardim Ipe
Lagoa Santa MG Brasil CEP 33400-000
Telefax: +55 (31) 3296-5876 and (31) 3689-6810
Website: www.alcompac.com.br (currently down)

This company entered bankruptcy in 2009 and is being reorganized. The technology is attractive and has one operating plant in MG, Brasil. It is likely that the plant design and technology will re-emerge under new ownership. (See also: http://www.sag.gob.hn/arch_desc/otros/Alcompac(english).pdf.)

2 United States

2.1 Blume Distillation LLC

343 Soquel Avenue # 17
Santa Cruz, California 95062-2305
http://www.blumedistillation.com/index.html

Blume Distillation is a new company that will manufacture micro distilleries appropriate for the developing world. This company is associated with: International Institute for Ecological Agriculture, 343 Soquel Avenue #191, Santa Cruz, California 95062-2305.

Blume Distillation LLC is dedicated to the development of a new generation of appropriately scaled bio-ethanol production equipment. The equipment is designed for modularization and for easy shipping. It is built on the floor plan of a standard shipping container. Capacities range from 10,000 to 100,000 gallons per year. It is powered with biofuels and the electricity for the unit is provided from a small ethanol-fuelled generator. Energy balance is 25,000 Btus invested for 88,000 Btus of ethanol at HHV, with 60% excess heat recovery on the system to generate hot water for another use. The unit is equipped with computerized monitoring so that Blume Distillation technicians can assist operators of the wherever they are situated in the world. The distillation unit produces 92% ethanol with the capability of producing up to 99% by use of an automatically regenerating drying unit using corn meal to selectively absorb water from the ethanol. These plants have been decades in development, many prototypes exist, and will soon be ready to be “assembly-line” produced, rather than built as one-of-kind units.

The materials handling equipment is designed for traditional or alternative feedstocks, ranging from mango peels to waste whole fruit to stale donuts to mixed residues.

Inquiries should be directed to: Main office number: 831-471-9164; Fax: 831-471-9166; General e-mail: info@alcoholcanbeagas.com.

Office contact Linda Byrum at Linda@alcoholcanbeagas.com

2.2 Circle Biodiesel and Ethanol Corporation

141 N. Pacific Avenue, Suite D, San Marcos, CA 92069
Website: http://www.circlebio.com

Media & Operations Contact: Aubree Fowler, Director of Operations
Technical & Investment Contact: Peter Schuh, C.E.O.
Email: peter@circlebio.com.
Circle Biodiesel & Ethanol Corporation
Tel.: 888.809.9980

Stills and micro distilleries from 25,000 to 500,000 gallons per year

2.3 Easy Energy Systems

Sales Representative: Tom Gallager (800) 397-9736
Complete turn-key systems, requiring 23,000 BTU/hr to operate, sized at 500,000 gal/yr. Total system cost $2.5 million.
Website: http://www.easyenergysystems.com/Index.htm

2.4 E-Fuel Corporation

15466 Los Gatos Blvd., #37, Los Gatos, CA 95032
Complete turn-key system, producing 6.3 litres/hr. $9,995.00
Email: sales@efuel100.com
Website: http://www.microfueler.com/

The MicroFueler™ is a portable ethanol micro refinery system that can produce up to 10 gpd (40 gpd with enhanced feedstock) and supports a variety of organic waste as fuel, including discarded liquids rich in sugar, waste sugar, liquids with residual alcohol, cellulostic materials and algae. This product is geared toward homeowners and small businesses wanting to create their own fuel. It is combustion free and sells for $9,995. E-Fuel intends to offer electric generators for sale that can use ethanol from the MicroFueler in order to generate electricity. E-Fuel also offers a network, on a subscription basis, that maintains a communications link with all units, checking vital statistics and operating norms as well as billing and reporting for customers. The first year is provided at no cost and thereafter the charge is $9.95 per month or $99.95 per year (Blume, 2010).

2.5 Allard Research and Development, LLC

Farmersville, Texas
http://www.allardresearch.com/systems.html;
Email: sales@allardresearch.com
Tel: (972) 782-6444; Toll Free: 888-782-4505

Complete turn-key systems from 19 litres/hr to 500 litres/hr, these systems have remote monitoring capability and can be powered by small ethanol-fueled generators (included if needed). The company is focused primarily on ethanol fuel production systems and self-fueling electrical generators. Allard was the first company in the world offering automated commercial-grade ethanol production systems in small to medium-sized capacities, in standard product model offerings manufactured in production-line fashion with extensive quality control and standards.

The capacity of these systems ranges between 100 and 2,000 gpd and are scaled for businesses, municipalities, farms, ranches, and commercial markets. According to Allard's website, suggested feedstocks for their systems include waste alcohol, soft drinks, donuts, bread and pastry products, sweet sorghum, sugar, waste fruit and grains.

Allard offers both automated and manually operated ethanol fuel systems.

2.6 Gildred/Butterfield

http://journeytoforever.org/biofuel_library/Butterfield/butterfield1.html
Producing 37.8 litres/hr (cost to produce ethanol 0.105KWH/litre). Complete system including fermentation tanks and boiler $57,800.00

2.7 Alternative Energy Ltd

P.O. Box 353,
Colby, Kansas 67701
Tel: 913-462-6753

2.8 Great Northern Equipment Co,

3550 Great Northern Avenue
Springfield, Illinois 62707
Tel: 217-787-9870

2.9 Robert Brautigam

Tallgrass Research Center
Route 2 Box 21
Formoso, Kansas 66942

2.10 Schmitt Energy Systems

RR2
Hawkeye, Iowa 52147
Tel: 319-427-3479

2.11 ACR Process Corporation

808 S.Lincoln Avenue No. 14
Urbana, Illinois 61801
Tel: 217-384-8003

2.12 Ethanol International Inc

1372 South Fillmore
Denver, Colorado 80210
Tel: 303-744-8355

2.13 Zeithamer Enterprises Inc

Route 2 Box 63
Alexandria, MN 56308
Tel: 612-763-7392
Tel: 612-762-1798

2.14 Charles 803 Still

This equipment is available from several sources. Approximate cost is $1,400.00 without boiler or fermentation tanks, this still produces 7.5 litres/hr.

A more complete list of U.S. distillers, plants and distillers' associations may be found at http://www.distill.com/usa.html.

Note: The American micro distillery movement, which has been primarily a farm-based movement since its inception, began in earnest when the Model-T Ford automobile was developed, which was originally designed to run on ethanol fuel (Blume 2007). The movement became quite active in the 1970s during the period of high oil prices and again in this decade as interest in ethanol fuel has returned. A good reference for the American micro distillery movement, the producers and the technology is David Blume's "Alcohol Can Be A Gas," International Institute for Ecological Agriculture, Santa Cruz, CA, 2007.

3 Italy

3.1 La Frilli Impianti srl

Located in Monteriggioni, in the centre of Chianti region, distance about 40 Km from Florence and 20 Km from Siena.

Frilli Impianti srl
Loc. Rigoni – Strada dei laghi - P.O. Box n°8
53035 Monteriggioni (Siena)
Tel +39.0577.307011
Fax +39.0577.307080
Marketing: info@frilliimpianti.it
Technical contacts: tecnico@frilliimpianti.it
Office of purchasing: acquisti@frilliimpianti.it
Front office: amministrazione@frilliimpianti.it

4 India

4.1 Nimbkar Agricultural Research Institute (NARI) – Solar Still

NARI also makes a pressurized ethanol stove that will burn with hydrous ethanol and will tolerate ethanol to 50%.
Website: http://www.nariphaltan.org/nari/technology_ren_ene_3.php
Anil K. Rajvanshi , S. M. Patil and Y. H. Shaikh
P.O. Box 44, PHALTAN-415523,
Maharashtra, India
E-mail: nariphaltan@sancharnet.in

4.2 Praj Industries Ltd. – Skid-mounted plants (small scale)

Head Office: Praj House, Bavdhan
Pune – 411 021, Maharashtra, India
Tel: +91 20-22951511 and +91-20-22951511 / 22952214
Fax: +91 20-22951718 and 20-22951515
Contact Person: Ms. Vinati Moghe
E-mail : info@praj.net
Web: http://www.praj.net/

4.3 Sterling Equipments Pvt. Ltd.
A – 14, H Block, MIDC, Pimpri,
Pune – 411018, Maharashtra
India
Tel: 20-27470308
Fax: 27474241
Contact Person: Mr. Ramesh Nadgauda
Product Description: Bio diesel plants, Ethanol plants, Columns, Heat exchangers, Condensers, reflux towers

4.4 Surendra Engineering
Surinder Singh
Plot No. 4, Sector 21_A Near Bank of India
G.T. Road, Mandi Gobingarh 147301
India
Tel: +91 1765 505024
Mobile: +91 9815 246408
Email: info@surindraengineering.com

4.5 KBK Chem Engineering PVT LTD
"Sustainable Renewable Energy Solutions"
A Group company of Shree Renuka Sugars Ltd.
Contact: Ajay Kulkarni, Marketing
Head Office: KBK House, I-DOT Complex
NDA Pashan Road, Bavdhan
Pune 411 021, Maharashira, India
Website: www.kbk-chem.com
Tel: +91 20 3043 8100
Fax: +91 20 3043 8326
Mobile: +91 96577 14407
Email: k.ajay@kbk-chem.com

4.6 ISGEC John Thompson
Mr. Vivek Khandekar or Mr. Suman Jain
Tel: + 91 1732 307217 or 307363 or 307375
Website: www.isgec.com
Email: pvd@isgec.com

4.7 NSI Equipment

Mr. Lokesh Varshney
Tel: + (91)-(121)-2519225/2529956
Website: http://www.nsiequipments.com
Email: info@nsiequipment.com, mcpaid@indiamart.com

4.8 Tinytech Plants
Tel: +91 - 281 - 2480166 Mobile
Website: www.tinytechindia.com
Email: tinytech@tinytechindia.com

5 Kenya
5.1 Kridha Limited
Mr. Suresh Patel, Chemical Engineer
P.O.Box 17777 – 00500, Nairobi, Kenya
Postal/Zip Code 00500
Tel: +254 20 557383
http://www.bizearch.com/company/kridha_Limited_80242.htm
Equipment supplier and manufacturer

6 Madagascar
6.1 CIMELTA Group BP
382 Ouest-Ambohijanahary
Antananarivo 101 Madagascar

English language contact is: Pierre Antoine Botton
Responsable du Département Arts et Fer
Tel 00261 20 22 226 31
Fax 00261 20 22 224 24
Mobile 00261 32 05 748 08
E-mail: pa.botton@cimelta.mg

This company helped to build the SIRAMA distillery, the largest plant in Madagascar, located in Ambilobe. This company is capable of the highest quality in construction standards and can meet international standards (interview with Henri Tsimisanda)[140]. It is likely that CIMELTA could build an advanced micro distillery to specifications.

Website is www.cimelta-madagascar.com.

7 Nigeria

7.1 Boskel Engineering Services Nigeria Ltd
23A, Trans Amadi Industrial Layout
Port Harcourt, Rivers State, Nigeria

[140] Email correspondence between Henri Michel Tsimisanda and Harry Stokes, Aug 5, 2010.

Tel: +234 80 69592199

8 South Africa

8.1 Taurus Distillation

14 Rupestris Street
Groenvlei, Paarl 7646
SOUTH AFRICA
Tel: +27 (0)21 872 4301
Fax: +27 (0)21 872 0762
E-mail: info@taurusdistillation.co.za
Website: http://taurusdistillation.co.za/index.php?BodyType=Home

TAURUS 480 "FUEL FOR THE FUTURE "
The Taurus 480 is a compact (2.35 x 2.39 x 12m), self-contained, modular, continuous column ethanol distillation unit specifically aimed at reducing the transportation cost of the raw material (sugar cane, sugar beet, molasses, cassava, maize, cereal grains, fruit, wine) by 60 to 95 percent. It can be supplied mounted either inside a 12 meter shipping container or I-beam support structure.

Feed capacity: 2 000 litres/hour fermented feed (2 - 12% alc/vol)
Product: Bio-ethanol @ 90/92% alc/vol.: 44 - 266 litres/hour. (Average 180 litres/hour for an 8.5% alc/vol. feed).

Energy consumption: 600 - 800 kg/hour reduced high pressure steam @ 220 kPa (30 psi).
Cooling water: 700 - 1000 litres/hour @ 15/23 Centigrade returned to boiler make-up water.
Stillage: 49,000 – 55,000 litres/24 hours @ 100/105 Centigrade.

Supported by ENDRESS HAUSER downloadable electronic temperature recording at critical points.

Distillation equipment construction: Stainless steel 304, 316 & electrolytic copper.
Annual production from an 8.5% a/v feed (11 months continuous operation):
15,840,000 litres @ 8% a/v = 1,463 million litres 92% bio-ethanol.

9 Great Britain

9.1 Rohrex

Tel: +44 (0)1728 452174
Email: info@rohrex.com
Website: http://www.rohrex.com

10 Sweden

10.1 Chematur Engineering AB (small scale)

Box 430, SE-691 27 Karlskoga
Sweden
Baggängsvägen 43
SE-691 46 Karlskoga

Telephone +46 586 641 00Telefax +46 586 791 700
info@chematur.se
Website: http://www.chematur.se/

Offices in Mumbai, Hong Kong, Atlanta, and Homburg.

From the website: Chematur Engineering has been active in Bioethanol distillation for more than 50 years. The core technology is the proprietary Biostil® 2000 continuous fermentation process, with low water demand and high yeast recycling. Easy to operate, superior yields, reduced stillage amounts and high resistance to infection, which means more on-stream time and higher process yields. The process uses molasses, sugar juices or grains as feedstock, producing bioethanol of all qualities, for fuel, beverage or chemical use. Compact system with small footprint. Maximum heat integration. High substrate concentration, higher stillage concentration. Less dilution water. Less effluent.

Annex 5
Large-scale Ethanol Production

1 Selected Case Studies for Africa

Ethanol production in Africa is concentrated on the Southern tip of the continent (Table 5.3), with the Republic of South Africa accounting for approximately 70% of the total[141] and leading the export market among the African nations.

Table 0-1: Ethanol Exports from African Countries (cubic metres)

	2008	2007	2006	2005	2004
South Africa	188,215	175,778	289,937	329,290	146,653
Zimbabwe	7,647	13,998	8,968	12,526	12,389
Senegal	0	0	0	0	285
Egypt	36,267	40,467	39,035	22,846	9,137
Kenya	15,000	12,370	17,766	8,239	6,637
Congo DR	2,238	0	0	2,343	449
Mauritius	6,552	11,028	5,569	3,909	4,637
Total	**255,919**	**253,641**	**361,276**	**379,152**	**180,196**

Source: F.O. Licht, 2009

Although Africa's ethanol base is less developed than those in Latin and North America, there is significant potential for the biofuels industry to expand. Two pioneer initiatives include the Ethanol Company of Malawi (ETHCO), which has been in operation since 1982, and a bioethanol fuel programme implemented in 1980 in Zimbabwe, which was cancelled in the early 1990s due to a serious drought, but which could be re-implemented in the future. Currently, at least 11 African Countries are creating rules for bioethanol production and trading, including South Africa, Angola, Mozambique and Benin. Further details are provided in the following sections.

1.1 South Africa

South Africa exported 188,215 m^3 of ethanol in 2008,[142] mainly to Africa, Asia and America. If ethanol production proves to be viable, South Africa will produce 1.1 billion litres of alcohol per year, constituting some 10% of the country's petrol needs.[143] Bulk prices for industrial ethanol suitable for household use are typically R2.50 (US$0.38) per litre for synthetic hydrous (96%) ethanol and R3.70 (US$0.57) per litre for industrial grade ethanol.[144]

Molasses is currently the main feedstock, and its price is determined by the sugar content (Biofuels-Overview, 2007). South Africa's molasses production in 2007/08 fell marginally to 817,000 tonnes

[141] Berg, C (2001) World Ethanol Production 2001, July 31, 2001
[142] Licht, F.O (2009) Ethanol Exports African Countries
[143] Tyrer, L (2006) Ethanol Study Results Expected by Year End: Ethanol – SA, May 2006
[144] Lloyd, P (2009) Developing Safe Paraffin Appliances in South Africa, Boiling Point, Issue 56 – 2009, Pg 7.

from 835,000 tonnes per year because of a 3% drop in the cane crop. Prospects for 2008/09 are for a similar molasses crop of possibly 819,000 tonnes. The uncertainty over land ownership and adverse weather condition in recent years has contributed to reduced cane supply.[145]

Current Status of Production

The South African government's aim is for biofuels to account for 40% of South Africa's renewable energy in order to achieve their target of 10,000 GWh of renewable energy by 2013.[146]

The Illovo Sugar Merebank plant produces 40 million litres of ethanol from molasses. Its product is sold into markets ranging from industrial through pharmaceutical to potable (drinkable) ethanol, locally and internationally

The National Chemical Products Company (NCP) plant produces 25 million litres of ethanol per annum from molasses

Ethanol Africa is South Africa's first 'green fuels' company, located in the maize-producing heartland in the Free State. It was set up by a consortium of maize farmers as a solution to grain surpluses with the aim of supplying up to 12.5% of the country's fuel need by 2015.

Ethanol can also be synthetically produced from coal and gas using technologies developed by SASOL, the chemical conglomerate, which is a world leader in coal and gas to liquid technologies. It produces 400 million litres of synthetic ethanol per annum, while Mossgas, a gas to liquid plant produces a further 160 million litres per year[147].

PetroSA is a state-owned energy company using natural gas as a feedstock to produce "mosstanol" (65% ethanol and 35% iso-propanol). Its Mossel Bay plant averages 140 million litres of alcohol products a year, and the majority of this output is exported.

Plans and Prospects

In 2006, South Africa's cabinet approved a National Biofuels Industrial Strategy, which proposed that 4.5% of liquid road transport fuels[148] should be biofuels, allowing the country to produce around 40% of its own fuel supply.[149] The strategy was predominantly driven by the need to address the issues of poverty, rural development, and Black Economic Empowerment (BEE). In 2007, the South African cabinet announced that the country would aim for biofuels to account for 2% of its total fuel production by 2013.

Besides cushioning the effects of oil prices, the large scale production of biofuels in South Africa is projected to provide several other benefits, which include job creation, rural development, and foreign exchange savings.

1.2 Ethiopia

The Ethiopian economy has a strong agricultural base which accounts for 46% of GDP, 60% of exports, and 80% of total employment. Biomass contributes to more than 90% of the country's

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[145] Licht, 2009, World Molasses and Food Ingrdients Report; Vol 7, No 12 / 25.02.09
[146]146 Energy and Resources, Country Profile for South Africa http://earthtrends.wri.org/pdf_library/country_profiles/ene_cou_710.pdf
[147]147 (Castro JFM, 2007 – Biofuels Overview, Final Report, May 2007)
[148]148 Mayet, M (2006) South Africa, Bioethanol and GMOS: A Heady Mixture: African Centre for Biosafety, May 25 2006 www.biosafetyafrica.net
[149]149 Nilles, D (2006) Biofuel Requirements Going Global: Ethanol Producers Magazine, available at: http://www.ethanolproducer.com/article.jsp?article_id=2574

energy demand[150]. Modern energy sources are mainly petroleum products and electricity with 28KWh per capita consumption. It is estimated that Ethiopia has 700,000 hectares suitable for sugar cane production, but only 26,500 hectares are currently in use.

Current Status of Production

Sugar production has reached 300,000 tonnes a year, and the Finchaa factory built a distillery to start to process its molasses by-product into ethanol in 1999, with an annual production capacity of 8 million litres. During the early years of production, local factories consumed only 2 million litres annually, and the rest went to export. Project Gaia came to Ethiopia in response to a request by Finchaa and the Ethiopian Sugar Industry to help develop a domestic market by introducing alcohol-fuelled cooking stoves to Ethiopian homes. An 18-month pilot study funded by the Shell Foundation's Sustainable Energy Programme tested 850 alcohol stoves in households in Addis Ababa and in three refugee camps in Ethiopia in 2004 and 2005.[151]

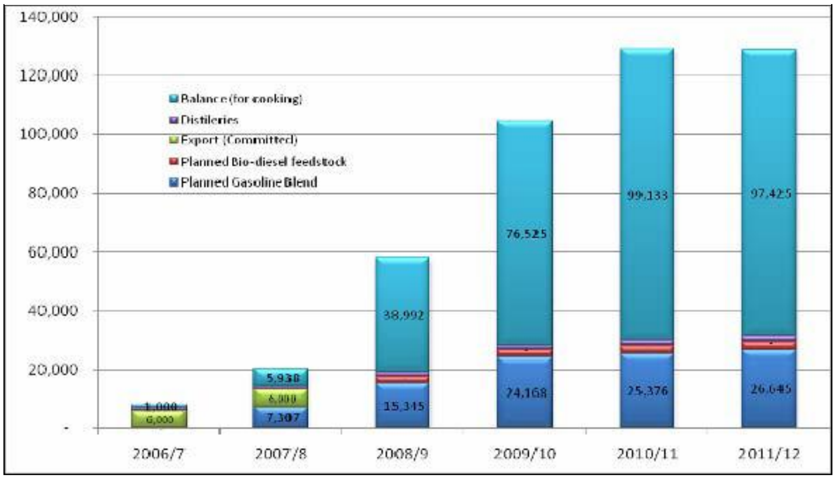
The future national demand for ethanol is expected to come from three main sectors (summarised in Figure 2.5):

As gasoline blend for the transport sector: Depending on the government's strategy on levels of blending, 7 million litres (if E5 blending level is used) to 15 million litres (if E10) of ethanol will be required with demand growing by about 7% per year[152]

As a biodiesel processing feedstock in the oil esterification process: In another government biofuel development strategy, 10% ethanol by volume will be required in the oil-to-biodiesel processing technology (esterification). Demand for ethanol as esterification feedstock will be about 1.6 million litres growing by about 7% per year[153]

The Project Gaia pilot study established demand for ethanol as a household cooking fuel: Kerosene, used by more than 90% of households across all income levels, is the main competitor for ethanol. The study clearly demonstrated that one measure of ethanol fuel displaces at least one measure of kerosene fuel.

[150]150 Dr. Tewolde Brehan G/Egziabher, Federal Environmental Protection Authority, 6 July 2009
[151]151 www.projectgaia.com
[152]152 Ethanol Cooking Fuel and Stove Market Development in Ethiopia Business Plan, Mekonnen Kassa, 2006
[153]153 Ethanol Cooking Fuel and Stove Market Development in Ethiopia Business Plan, Mekonnen Kassa, 2006



Plans and Prospects

The Finchaa refinery currently has the capability to distil ethanol, with an annual production level of 8 million litres, but does not have the capacity to process molasses from the other two main sugar factories, Metahara and Wonji-Showa. These could provide an additional 16.8 million litres of ethanol annually (Boyd, 2008).

Ethiopia is expanding its sugar factories to scale up sugar and ethanol production, and existing sugar factories will be expanded to 700,000-tonnes a year from the current 300,000 tonnes a year. Tendaho, a new sugar factory being built, will produce 600,000 tonnes of sugar annually when it starts to operate in 2011. The five main sugar factories will have a combined production capacity of 1.3 million tonnes of sugar per year.154 Ethanol production is expected to reach 130 million litres per year by 2011/12.155

The fuel blending market is prioritized by the government for the transport sector due to soaring global prices of fossil fuels, and the household sector and local industries are on the waiting list to get locally produced ethanol. The government biofuels policy is aiming for massive upscaling of local production coupled with using ethanol for both the transport and household cooking sectors. It has signed an agreement with fuel companies to blend ethanol with gasoline, starting with a 5% ethanol blended gasoline for the transport sector, but this percentage is set to increase in the coming years.

1.3 Kenya

Oil crises and low sugar prices during the 1970's motivated the Kenyan Government to start to invest in ethanol production. In 1978, the Kenyan Government initiated a programme to distil ethanol from sugarcane, in a 10% blend with gasoline; but this programme faltered due to drought, poor infrastructure, and inconsistent policy (Current Status of the Biofuel Industry and Markets). In 1983, the first ethanol plant was successfully installed as an annex to the Muhoroni sugar factory in Nyanza province.[156] The ethanol produced was used in a 10% blend with gasoline, as part of a national

154 Ministry of Mines and Energy, 2008
155 Ibiddi.
[156]156 HABITAT (1993) Application of Biomass-Energy Technologies p.168

programme.[157] Ten years later the ethanol plant was closed down due to management and pricing problems.

In 2001, ethanol production was revived through the Kisumu ethanol plant in Western Kenya. The plant produces 60,000 litres per day of industrial and beverage grade ethanol. An estimate of crushed cane in Kenya in 2002 was 5,904,108 metric tonnes, while the ethanol production potential is estimated at 413,288,000 litres, (assuming an average of 70 litres of ethanol produced per ton of crushed cane and all is used for ethanol production).[158] The ethanol produced in Kenya is mainly sold to Uganda, Rwanda and Central Africa.

Current Status of Production

The estimated total area under cane cultivation is 123,622 hectares of which 111,189 hectares are operated by smallholders and 12,433 under nucleus estates. Smallholder farms generally occupy units of 4 hectares or less and are operated as family units. Cane is supplied from the farmers to out-grower institutions and then finally to factories. The annual production ranges from 400,000 to 490,000 metric tonnes, however production decreased from 492,249 metric tonnes in 2002 to 448,489 metric tonnes in 2003 (Kenya Sugar Board). This decrease in output was mainly attributed to a reduction in hectares under cane production leading to lower total production and delivery of cane to the mills.

The domestic sugar industry in Kenya produced an estimated 168,124 tonnes of molasses in 2005 that could possibly be converted to 37 million litres of ethanol, providing just 2.6% of all petroleum products. As for ethanol feedstocks, sugarcane is the dominant crop in Kenya with a 2002 production figure of 5,150,000 tonnes.[159] Kenya's leading sugar companies include Mumias Sugar Company, located in the Western sugar belt, and the government owned Nzoia Sugar Company, located between Webuye and Bungoma town in the Western Sugar province with a capacity of 3,000 tonnes per day.

Plans and Prospects

The ruling body regulating the energy sector is currently the Energy Regulatory Commission which handles the permitting and licensing for the development of biofuel markets. In liaison with The Kenya Bureau of Standards (KEBS), which enforces and reviews environmental health safety, their responsibilities include quality standards and code/regulation standards. While there is a license requirement for production, trade, distribution or sale of petroleum or electricity, there is no license requirement for the section governing biofuels.[160]

Whereas Kenya Bureau of Standards KEBS has already produced a standard for 10% ethanol fuel blending, there is no existing regulation on biofuels or alcohol fuels. From the absence of KEBS biofuel standards, it is indiscernible whether or not it is currently permissible by law to produce or sell biofuels to the public. Prior to the creation of a biofuels standard, KEBS is required to conduct an environmental impact assessment which will analyze the effects of such regulations.[5]

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[157] 157 Ministry of Energy (2004) Sectional Paper No. 4 on Energy, Nairobi. Government of Kenya

[158] 158 Karekezi, S (2007) Biofuels in Eastern and Southern Africa, (AFREPREN) FWD, Nairobi, Kenya.

[159] 159 FAO (2002) "FAOSTAT Statistical Databases 2002 (Accessed 2002) available at: http://www.fao.org/acgi-bin/nhp-db.p/?subject=agriculture

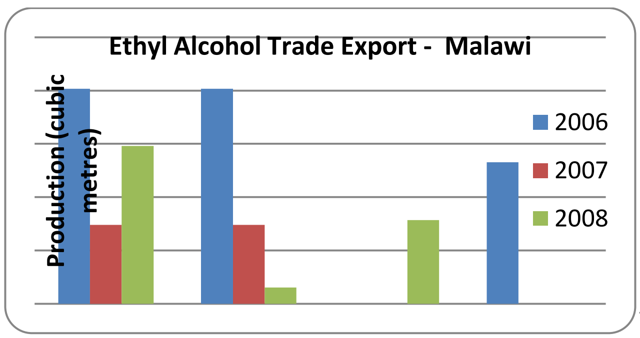
[160] PISCES- Muok, Benard O., Kirui, Shadrack, Theuri, Daniel, and Judi W. Wakhungu (2008) Policies and Regulations Affecting Biofuel Development in Kenya- Policy Brief No 1

1.4 Malawi

The fuel crisis of the 1970's sparked many nations to investigate sources of alternative energy, and Malawi was the second country to spearhead the production of ethanol as a fuel. About 95% of the gasoline consumed in Malawi is blended with ethanol. During 2002-2005, Malawi utilized ethanol as a gel-fuel for domestic cooking, but due to a lack of efficient and appropriate stove technologies, production ceased and Malawi turned to ethanol export and the beverage industry. Malawi is the African country with the longest record producing ethanol for gasoline blending.[161]

Current Status of Production

Annual ethanol production in Malawi is about 18 million litres. The two leading companies driving this production are Ethanol Company Ltd (ETHCO) and Press Cane Ltd, producing 5.4 and 12.5 million litres respectively (2006).[162] Malawi uses molasses from the major national sugar companies, Illovo Sugar Ltd. and Sugar Corporation of Malawi (SUCOMA) as feedstock. Ethanol production levels have allowed Malawi to become an exporting nation, sending locally-produced ethanol to Europe, South Africa, Mozambique, Zambia, and Botswana (Figure 2.6).



[163]

The 2006 Malawi Energy Policy supports the development of ethanol as a household cooking fuel, and policy goals include:

7. Enhancing access to efficient modern energy and to renewable energy in both rural and urban areas
8. Promoting the efficient use of biomass energy and sustainable use of forest resources
9. Enhancing the operational performance of the power sector (specifically in reliability, efficiency, and effectiveness)

Government support is pledged through financial incentives, research and development, and the facilitation of the clean development mechanism (CDM).[3]

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[161] 161 Utria Boris. Ethanol and gelfuel: clean renewable cooking fuels for poverty alleviation in Africa. Energy for Sustainable Development. 2004.
[162] 162 Owen, Matthew and John Saka. The Gel Fuel Experience in Malawi: An evaluation. October, 2006.
[163] Charts Compiled from F.O. Lichts Vol. 7, No 17./1/05/2009

Supply and Demand Analysis

Demand trends

For households, energy is the second highest consumption expenditure at 12% of spending capital, coming second only to food. In rural areas, this is used mostly for lighting while in urban areas household expenditure consists of cooking, lighting, electric appliances, and transport. As such, the Malawi energy balance is dominated by the household sector demands which account for 84% of the total energy consumed in the country. Less than 2% of rural households rely on electricity for cooking, instead they are heavily dependent on primarily charcoal followed by firewood. In urban households, electricity accounts for 11.5% of the cooking energy, while kerosene is used by only 1.2%.[3]

The current demand in Malawi for ethanol for petrol blending and other applications is 9-12 million litres per year. If the ethanol currently produced was diverted from export to domestic cooking use, the estimated demand would be 6-9 million litres per year. At present, much of the demand and consumption of ethanol, besides petrol blending, is used mainly for liquor industries and medical uses.

Supply trends

At the current market price of ethanol, the stove market segment in Malawi is only approximately 2% of the urban population (representing 7,000 households) which currently rely on kerosene and LPG fuel. When the price of ethanol is lowered, ethanol will become much more competitive with charcoal.

This is significant because around 4% (representing 14,000 households) of urban households might be persuaded to switch to ethanol for its positive attributes.

Two private entities BluWave and D&S Gelfuel Ltd. manufactured ethanol gel fuel for domestic cooking between 2002-2005, however, without appropriate stove technology being put in place, this production was discontinued as the supply no longer met the local demand.

Plans and Prospects

BluWave Limited is a Malawi corporation which developed a liquid Ethanol Combustion Technology for heating and lighting as well as industrial burners for the local market since 2001. In cooperation with the University of Vienna and UNDP Malawi, there is currently an ongoing search for ethanol-based alternative energy sources and appropriate technology. Additionally, the Danish Development Agency (DANIDA) and the U.S. Agency for International Development (USAID) have been providing assistance to another private entity, D&S GELFUEL Ltd. to introduce and market this ethanol-gelatine fuel blend.

1.5 Mozambique

Mozambique is home to 20 million people, and 80% of this population live in rural areas. The country has a land area of 799 380 km^2, located along the south-east coast of Africa, and is home to 12 locally owned oil companies including the National Oil Company (PETROMOC). Mozambique has three main ports allowing for transfer of oil across the border to Mozambique's landlocked neighbours including Swaziland, Zambia, South Africa, Zimbabwe and Malawi. One of the traditional sugarcane producing countries in Africa, Mozambique's sources of bio-ethanol includes sugarcane, molasses, and sweet-sorghum.[164]

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[164] 164Mozambique:http://mediabase.edbasa.com/kunder/yaraimages/agripres/agripres/agripres/j2006/m09/t04/0000443_2.pdf.

In 2004, primary energy consumption in Mozambique was about 7.9 million tonnes of oil equivalent (toe), equating to about 0.425 toe per capita. Of this, firewood and charcoal accounted for 89.94% (Figure 2.7). Fuelwood consumption is expected to increase in the future by about 2% per year, an amount of 16,000 tonnes per year by 2014.[165] It is estimated by 2014, that about 14 million Mozambicans (about 70% of total population) living in the rural areas will be exclusively using fuelwood for cooking.[166] The average nationwide deforestation rate in Mozambique is 4.27% per year, and about 90% of Mozambican urban households use fuelwood for cooking, of which about 60% use firewood and 30% charcoal.[167]

Current Production and Use

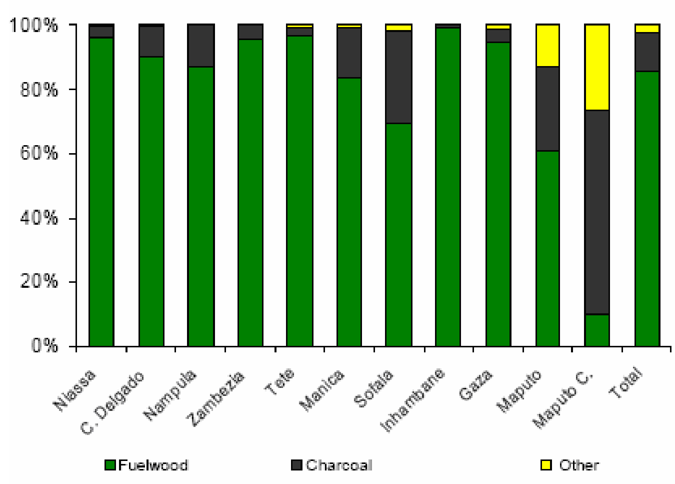
Mozambique has significant forestry resources, about 61.8 million hectares of forestry, approximately 78% of total land area. Most recently Mozambique has stated that only 9% of the county's 36 million ha of arable land is currently in use and there is the possibility of bringing into production an additional 41.2 million ha of marginal land currently not being used.[168] It is estimated that much of this land will be allocated for the production of biofuels.

Comprising mostly liquid and gas fuels, the fuel industry in Mozambique is heavily dependent on imports. In 2005, Mozambique imported about 500,000 tonnes of petroleum products, against 612,000 tonnes in 2004.[169] The country does not produce any oil domestically and therefore is 100% reliant on imports. The transport sector is heavily responsible for the use of imports followed by industry. Diesel accounts for about two thirds of total imports, followed by gasoline and jet kerosene, each accounting for about one sixth of total imports. A small fraction of imports are re-exported to neighbouring countries.

Plans and Prospects

As early as 2002, the government of Mozambique began searching for renewable ways to supplant its heavy dependence on oil imports as well as the overwhelming pressure on fuelwood for cooking needs. Almost 90% of its renewable energy sources still consist of fuelwood, however alternative sources of energy are beginning to pick up and solar accounted for about 12 000TJ in 2005, which is roughly 3% of total renewable energy.

[166]166 Direção Nacional de Energia, 1997, AfDB, 2006)
[167]167 DNE 2007
[168]168 Namburete, 2006
[169]169 A Brief Analysis of the Energy Sector in Mozambique.



(Source: Ministry of Energy Statistics 2005)

In the last few years there has been a transition to the implementation of wide-scale biofuel development projects, which include both small and large scale initiatives. Procana, a private company has already released plans to invest US$150 million to develop 30,000 hectares of land for sugarcane feedstock and a plant producing bioethanol. These plans also encourage rural development with the use of out-grower schemes to add additional hectarage. In fact, out-grower schemes are becoming increasingly popular as the Mozambique experience shows out-grower farming, less than a hectare, can bring in more income than factory employees earning a large salary. These integrated projects are taking off in Mozambique with the companies, Mozambique Principle Energy (large and small-scale) and Elaion (small-scale jatropha), investing in the country.[170]

1.6 Nigeria

In a bid to link Nigeria's oil to the agricultural sector, a fuel ethanol programme has been put in place by the Nigerian Government through the National Petroleum Corporation.[171] The programme, which is backed by official policy, is based on the development of large-scale cassava and sugar cane plantation. The aim is to gradually reduce the nation's dependence on imported petrol, reduce environmental pollution, and at the same time create a commercially viable industry that can produce sustainable domestic jobs.[172] The objective of the programme is to firmly establish a thriving fuel ethanol industry that would utilize agricultural products as a means of improving the quality of automotive fossil-based fuels in Nigeria. Nigeria has the largest potential in Africa to produce fermentation ethanol. In the regional context, however, ethanol has a great potential as a clean household fuel for cooking, heating, and lighting purposes.

Nigeria is the world's leading cassava producing nation.[173] The nation's estimated 2006 cassava production was 41,500 tonnes at a productive rate of 3.8 million hectares compared to that of the total world's production at 218,569 tonnes and productive rate of 18,200 million hectares in 2006.

Current Status of Production

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[170] 170 www.iied.org/pubs/display.php?o=17059IIED
[171] 171 Daily Trust (2006) "Can Nigeria Develop Ethanol as Alternative Fuel?"
[172] 172 Federal Republic of Nigeria Official Gazette, No 72, Vol. 94, Lagos, 20th June 2007
[173] 173 Food and Agricultural Organization. Statistical Database, 2006.

Ethanol has been a commercial commodity in Nigeria since early 1960s when it became popular as an intoxicating ingredient in an alcoholic beverage known as *ogogoro.* Ethanol is distilled from palm wine in some rural communities in Niger Delta and Eastern Nigeria, and the portable ethanol output from these largely moonshine stills is estimated to be 13.5 million litres per year.[174] Nigeria's biofuel market is currently driven by three major macroeconomic factors, namely energy security, job creation, and diversification of the economy. Nigeria is taking a more top-down supply-led approach that seeds the market through importation of cargos of fuel ethanol until such a time that sufficient local capacity and capabilities have been developed for large scale production of ethanol feedstock and ethanol plants.[39]

In 2007, the Federal Government of Nigeria approved the blending of biofuel as a component of fossil-based fuels. The policy envisioned that from the take-off of the programme, full national implementation should be achieved within 10 years, and the market[7] should be led through registration of bio-fuel plants manufacturing fuel ethanol and/or biodiesel.[39] The success of Nigeria's bio-fuels programme is anchored on local availability of high quality feedstock in sufficient quantity from both out-growers and independent plantations to feed the ethanol plants on a sustainable basis. Policy commitment to the development of a national programme on biofuels, as well as the few planned and on-going private sector-led initiatives on bio-ethanol are centred around the use of cassava and sugar cane as feedstock. All ethanol used in Nigeria, particularly the industrial and pharmaceutical grade ethanol, is imported. There are companies importing either sugar cane molasses or crude ethanol for other ethanol production in Nigeria.

Plans and Prospects

The total market volume of ethanol in Nigeria is estimated to be around 90 million litres, the largest part of which is supplied by South Africa, Brazil, and Spain (Utria Berg 2001). Estimates from the Central Bank of Nigeria put the national annual ethanol consumption in Nigeria at 88,000 MT, while the Federal Office of Statistics estimates Nigeria's annual ethanol imports, besides the importation of fuel ethanol for fuel blending, at 42,600 MT. Based on current demand for gasoline in the country, at 10% blend ration with fuel ethanol, about 1.3 billion litres of ethanol will be required for the country, and is estimated to increase to about 2 billion litres by 2020. Total projected future demand of around 5 billion litres is shown in Table 2.4 (Anga).

s/n	Ethanol Markets in Nigeria	Market Demand Per Year
1	Gasoline (E-10 Blend)	1.2 Billion litres
2	Kerosene Replacement with Ethanol-blended cooking fuel	3.75 Billion litres
3	Raw material for potable ethanol (Redistillation market)	90 million litres
	Total market size	**5.04 Billion litres**

Source: Boma Anga (2008)175

1.7 Tanzania

[174]174 Izuagbe, Y and Uraih, N (1990) Public Health Food and Industrial Microbiology: Traditional Methods of Production of ogogoro. Pp 150 - 158

175 Anga, B. S. (2008) Ethanol Market Options in Nigeria; Survey for Cassava Agro Industries Ltd, Abuja.

Tanzania encompasses a total land area of 945,087 square kilometres.[176] Tanzania is an agrarian country, with more than 70% of Tanzanians residing in rural villages and over 80% deriving their livelihoods from agriculture and pastoralism. Biomass energy consumption comprises about 93% of total energy consumption in Tanzania.[177] According to various studies, the major energy sources consumed in Tanzania are biomass fuels (91.6%), petroleum products (6.8%) and electricity and coal (1.6%).[178] Paired with rates of deforestation (around 250,000 hectares lost per annum), sources of wood energy supply are becoming increasingly scarce.[179] Firewood and charcoal are the most expensive in the capital Dar-Es-Salaam as they are usually transported distances of up to 250 km away. Despite this, charcoal is still considered a reliable source of energy as it is easier to use than firewood. Random surveys in the cities of Dar-Es-Salaam, Tanga as well as the Municipality of Morogoro, indicate that many households are still using traditional charcoal cooking stove.[47]

Current Status of Production

Currently Tanzania spends US$1.3-1.6 billion on oil imports, about 25% of its foreign exchange earnings.[180] Tanzania is totally dependent on the importation of petroleum products and charcoal consumption. For example, in 2008, the consumption of charcoal in the capital alone was estimated at 20,000 tonnes per year.181 The liberalization of the energy sector in Tanzania led to the closing of the only available refinery (TIPER) in 1997, and the importation of fuel accounts for 40% of all imports into Tanzania with the transport sector consuming more than 40% of the imported petroleum. [182]

At present, three major sugar companies exist in Tanzania; all three were previously government-run but are now private entities. Each of these plants produces sugar for consumption and uses the bio-wastes to generate electricity. Through cogeneration, these plans produce electricity from their agricultural wastes and sell them to TANESCO, the national power utility. In 2006 and 2007, Tanzania produced 192,535 tonnes of sugarcane, although it fell short of national demand, only reaching 64% of the estimated 300,000 ton demand. As such, Tanzania was forced to import sugar from neighboring countries.[183]

Plans and Prospects

An increase in national biofuels production is considered to be a potentially cost-effective way for Tanzania to save on imports of costly oil. The international community, including major biofuels companies and governments has been promoting investment in biofuels to promote energy security. Tanzania is one of the African countries on the forefront of this trend. In fact, over 4 million hectares of land has already been requested for biofuels investment (jatropha, sugarcane, and oil palm). As of June, 2009 only 640,000 hectares had been allocated for this use, and only 100,000 of those acres have been formally granted the right of occupancy.[48]

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[176]176 CIA World Factbook. https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

[177]177 The Energy Sector in Tanzania: http://www.areed.org/country/tanzania/energy.pdf

[178]178 IEA, 2003;

[179]179 Impact of Increased Charcoal Consumption to Forests and Woodlands in Tanzania Dr. Felician Kilahama, President, Tanzania Association of Foresters, P.O. Box 426, Dar-es-Salaam

[180]180 Sulle, E. and Nelson, F. (2009) Biofuels, land access, and rural livelihoods in Tanzania. IIED.

[181]181 Kamanga, K.C. 2008. The Agrofuel Industry in Tanzania: A Critical Enquiry into Challenges and Opportunities. A research report. Hakiardhi and Oxfam Livelihoods Initiative for Tanzania (JOLIT), Dar es Salaam.

[182]182 Global Forum on Sustainable Energy – 6th Meeting. 'Africa is Energizing itself.' Dr. Rainer Janssen. 29 November – 1 December 2006, Vienna, Austria

[183]183 Songela, F. and Maclean, A. 2008. Scoping Exercise (Situation Analysis) on the Biofuels Industry Within and Outside Tanzania. Energy for Sustainable Development report for the WWF Tanzania Programme Office.

National policies which promote biofuels production, also attracts foreign investment and already some countries have proposed biofuels projects which have attracted investments of a few billion USD over the next two decades.[48] According to official government figures, about 20 companies had requested land for commercial biofuel production by March 2009 (varying from 30,000 to 2 million hectares).[48] There is considerable variation of biofuel production models in Tanzania, with some relying only on smallholder out-grower schemes while others requiring large swaths of land owned and farmed by the producer/investor.

In August of 2006, the government (Ministry of Energy and Minerals) of Tanzania implemented a National Biofuels Task Force, a body responsible for completing formal policy guidelines for potential biofuels investors. In fact, the most up to date National Biofuels Guidelines shows a willingness on the part of governments to adapt policy provisions based on field experiences. An initial draft of guidelines on biofuel production was presented in August 2008.[184] After receiving criticism from some NGO's, the government revisited the guidelines to include some of these suggestions in a revised draft, but to date, it has not been formally approved by the Cabinet.[48]

1.8 Uganda

Uganda is a landlocked country covering 236,000 kms^2 with a population of about 28 million growing at 3% per year.[185] Of the approximate 148,000 kms^2 of cultivable land, 30% is used for crop production while the other 70% is used for subsistence farming.[i] The rate of charcoal consumption increases annually at a similar rate to that of urban growth at 6%.[186] Uganda is greatly in need of alternative fuel sources as the per capita consumption of biomass is 680 kg/year for firewood in rural areas and 240kg/year in urban areas, while charcoal consumption is 4kg and 120kg per year in rural and urban areas respectively. Biomass demand by households in 2006 was 22.2 million tonnes while industries added an additional demand of 5.5 million tonnes. Currently Uganda is heavily dependent on petroleum for the transport industry, and the total fuel cost comprises almost 50% of the countries budget[187].

Current Status of Production

In 2007 Uganda released "The Renewable Energy Policy for Uganda" with the aim of "increasing the use of modern renewable energy, from the current 4% to 61% of the total energy consumption by the year 2017."[188] In Uganda, large quantities of crude ethanol are being produced from sugar molasses, cassava, finger millet, sorghum and banana. Cassava contributes 24.5% of the total volume of crops produced. Uganda currently has three sugar processing plants, namely Kakira Sugar Works, Kinyara Sugar Works Ltd, and Sugar Cooperation of Uganda Limited, and the national production is 200,000 tonnes of sugar per year.

The large amount of ethanol produced in Uganda is being primarily being used for alcoholic beverages. Uganda has the highest human alcohol consumption rate of 19.4 litres of pure ethanol per capita. With a population of about 28 million, this implies that Ugandans consume over 320 million litres of pure ethanol per year.[189] Uganda on average consumes a combined volume of 840

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[184] 184 URT (United Republic of Tanzania). 2008. Guidelines for Sustainable Liquid Biofuels Investments and Development in Tanzania (draft). Ministry of Energy and Minerals.

[185] 185 Sugar Companies Solve Biofuel Production Problems." All Africa. 13 June 2008

[186] 186 Kyamuhangire, William. Perspective of Bioenergy and Jatropha in Uganda. Presented at International Consultation on Pro-poor Jatropha Development. 10th -11th April, 2008.

[187] 187 Ugandan Renewable Energy Policy and Re-impact

http://www.ceg.ncl.ac.uk/reimpact/Uganda.htm#EnergyPolicy

[188] 188 Ibid

[189] 189 Kiza, Michael. "The Role and Potentials of Bioenergy in Uganda's Energy Sector".

million litres of refined diesel and petrol annually, which is higher than the cost of neighbouring countries that import crude oil and refine it locally. Currently Uganda is heavily dependent on petroleum for the transport industry and the total fuel bill comprises almost 50% of the countries budget. The government has mandated a mixing of petroleum that must now be mixed with 20% biofuels in order to reduce fuel consumption and states that there will be no taxes placed on bio-fuels. The Ugandan government also hopes to attract biodiesel investors, and has also begun the promotion of oil seed and vegetable oil production in the agricultural industry. Based on the current consumption rate at least 10.6 million litres of ethanol would be required every month to meet the Ministry of Energy's target of 20% blending.[190]

Plans and Prospects

Uganda has investigated its potential for production of ethanol from sugar molasses and cassava. The country produces a lot of alcohol that can be refined and used for fuels, although most of these crude beverages are locally distilled using very old inefficient distillation systems to yield a more concentrated and strong beverage called *waragi*, with an ethanol concentration of up to 40% (v/v).[191] In 2002, cane crushed in Uganda was 1,707,000 tonne with an estimated ethanol production potential of 119,490,000 litres. In 2003 the total production of cassava was 5,265,000 tonnes while stock residues produced 326,430 tonnes, and currently the Uganda Cassava Development Program (UCDP) is working to improve this cassava production. The government is targeting the transport sector since it is consuming high amounts of foreign currency. According to the plan, it is envisaged to reach 20% gasoline blending to reduce rising cost of fossil fuel import.[192]

1.9 Zimbabwe

Zimbabwe's ethanol production is principally located in the Lowveld region, and began in 1980 at Triangle Ltd, a sugar company located in north-eastern Zimbabwe, with an annual production capacity of 40 million litres. Rising domestic energy costs and post-independence export restrictions created the need for ethanol to be produced for fuel blending. Originally Triangle's output of ethanol blended fuel was supplied exclusively to the National Oil Corporation of Zimbabwe (NOCZIM), which required other Zimbabwean fuel distributors to purchase and blend as required. For many years, the only gasoline available consisted of 13% ethanol blend by volume. However, in 1992 as a result of NOCZIM's financial woes and a temporary supply interruption, Triangle's ethanol ceased to contribute to the national energy supply.[193]

At commissioning, the blending target ratio of ethanol/gasoline for the country was 15:85, but by 1993 it stood at 12:88. The ethanol production programme has contributed significantly to the Zimbabwean economy. Benefits include reduced gasoline imports by about 40 million litres, increased incomes to approximately 150 cane farmers and availability of a market for molasses, which was formerly a waste product (Scurlock et al, 1991b; Hall et al, 1993).

Using on-site molasses as feedstock, ethanol production peaked in 1987 at 41 million litres per year.[194] Demand for molasses for producing ethanol became so high at Triangle, that surplus molasses was purchased from nearby Hippo Valley Estates as well as Nakambala in Zambia.

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[190]190 "East Africa: Uganda to blend fuel with ethanol". MyAfrica. October 2, 2006.

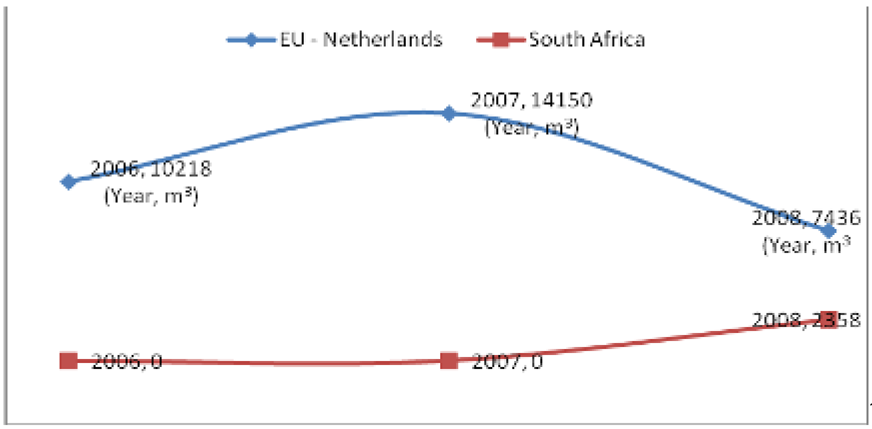
[193]193 Stockholm Environment Institute. World Bio-Energy Prospects: Report for the World Bank, Chapter 6, Bio-Energy Project Profiles, in review.

[194]194 Biotechnology: economic and social aspects: issues for developing countries. By E. J. DaSilva, Colin Ratledge, Albert Sasson

Current production is around 14 million litres per year, of which almost 80% is exported, mainly to Europe in the form of industrial grade ethanol (Figure 2.8).

Current Status of Production

Zimbabwe has two main sugar-producing plants; Triangle Ltd and Hippo Valley Estates Ltd. The ethanol plant in Triangle experienced considerable success in the decade after its inception was locally monitored and low-cost technologies were used successfully. The distillery was built mostly from local materials and Zimbabwe was able to produce an ethanol plant with a 42 million litres per year capacity, at a total capital cost of $6.4 million (at the 1980 dollar value) which is among the world's lowest costs for such plant types.[2]



[195]

Under the World Bank's "Development Marketplace" programme, the Regional Program for the Traditional Energy Sector (RPTES) of the Africa Region Energy Unit (AFTEG), teamed up with a Zimbabwean company, Millennium Gel fuel Company (MGC) to participate in Research and Development to reproduce MGC's existing "Greenheat Gel fuel" into a renewable, low-cost, safe and clean household cooking fuel.

Plans and Prospects

Zimbabwe's government has established a policy to support biofuels such as biodiesel and ethanol-based fuels, to reduce fossil fuel use, thereby reducing carbon emissions and helping to curb climate change and global warming.

2 Selected Case Studies Worldwide

The following sections highlight cases from outside of the African continent where ethanol production and/or consumption offer important insights into both how the international market as well as the Malagasy industry may develop.

2.1 European Union

In the European Union, ethanol production rose to approximately 2.3 billion litres in 2007 from 1.6 billion litres in 2006. The largest producer in the European Union is France, which produced an estimated 1.2 billion litres in 2007, followed by Germany with 850 million litres.[196] Based on the EU's current ethanol targets for fuel blending, 17.7 billion litres of ethanol will be required by 2020.

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[195] Charts Compiled from Fo.Lichts Vol. 7, No 17./1/05/2009
[196] F. O. Licht (2007)

Figure 2.3 Bioethanol capacity, production and consumption in the EU (million litres p.a.)

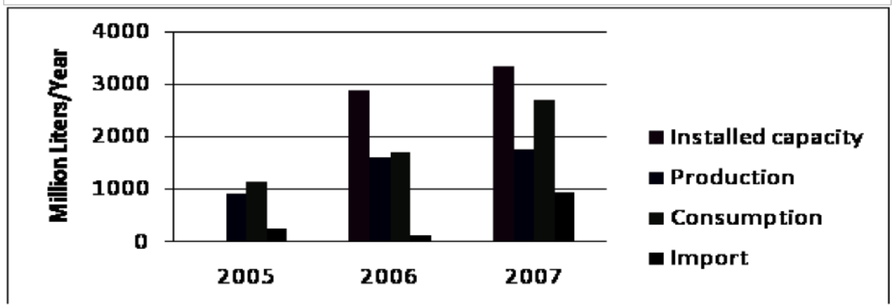
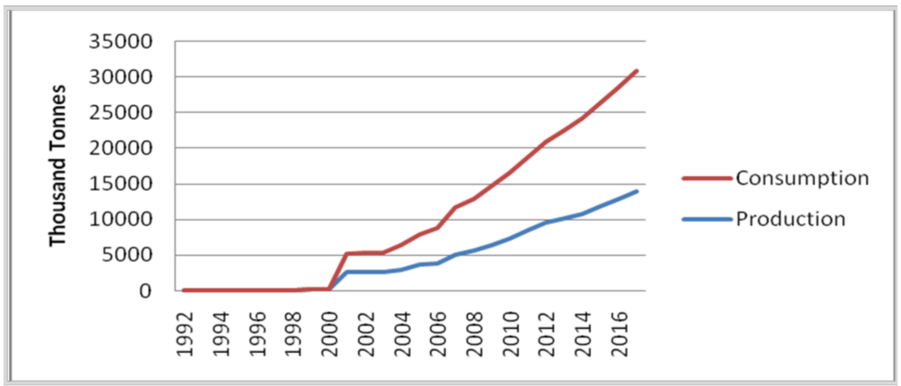


Figure 2.4 European Union Ethanol Production History and Projection



Local production capacity may reach 12.16 billion litres by 2015 and might remain constant thereafter based on the current trajectory of first generation and cellulosic projects entering the market. In short, as a result of the EU's mandated targets, and individual ethanol and biodiesel targets in several countries, the growth of demand in the EU will be significant and above its internal production capacity. Imports will continue to make up the difference between domestic supply and demand and are likely to play an important role in global ethanol trade.

2.2 India

As one of the leading emerging markets, with one of the fastest growing communities, India is the 5th largest consumer of petroleum products in the world, importing over 72 percent of its energy requirements.[197] The country's expenditure on petroleum products has steadily increased with rising oil prices over the years, and with respect to ethanol production India focuses on non-food sources such as sugar molasses for fuel blending given the high population growth and fear of food insecurity.

In 2003, the Ministry of Petroleum and Natural Gas introduced the first Ethanol Blended Program (EBP). This programme mandated the blending of 5% ethanol in 9 states out of the 29 in India, and

[197] http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_New%20Delhi_India_6-12-2009.pdf

in 4 out of 6 unions. However, the programme was not very successful during 2003-2004 as sugar supplies were erratic, with ethanol supplies to sugar companies coming to a halt in 2004. In 2005/2006, sugar production rebounded causing renewed interest in the ethanol programme. In September 2006, the Government of India announced the second phase of the EBP programme. In late September 2006, the petroleum companies floated open tenders for the procurement of over 1.8 billion litres of ethanol from domestic producers over a period of three years. After a series of negotiations with domestic producers, the petroleum companies contracted for over 1.4 billion litres of ethanol for the EBP programme at Rs. 21.50 per litre over a period of three years starting in November 2006.[198]

Current Status of Production

Currently, India is experiencing a glut situation with closing stocks of over 100 lakh tonnes since 1999-2000.[199] In addition, the availability of molasses has also increased. Table 5.5 details the production of molasses, alcohol utilization by the alcohol-based chemical industry, the potable sector and the surplus at the end of each year. According to MPNG, 5% ethanol blends on an all-India basis would require 500 million litres. The current availability of molasses and alcohol would be adequate to meet this requirement after fully meeting the requirement of the chemical industry and potable sectors, but not many distilleries have been producing ethanol in the past years due to a lack of a comprehensive policy on the purchase and blending of ethanol.

Only 3 distilleries attached to sugar mills were well established for production, and were able to supply ethanol immediately. Now, about 11 factories in Uttar Pradesh will be adding facilities to produce about 75 million litres of anhydrous alcohol by end-September 2010; 7 units in Tamil Nadu (production capacity of 62.5 million litres of anhydrous alcohol); 8 in Karnataka (anhydrous alcohol production capacity of 66.5 million litres); and 4 units in Andhra Pradesh (capacity of over 40 million litres). Similar steps have also been adopted by the cooperative sector units in Maharashtra, Punjab and UP. By the end of the year it is estimated that about 300 million litres of capacity will have been created for the production of anhydrous alcohol.[200] There has been a steady increase in the production of alcohol in India, with estimated production rising from 887 million litres in 1992-93 to nearly 1,654 million litres in 1999-2000. Surplus alcohol leads to depressed prices for both alcohol and molasses.[201]

Alcohol Year	Molasses Production	Production of Alcohol	Industrial Use	Potable Use	Other Uses	Surplus Availability
1998-99	7.00	1411.8	534.4	5840	55.2	238.2
1999-00	8.02	1654.0	518.9	622.7	576	455.8
2000-01	8.33	1685.9	529.3	635.1	588	462.7
2001-02	8.77	1775.2	5398	647.8	59.9	527.7
2002-03	9.23	1869.7	550.5	660.7	61.0	597.5
2003-04	9.73	1969.2	578.0	693.7	70.0	627.5

198 http://www.thebioenergysite.com/articles/369/india-biofuels-annual-report-2009
199 http://www.ethanolindia.net/sugarind.html
200 http://www.ethanolindia.net/sugarind.html
201 http://www.ethanolindia.net/sugarind.html

2004-05	10.24	2074.5	606.9	728.3	73.5	665.8
2005-06	10.79	2187.0	619.0	746.5	77.2	742.3
2006-07	11.36	2300.4	631.4	765.2	81.0	822.8

Plans and Prospects

In May 2009, the Petroleum Ministry proposed to lower the import duty on denatured alcohol from the present 7.5% to 5% and that on molasses from 10% to 5%. The government's 5% petrol blending plan has been affected due to the decline in molasses production in India which arose from a decrease in sugarcane production. Currently, the Ministry's proposal is awaiting clearance from the Cabinet. Analysts are of the view that at 5% blending the requirement for ethanol is about 600 Mlt/y and there has been a shortage of about 40%. The oil marketing companies are unable to take up blending in the areas of Tamil Nadu and Kerala due the taxation policy of these State Governments.[202]

However, as mentioned above, a major hindrance to the blending programme has stemmed from the erratic supply of ethanol. The original plan to make 10% blending available from October 2008 has still not been implemented. Contracts for 1,320 M litres of ethanol had been signed for by oil companies, but as of January 2009, they had only received 120M litres.

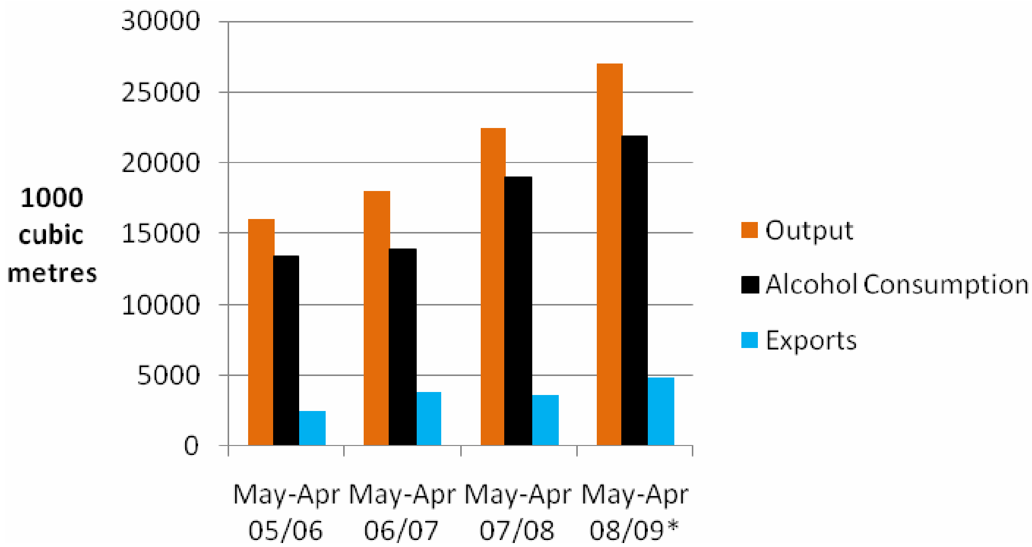
2.3 Brazil

Brazilian ethanol is produced from sugarcane, and Brazil is the second largest producer and leading exporter of ethanol. As a consequence of the 1973 oil crisis and concerns over energy security, Brazil began to develop its own ethanol market. The 1975 National Alcohol Program, Proacool required Petrobras (Brazil's major oil company) to purchase a set quantity of ethanol; provided subsidies to keep the price of ethanol at the forecourt below the gasoline price and set blending mandates for ethanol.[203] The ethanol market was only deregulated in 2000. The fossil fuel market remains highly regulated though with state oil company Petrobras regulating prices, but a number of policy measures remain in place.[204] Biofuel policy mandates that all gasoline must contain between 20% and 25% of anhydrous ethanol. Currently, the mandate is 23% (5% biodiesel in 2010).

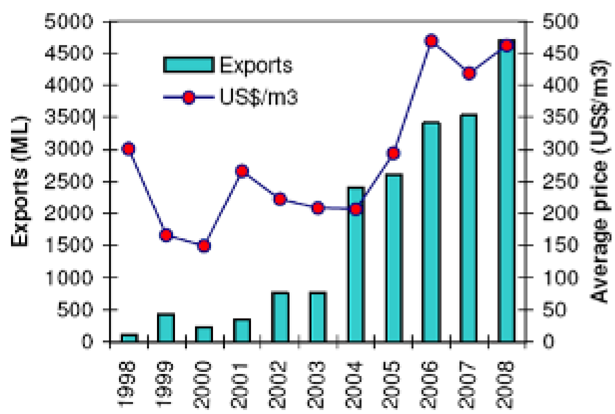
[202] Godfrey, John. ICIS 29 May 2009, Chemical Business NewsBase (CBNB)

[203] Hayes et al., 2009

[204] Moreira, 2007



The production in 2007 was 21.6 billion litres, while the domestic consumption grew from about 14 billion litres in 2006 to about 18 billion litres in 2007 (Figure 2.9). Brazil exported 3.4 billion litres of fuel ethanol in 2006 and 3.5 billion litres in 2007.[205]



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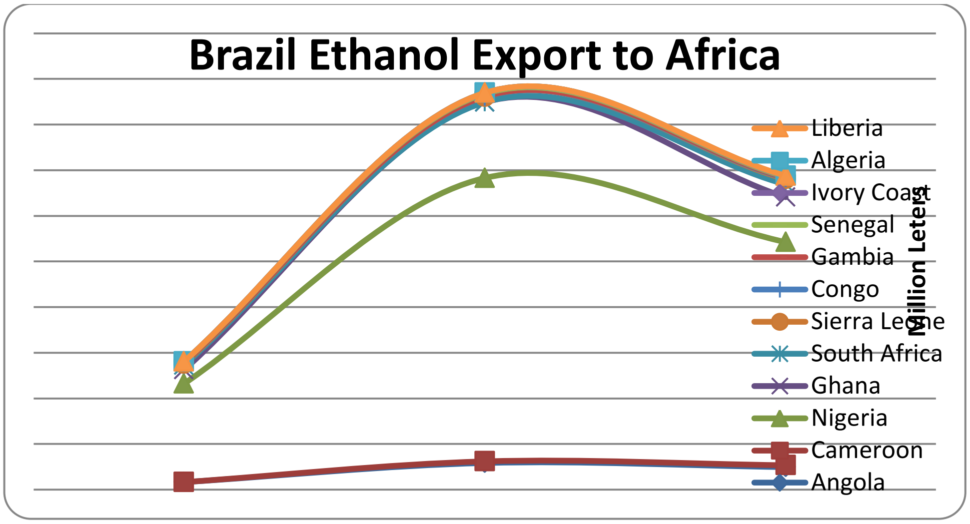
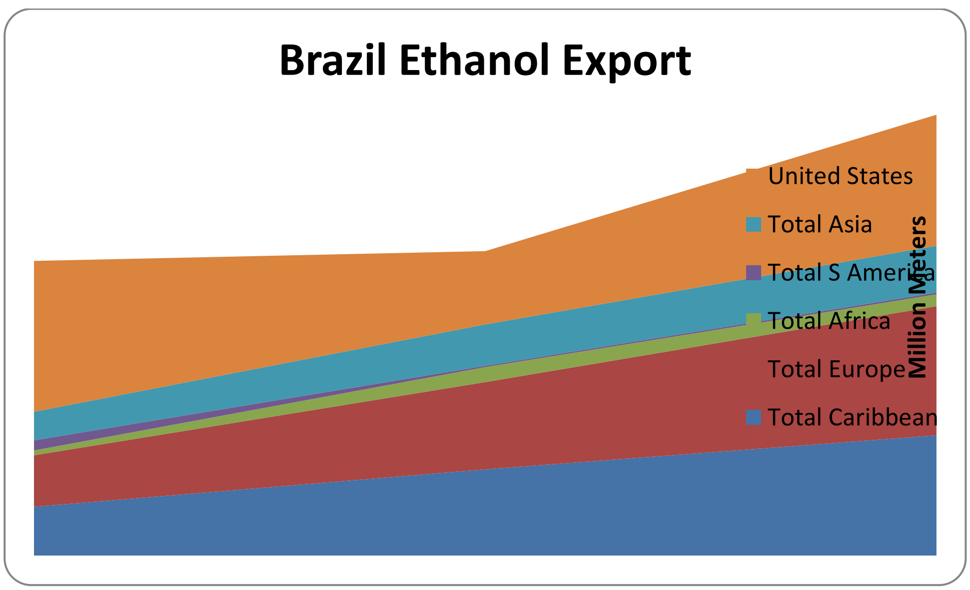
The graph above shows ethanol Brazil ethanol exports from 2006 to 2008 to Africa, and the abrupt growth of ethanol exports in 2009 were due to relative imbalances between consumption and domestic production in Africa.

[205] MAPA, 2008
[206] MAPA (2008)



The graph above shows ethanol exports from 2006 to 2008, indicating that the majority of world ethanol was imported by Europe from 2006 to 2008, next to America. In 2004-2005 Europe was the first region to import ethanol. The relatively small size of the African fuels market, even if there is significant energy potential, and the limited ethanol importation, especially in the southern regions, could be used to support social and economic development goals.



The Energy Research Company (EPE) has put in place a ten-year plan for the period of 2008-2017, anticipating that demand for ethanol fuel in the domestic market will rise from 20 billion litres in 2008 to 53 billion litres in 2017, at a growth rate of 165%. In 2007 alone, 1,995 billion litres were sold for use in bio-fuel vehicles, representing 89% of total sales of light vehicles. Estimates are that 75% of bio-fuel vehicles use ethanol, plus the 25% which added to gasoline. The forecast for 2017 is that 80% of the national fleet will be supplied by ethanol.[207]

In terms of international demand, the expansion of Brazilian exports has been leveraged by external events, such as U.S. and European law which broadened the goals of their use of biofuels. In 2007 Brazil exported 3 million litres of ethanol. Only the European Union has set a target of 5% renewable transportation fuel by 2015 and 10% by 2020. In this scenario, the expectation is that Brazil will increase their amount of exports from 3 billion litres in 2007 to 8 billion litres in 2017, eying Japan as one of the most promising markets.[208]

2.4 United States of America

Beginning in 1978 the government offered ethanol subsidies at between 40-60 cents per gallon, and currently the federal subsidy is 51 cents per gallon, and this subsidy is independent of changes in world oil or corn prices. The governmental gold rush for oil production began as a government subsidy when crude oil price was less than $30 per barrel. At such a low price, a government subsidy was necessary to make ethanol profitable, however as crude oil prices rise; ethanol production becomes highly profitable incurring major investments.[209] Congress bolstered this growth by offering tax benefits to producers and blenders.

Current Production and Use

Faced with plummeting gasoline prices and rocketing grain prices, the ethanol industry managed to generate enormous growth from 2007-2008. Production increased from 6.5 billion gallons in 2007 to 9.2 billion gallons in 2008. Twenty-one new plants were built, and in 2007 6.8 billion of those gallons were blended with gasoline.[210] Along with increased domestic ethanol production, the U.S. continued to import ethanol from Brazil, receiving 740 million gallons in 2008.

In the U.S. currently most gasoline/alcohol blends are capped at 10% ethanol inclusion (E10), since any higher rates void most vehicle warranties. Since the percentage of ethanol blended with gasoline will not increase, the market will eventually reach a “blending wall”. Using contemporary prices the market is not expected to exceed 14 billion gallons. An estimated 142 billion gallons of gasoline is consumed in the U.S. per year, and it is unlikely that 10% ethanol blend is included in every gallon, so this number is probably closer to 12.5 billion gallons.[2] Yet alcohol production is on course to continue, even to increase by 2011, and the transport fuel market will not be able to consume the ethanol output. This blending ceiling may even be reached earlier, as gasoline consumption decreases, which is the current American trend. Without a market for surplus ethanol, industry sources predict slowdown in existing plans, plant closures, decrease in capital investment in the renewable energy sector, and widespread job loss.

Plans and Prospects

Due to the additional steps in biochemical conversion, the U.S. has not yet commercially produced cellulosic ethanol. In the last few years however, intensive research and government incentives have advanced the agenda for the development of cellulosic ethanol plants. At the start of 2008, the Department of Energy pledged $114 million to support the creation of cellulosic bio-refineries at a small-scale. One of the goals is to test new and various feed-stocks to create a multiplicity of biofuel

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[207] EPE is a government business located in the Ministry of Mines and Energy – www.epe.gov.br.

[208] “Ethanol – fuel of the future” by Marcelo Junqueira.
[209] BioEnergy Perdue Extension http://www.agmrc.org/media/cms/ID339_C5A91733338CF.pdf
[210] F.O. Lichs, March 2009

and bio-products.[211] Furthermore the Department of Energy chose six projects to fund over four years, with the aim of demonstrating that bio-refineries can operate profitably and with greater net energy yields once the construction cost is paid, and this the model can be replicated. Cellulosic ethanol is enticingly desirable to U.S. production since the final fuel product contains a net energy yield which is close to CO_2 neutral.

[211] U.S. Department of Energy. *Alternative Fuels and Advanced Vehicles Data Center*. http://www.afdc.energy.gov /afdc/ethanol/production_cellulosic.html, February, 2009

Annex 6

Buying from Abroad – The Effect of Remittances on Consumer Purchases

The size of the remittance flow to Madagascar is not completely known, as it is believed that remittances flow through informal as well as formal channels may add up to 50% percent of the recorded flows (World Bank, 2006). This is true for Sub Sahara Africa as well. Since 2000, remittances to Sub Sahara Africa have increased on average by 15% in annual terms. Although some part of the growth may be attributable to better reporting by recipient countries, it appears that over the last decade remittances have outpaced private capital flows and official development assistance to many countries (World Bank, 2006, Global Economic Prospects: Economic Implications of Remittances and Migration, Washington: World Bank).

Remittances are private intra-family and intra-community income transfers that directly address the single most relevant challenge for Sub Sahara Africa—poverty. The long-term development potential of such transfers is determined by the use of the portion of remittances left over after basic consumption needs are met (Gupta et al, 2007).

Remittances are thus part of a private welfare system that transfers purchasing power from relatively richer to relatively poorer members of a family or community. These transfers reduce poverty, smooth consumption, affect labor supply, provide working capital, and have multiplier effects through increased household spending. Anecdotal evidence suggests that most often women head the recipient households (Gupta et al, 2007).

Remittances seem to be used to finance basic consumption and investment in human capital, such as education, health, and better nutrition.

Remittances that flow to the lower wealth quintiles may be used for the purchase of goods and services supplied by the local economy, giving these remittances an increased multiplier effect in the economy. Remittances that flow to families in the upper quintiles may be used to finance conspicuous consumption, such as a larger home, modern appliances or an automobile.

For some countries, remittances may also serve as an important source of foreign exchange.

Since remittances are private transfers dispersed over a large number of households, many of them poorer households, it has been argued that their impact on domestic demand differs from that of donor-funded social and infrastructure projects, foreign aid and other transfers of wealth through development programmes for quality of life improvements (World Bank, 2006). Remittances may be a far more effective way to stimulate demand and increase buying power.

On average 20% of Sub Sahara Africa's tertiary-educated population older than 15 works in OECD countries. This is much higher than for other regions of the world. Less than 10% of South Asia's tertiary-educated population is found in OECD countries. For some African countries, such as Angola, Guinea-Bissau, and Mozambique, expatriation rates are in excess of 50 percent of the educated population (Gupta et al, 2007).

Remittances may be propelling poorer families into the formal financial sector and into banking. But in additions to banking, another interesting phenomenon is taking place around the cell phone.

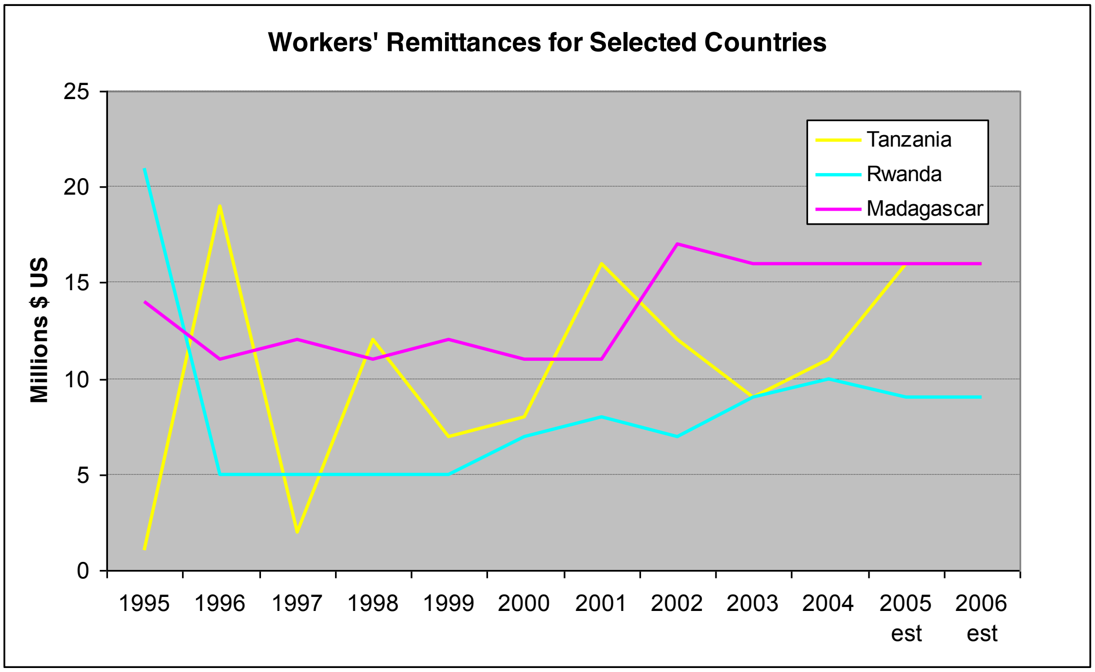
Recent strides in cell phone encryption technology have facilitated fast, low-cost money transfers between OECD countries and recipient countries, allowing customers to avoid the higher fees of banks and the longer waiting periods associated with money transfers and banks (Jordan, 2006). Access to this form of money transfer is likely to stimulate the receipting of funds to families in Africa.

With the help of remittance income, a modern stove may become an item that can be prioritized for purchase by a poorer family, or it may be an item of 'conspicuous consumption' for a more financially secure family. For a poorer family, it becomes an investment in human capital, a health-giving and quality of life purchase that improves the environment in the home, gives more time to the women in the home for tasks other than cooking and fuel management, and it might also become a money saving strategy if the running cost of the modern stove is less than that of the traditional stove or stoves in the household.

In household surveys in Ethiopia, women commented on the smell that kerosene stoves and wood smoke gave to their and their children's clothes when they went out of the house (Gaia reports). This provides an example of how a family might decide to prioritize a stove purchase. In order not to send their child to school smelling of wood smoke, a mother might decide to purchase an improved stove, such as an ethanol stove, to eliminate the odor from the house. While institutional actors might be focused on what are deemed more important issues, such as family health and environment, a family's actual motivation for buying a stove might be more personal and held privately. The personal nature of remittances—a son working abroad providing funds to his mother for the raising of his siblings—may lend support to the idea that remittance income could play a significant role in buying decisions relating to the household, and to the investment in 'human capital' in the family.

(Jordan, Mary, 2006, 'New Conductors Speed Global Flows of Money,' Washington Post, Oct 3, 2006.)

(Sanjeev Gupta, Catherine Pattillo, and Smita Wagh, Impact of Remittances on Poverty and Financial Development in Sub-Saharan Africa, IMF Working Paper WP/07/38, February 2007.)



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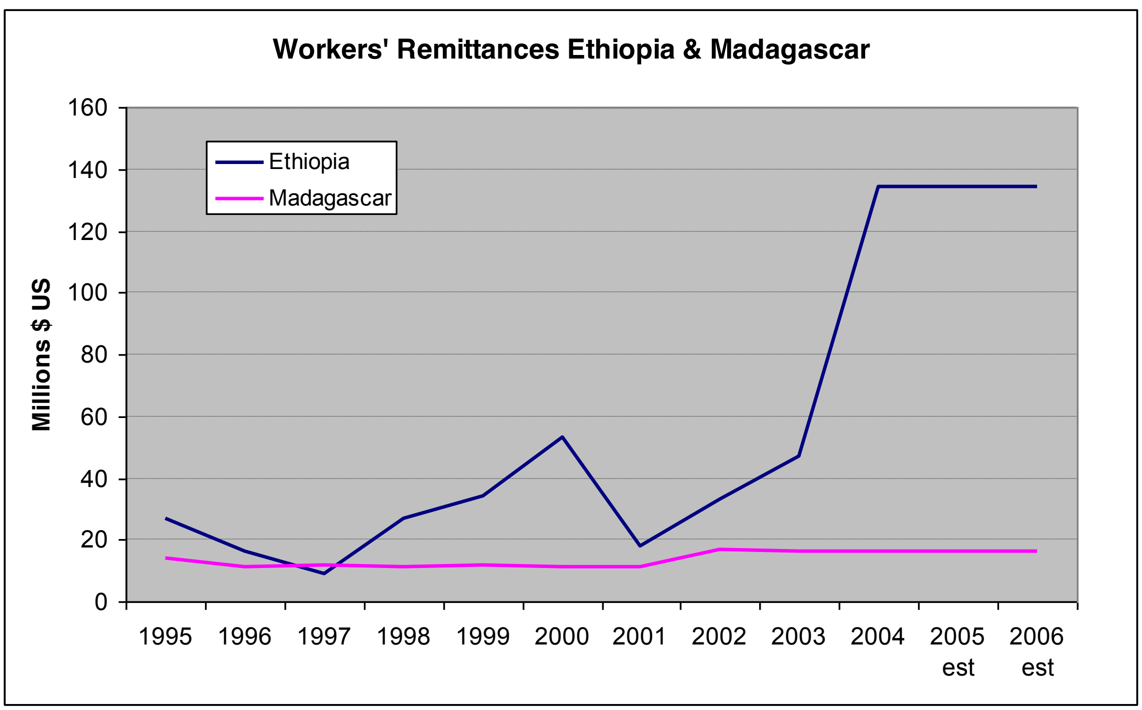

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212 Source: World Bank, 2006

Annex 7

Mobile phones as an example for the uptake of improved stoves

Mobile telephony in Madagascar has experienced rapid development in the last decade. Promotion of cell phones has been spurred by competition: Trade agreements between the French company Orange (owned by France Telecom), Zain of Kuwait European and Telma. The penetration rate increased from 2.7% in 2005 to 11.4% in 2007 and is estimated at 24.67% in 2008. (African Economic Outlook, at: http://www.africaneconomicoutlook.org). After a growth rate of 2.66% during the first decade of introduction, the growth rate of the cell phone in Madagascar has ballooned to almost 23% over the last five years.

Cell phone handsets are imported, mainly from China, and networks are built by foreign companies which rely in part on the Malagasy work force. Affordable product prices have helped to stimulate rapid growth. At the end of 2008, a mobile phone with SIM-card could be purchased for as low as MGA 13,000 ($7.88).

A recent survey of cell phone prices in Antananarivo shows that the price of a mobile phone varies upward from $12 for a basic phone to $500 for a 'smart' phone (Tiana Razafindrakoto, 1-8-10). The cost of a simcard is $1 to $2.

Airtime, however, is more expensive. The cost of a call on any of the three available networks is 3 to 10 MGA per second. Twenty minutes of airtime use daily would cost from $2 to $6. Mobile phone cards are purchased in amounts from 1,000 MGA to 50,000 MGA ($25.64) (Tiana Razafindrakoto).

The question arises: How are mobile phones like ethanol stoves? One might evaluate the question of whether the mobile phone can serve as an example for the ethanol stove in African markets in this way.

Matrix -- How Does the Ethanol Stove Resemble the Mobile Phone?

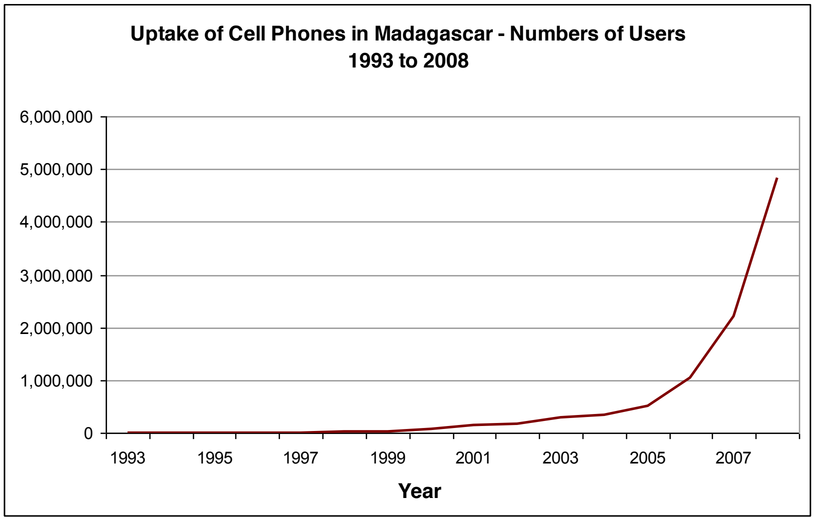
Comparator: Like or Different?	Mobile Phone	Ethanol Stove
Utility (how necessary?)	High	High
Close Competitors	Formerly yes, now no	Yes, but all with challenges
Capital Cost	Once thought too high, now considered affordable	Presumably similar to mobile phone
Operating Cost	High	Lower, possibly significantly lower than other stoves
Demand	High	High for a good stove
Impact, Benefits	High	High
Amenities, Appeal	High (modern, fashionable)	High (modern, status item)

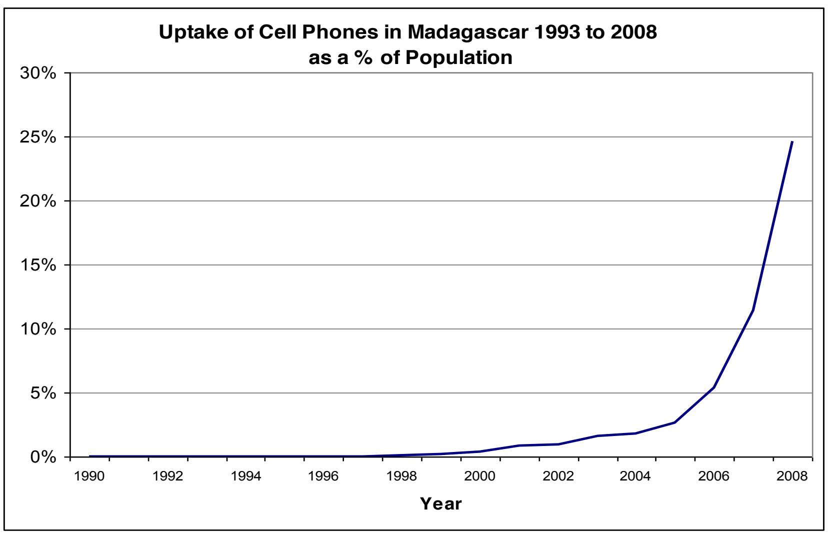
[213] Source: World Bank, 2006

The matrix shows a critical advantage for the ethanol stove. If ethanol fuel is priced competitively with other fuels, the ethanol stove could compete economically with its rival stoves, once the ethanol stove was in use, even though it was more expensive to purchase.

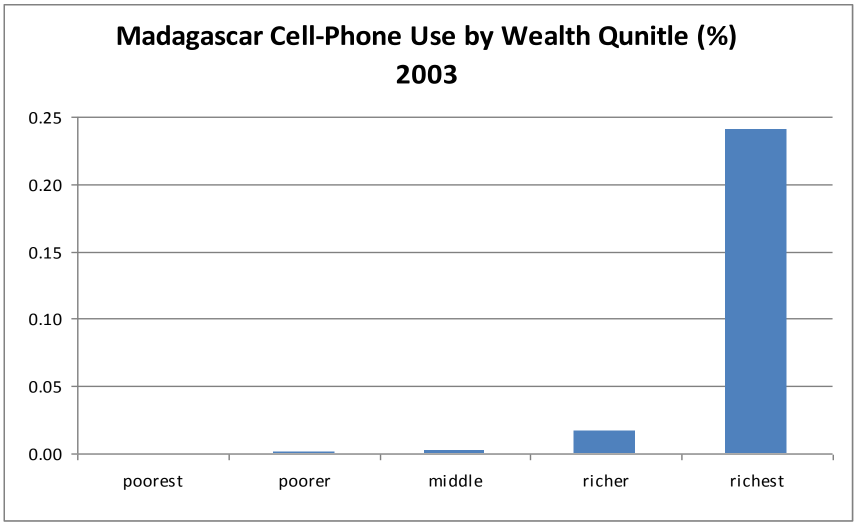
Madagascar Cell Phone Absorption as % of population			
Year	Value (Million)	Total Population (Million)	% Population with Cell Phone Account
1993	0.00	13.53	0.00%
1994	0.00	13.95	0.00%
1995	0.00	14.39	0.01%
1996	0.00	14.83	0.02%
1997	0.00	15.28	0.03%
1998	0.01	15.73	0.08%
1999	0.04	16.19	0.22%
2000	0.06	16.66	0.38%
2001	0.15	17.13	0.86%
2002	0.16	17.61	0.93%
2003	0.28	18.11	1.57%
2004	0.33	18.6	1.80%
2005	0.51	19.11	2.67%
2006	1.05	19.3	5.42%
2007	2.22	19.4	11.43%
2008	4.84	19.6	24.67%
2009		20.7	

UN Data; Source for Cell Phone Data for 2008: World Fact Book

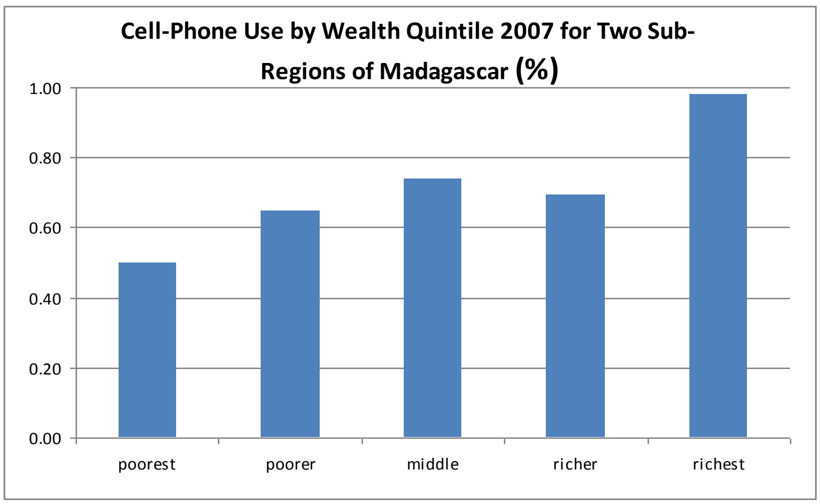




UN Data 2008, World Fact Book (both Figures)



(Source: Demographic and Health Survey, Madagascar 2003)



(Source: Socio-Economic Survey, Madagascar 2007)

Background to the African Caribbean and Pacific (ACP) and EU Agreement

In a move to reduce the reliance on international aid to African countries, the European Union (EU) set up measures to facilitate trade between Europe and Africa. Although the EU has provided trade preferences to the former colonies of the African, Caribbean and Pacific (ACP) regions since 1975 under successive Lomé conventions, these preferences have been of limited value.[214] This is not surprising as trade preferences in general have not provided significant benefits to developing countries[215], especially Africa.[216] An Agreement, known as the Cotonou Agreement, was signed on

[214] Langhammer, 1992
[215] Ozden and Reinhardt, 2003
[216] Brenton and Ikezuki, 2007

the 23rd June 2000, was set to last for 20 years, from 2000 to 2020, and was initiated in April 2003. The first revision took place in June 2005, with the revisions being put into effect on July 1, 2008. The Cotonou Agreement is founded on 3 basic pillars of development cooperation, economic and trade cooperation, and a political dimension.

The Objectives of the Cotonou Agreement

The partnership is centred on the objective of reducing and eventually eradicating poverty consistent with the objectives of sustainable development and the gradual integration of the ACP countries into the world economy (Cotonou Agreement Article 1).[217] Revisions of the agreement take place usually every 5 years, and the next revision is set to take place in 2010. The first revision in 2005 focused on the following aspects and amendments:

- **Political Dimension:** strengthening the political dimension by placing greater emphasis on effective dialogue and results (Art. 8, 9, 96, 97, Annex VII); inclusion of a provision on the International Criminal Court, of a reference to cooperation in countering proliferation of weapons of mass destruction, of a clause which confirms partners' international cooperation in the fight against terrorism, and of provision relating to the prevention of mercenary activities.
- **Development Strategies:** amendments relating to sectoral strategies; a reference to the promotion of the fight against poverty-related diseases and protection of sexual and reproductive health and rights of women; insertion of provisions to facilitate non-state actor access to indicative programme resources; facilitation of cooperation between ACP States and other developing countries (regional cooperation); promotion of traditional knowledge as part of sectoral economic development; strengthening of existing provisions on island ACP States.218
- **Investment:** a more flexible and more effective implementation of the investment facility,219 which is managed by the European Investment Bank.
- **Implementation and Management Procedures:** the first revision provided, among others, greater flexibility in the allocation of resources; possibility to use resources for policies to promote peace and to manage and settle conflicts, including post-conflict support; and reformulation of the responsibilities of managing and executing agents.220

In accordance with Article 95 of the Cotonou Agreement, the main reasons for the second revision are:

- Preserving the relevance and the outstanding character of the Partnership between ACP and EU countries
- Adapting the Agreement to recent major changes in international and ACP-EC relations
- Further development of several themes that are essential for both parties:
    - political dimension: institutional issues and sector specific policy issues
    - economic cooperation: regional integration and trade
    - development finance cooperation: including humanitarian and emergency assistance and development advances in aid programming and management

[217] http://ec.europa.eu/development/geographical/cotonouintro_en.cfm
[218] http://ec.europa.eu/development/policies/9interventionareas_en.cfm
[219] http://www.eib.org/projects/events/launch-of-the-eibs-investment-facility-according-to-the-cotonou-agreement.htm?lang=-en
[220] http://ec.europa.eu/development/geographical/cotonouintro_en.cfm

Currently, there are 79 countries in the ACP, 78 of which signed the Cotonou Agreement (the exception being Cuba).

New Trade Deals

Currently, Africa is split into different economic regions namely Southern African Development Community (SADC), Common Market for Eastern and Southern Africa (COMESA), Monetary and Economic Community of Central Africa (CEMAC), and the Economic Community of West African States (ECOWAS). However, these regional blocs are not necessarily representative of the Economic Partnership Agreement (EPA) negotiating groups.

At the same time, some members of COMESA are not a part of the EPA negotiations, namely, Egypt and Libya. Egypt already has an association agreement with the EU – under the Euro-Med agreements between the EU and other countries around the Mediterranean Sea – under which a free trade area is to be gradually formed between Egypt and the EU. The other North Africa countries also have association agreements with the EU.

In Central Africa, CEMAC rather than Economic Community of Central African States (ECCAS) is the negotiating group, and the Banjul Summit designated ECCAS as the regional economic community for Central Africa. In this regard, there could be merit in considering much closer unity between CEMAC and ECCAS in the context of regional integration in Africa and the EPAs. The CEMAC group is entering a free trade area with Sao Tome and Principe in order to include this country in the CEMAC negotiating group.

In West Africa, Union Economique et Monétaire Ouest-Africaine (UEMOA) and ECOWAS (ECOWAS being the regional economic community that the Banjul Summit designated for West Africa) have formed the ECOWAS EPA group. The ECOWAS secretariat/commission services the EPA negotiations but UEMOA also participates. The ECOWAS regional economic community has agreed to work towards adopting the UEMOA common external tariff, so that the two communities can negotiate the EPA from a common stand point on customs duties. There is merit also for ECOWAS and UEMOA to consider their much closer unity.

Parts of the current Cotonou agreement already expired at the end of 2007, and since 2002, the EU and ACP member countries have been negotiating new trade agreements to replace the Cotonou framework. These EPA agreements consist of regional trade deals with the EU, however progress on achieving these regional trade blocks has been really slow as there are many regional disagreements which have prevented a united front. For example, part of the Southern African Development Community (SADC) member states broke away from the regional bloc to form their own individual 'interim EPAs' with the EU, and other SADC countries left to join other regional blocs that are bargaining separately with the EU, and several of the remaining countries are refusing to sign the agreements. Criticism of these 'interim' EPAs has come in many different forms, the main being that they have broken any efforts to promote regional integration and have in fact encouraged division among the different regional blocs. The only region that has signed as a bloc is the East African region.

Different agreements between the EU and ACP countries have existed since 1975. ACP countries received preferential treatment in terms of trade with the EU and in the form of technical assistance. However, in 1995, global trade rules were revised at the World Trade Organization (WTO) and this resulted in many of the EU-ACP agreements falling out of compliance with the WTO standards. The

EU-ACP agreement was to be revised by December 2007, and resulted in the formation of the EPAs. Given the above change in legislation, and the fact that the some African countries refused to sign the EPAs, it has become difficult for countries to set up common tariffs and trade policies. Another existing challenge is the fact some of the ACP member nations include the Least Developed Countries (LDCs) which have been given separate duty-free access to European markets. These countries, as well as their more developed counter-parts were receiving equal preferential trade terms under the Cotonou Agreement, but this inequality was corrected at the end of 2007 and now solely LDCs receive this preferential treatment.

By the end of 2007, only 18 African countries had signed the EPAs (8 of which are LDCs), with many refusing to sign due to the controversy that surrounded the partnership agreements. Generally LDCs were not in a hurry to sign the EPAs as they were still receiving preferential treatment under the Cotonou agreement. The EPAs have caused a deep divide among member nations, a good example being the SADC bloc. From the 14 member SADC body, two left to initiate talks with other blocs (Tanzania and the Democratic Republic of Congo); Swaziland, Mozambique, Botswana and Lesotho signed the interim EPAs; Angola, Namibia and South Africa refused to sign stating that the demands of the agreements were not in line with their future goals for economic development. Some of the clauses that caused South Africa to refuse to sign the agreement include the fact that South Africa would be required to 'liberalize' services such as banking to European competition.[221] In addition, South Africa would be required to extend any trade benefits they offer to any other countries that post-sign the EPA agreement.

What do the EPAs mean for Developing Countries?

Analysis suggests that ACP countries should not be excessively concerned about the impact of EPAs. Even assuming immediate complete elimination of all tariffs on agriculture imports from the EU, and excluding up to 20% of imports as sensitive products, over half of ACP countries are likely to experience welfare gains. However, although most LDCs gain (10 out of 13), most non-LDCs (about 60%) lose.[222]

In conclusion, current progress on EPAs is slow as there are many stumbling blocks to the agreements, some of which have been detailed above. It appears that the impact of these agreements on African countries is minimal, and it is yet to be seen what progress will be made given the regional differences amongst African countries on which stance to take.

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[221] http://www.un.org/ecosocdev/geninfo/afrec//newrels/new-trade-pact-08.html
[222] http://driver-support.eu/economics/credit/research/papers/CP0709.pdf

Annex 8

Absorption Models

1 Millennium Gel Fuel December 2003 Absorption Model for Ethiopia

In 2003 a study was published on the potential for gelfuel stoves in Ethiopia (Tilimo & Kassa). It was written when kerosene fuel pricing was the low-cost fuel in Addis Ababa, cheaper than purchased fuelwood and charcoal. At that time, kerosene cost 2 ETB per litre ($0.23 US).

Today, in an almost entirely deregulated market, kerosene retails for 9.8 ETB or 0.78 US per litre. Kerosene is now more expensive than fuelwood and charcoal, even though these fuels have also increased substantially in price. Kerosene still receives some favourable treatment by the Ethiopian Government as it is not taxed prior to market (both gasoline and diesel are taxed); therefore, it is slightly cheaper than those fuels.

The 2003 Gelfuel study was also completed before the CleanCook stove using liquid ethanol was introduced to Addis Ababa but just after an unfortunate K-50 experiment conducted by the Finchaa Sugar Factory [1]. For a period of time, until the CleanCook stove established its record of safety, this gave liquid ethanol fuel use a bad name. The assumptions for gelfuel absorption into the Addis Ababa market were that 50 percent of urban households who currently purchase firewood would substitute this with gelfuel, for non-injera cooking, and similarly, about 50 percent of all the income groups who are using charcoal and from 75 of low-income to 10 percent of high-income households who were currently using LPG, would substitute it with gelfuel (Table xx).

Assumptions for Estimates of Market potential for Millennium Gelfuel

Percent of Urban Households substituting:	Income Group			
	Low	Lower Middle	Upper Middle	High
Firewood with Gelfuel	50	50	50	50
Charcoal with Gelfuel	50	50	50	50
LPG with Gelfuel	75	50	25	10

2 Millennium Gel Fuel Absorption Model for Madagascar - January 2004

This study, entitled ‘Etude de Faisabilité Economique et Financière du Gel Fuel Millenium - Énergie Domestique de Substitution,’ was published in January 2004 by the firm Ingénieurs de technologies industrielles, and further edited by Cabinet MAZOTO.

The identification of the demand is based on statistical information selected from the Enquêtes Prioritaires sur les Ménages (EPM de 2001) namely:

Target demand

- population of Madagascar: 15,600,000
- distribution of population in Table (XXX)

	White Collar	Employee and labourer	Manual Labour	Independent Operator	Family Help	Total
URBAN						
Distribution	9.50 %	32.11 %	8.41 %	31.87 %	18.10 %	100 %
Number of Households	50,542	170,850	44,761	169,573	96,296	**532,022**
RURAL						
Distribution	1.60 %	7.00 %	3.10 %	42.20 %	46.10 %	100 %
Number of Households	26,956	117,932	52,227	710,959	776,664	**1,684,738**

Market
In urban areas, it was assumed that households that cooked with the gas, electricity, and kerosene (exclusively with one or with several of these energy sources) would not change their habits even if they had purchasing power. Households using charcoal and / or firewood might convert to new sources of energy, whether gelfuel or other improved energy sources if prices were affordable and strategies were undertaken by the project sponsors.

In rural areas the situation was rather more complex because:

(i) the reliance on charcoal is marginal compared to firewood

(ii) and firewood is not the subject of a purchase but is collected and therefore has a zero market value.

It is therefore necessary to repeat the calculations of energy use on the basis solely of the urban demand.

Market Share of Gelfuel

The report dealt with potential market for gelfuel. Knowledge of the eventual market for gelfuel could be determined because the consumer did not know the fuel or fuel. The need for a lot of promotion before the launch of this product was highlighted. The market share of gelfuel was evaluated as follows in urban areas:

T_{TEP} = T x 50% = 210,017 TEP or 395,512 tonnes of gelfuel

T=Total urban energy use of firewood and charcoal but not LPG, kerosene and electricity

TEP = Tonnes of Petroleum Equivalent

Under these conditions the gel fuel prices could drop below 2,500 Fmg / litre (US$0.45), using the assumptions that had been made. The authors of the Madagascar Gelfuel Study considered urban cooking as the target for displacement with gelfuel, and considered that kerosene, LPG and electric stoves would not be displaced, but possibly that 50% of charcoal and wood stoves would be displaced, especially if the price of gelfuel were to drop below $0.45 per litre, which they assumed it could with the reworking of the Sirama Sugar factories and the economies of scale created by an urban gelfuel market.

3 Private Sector CleanCook Stove Market Study January 2007 for Ethiopia

Mekonnen Kassa of Partners Consultancy and Information Services prepared a UNDP-funded market study and business plan for Makobu Enterprises PLC of Addis Ababa in January of 2007. It assumed that the only limit to the absorption of stoves in the market was the supply of ethanol that was being produced in Ethiopia which would be sold to the stove fuel market. The absorption rate was set as follows:

Total ethanol available for stoves was shown as follows:

Potential ethanol production and demand, 2007-2012 ('000 litres)

Total Ethanol Demand Other ('000)	7,000	14,307	19,113	28,095	29,973	31,424
Ethanol Available for Cooking	1,000	5,938	38,992	76,525	99,133	97,425
Market potential (Households)	2,083	12,371	81,234	159,428	206,527	202,970
Households in Addis Ababa	564,921	593,167	622,825	653,967	686,665	720,998
Market potential in Addis Ababa (%)	0.4%	2.1%	13.0%	24.4%	30.1%	28.2%

This resulted in stove sales that began with an initial 2,000 stoves (one of the starting assumptions), and culminated with the sale of 25,000 stoves in Year 6 of commercialization for an amassed sales of 77,000 stoves by the end of Year 6. This represented 38% of middle income households, which represented 28.2% of total city households.

Clean Cook Stove Sales

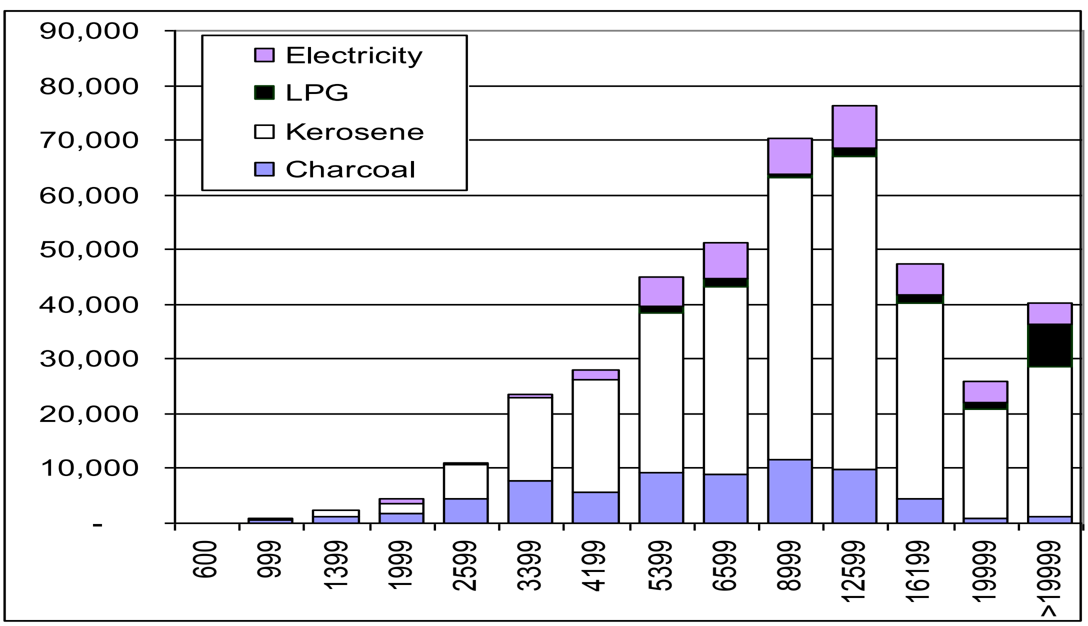
	2006/7	**2007/8**	**2008/9**	**2009/10**	**2010/11**	**2011/12**
Market potential (number of households)	2,083	12,371	81,234	159,428	176,785	176,785
Potential market	2,083	10,287	68,863	78,194	17,357	-
Assumed market penetration	2,000	5,000	10,000	15,000	20,000	25,000
1 Burner	2,000	5,000	9,000	13,500	18,000	22,500

2 Burner	-	-	1,000	1,500	2,000	2,500
Cumulative # Stove sales	2,000	7,000	17,000	32,000	52,000	77,000
1 Burner	2,000	7,000	16,000	29,500	47,500	70,000
2 Burner	-	-	1,000	2,500	4,500	7,000

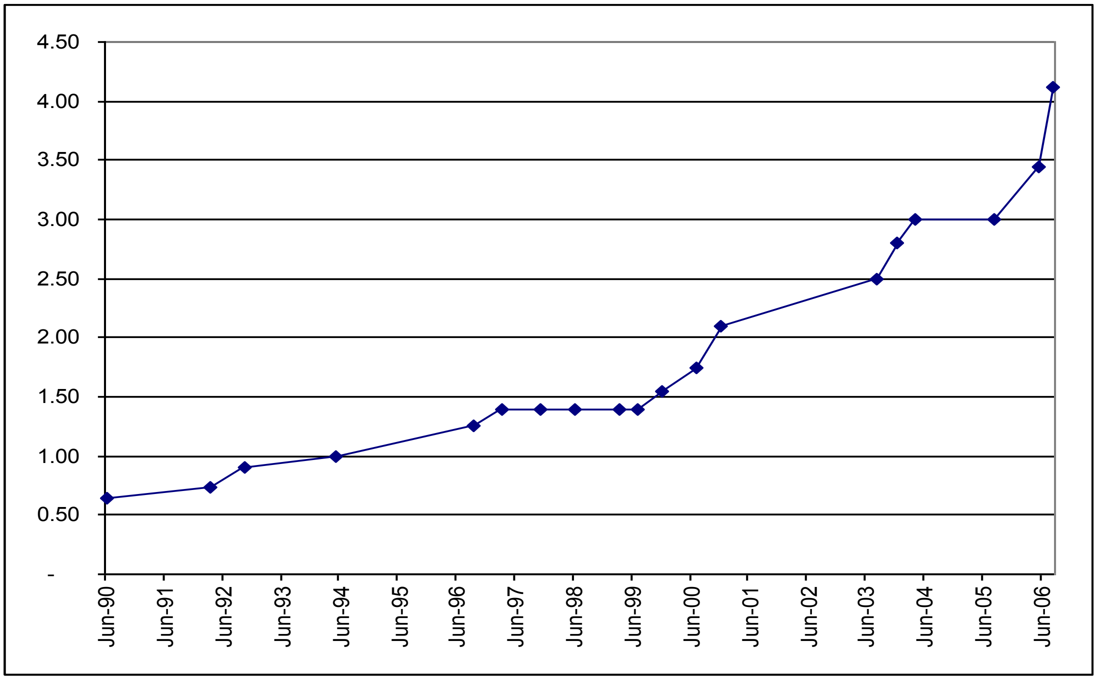
The market potential was identified as middle income households in Addis Ababa and the primary stove to be displaced was the kerosene stove. Despite the relatively low price of kerosene, it was believed that ethanol could compete with this price and further have the advantage of being a more desirable stove. Kerosene use in Addis Ababa as of 2006 was shown as being quite predominant even as the price of kerosene was escalating steadily.

It should be noted that this plan has not yet been implemented. As of this writing the private sector business is still awaiting an assured supply of ethanol from the government of Ethiopia. Approximately 5.5 million litres of ethanol were produced in Ethiopia in 2009 and all of it was devoted to an experimental gasoline fuel blending program. It is hoped that ethanol will be available for the stove fuel market in 2010 when a second state-owned distillery comes on line, increasing nominal capacity from 8 million litres per year to approximately 20 million litres per year, with additional increases coming in the following years.

Distribution of urban households by fuel for cooking, Ethiopia – 1996



Trends in Kerosene Prices in Addis Ababa, ETB/Litre



Tables and Figures are from Kassa, M., Business Plan for Ethanol Cooking Fuel and Dometic CleanCook Stove Market Development in Addis Ababa, Ethiopia[1]

PRACTICAL ACTION Consulting

Annex 9

Usability Questionnaire

Ethanol as a Household Fuel in Madagascar - individual

Usability study – Part 1 – start of study.

Sheet 1: BACKGROUND QUESTIONS – to be asked at start only (BQ)			
BQ_1	Study household ID number (eg USER_07)	USER _	
BQ_2	Group	GROUP _	
BQ_3	Name of Interviewer		
BQ_4	Date of interview (DD/MMM/YYYY)	__ __/__ __ __ /__ __ __ __	
BQ_5	Does respondent do most of the cooking?	1 = Yes 2 = No	

EMPLOYMENT (EM)			
1	Farms his/her own land	6	Craftsperson
2	Day labourer	7	Runs the household / Cares for family
3	Government employee	8	Other type of job
4	Employee in a business	9	Unemployed or retired
5	Has own business	10	Not married / separated/divorced

EM_1	What is your husband's main occupation / job? *Use list above*	First	
EM_2	What is your main occupation or job? *Use list above*	First	

POSSESSIONS & INCOME (IN)				
IN_1	Do you own/have any of the following?	Motor-bike	1 = Yes 2= No	
IN_2		Refrigerator	1 = Yes 2= No	
IN_3		Electricity connection	1 = Yes 2= No	
IN_4		Radio	1 = Yes 2= No	
IN_5		TV	1 = Yes 2= No	
IN_6		Bicycle	1 = Yes 2= No	
IN_7		Car/truck	1 = Yes 2= No	
IN_8		Cellphone	1 = Yes 2= No	
IN_9	Would you mind us asking a question about your family's weekly income		1 = Yes (*go to ST_1)* 2 = No	

IN_10	About how much money do you have available for household purchases each week? (AR)	

CURRENT STOVE USE (ST)

	1	Traditional (3-stone) fire	**2**	Improved biomass stove
	3	Traditional metal charcoal stove	**4**	Improved charcoal stove with ceramic liner

ST_1	What is your main cooking stove?		
ST_2	How many pots can be used on this stove at any one time?		
ST_3	About how much do you spend per week on cooking fuel?		(Ar)
ST_4	How many people do you usually cook for in the household – including yourself each day?	Children less than 15 years	
ST_5		Male adults 15 years and over	
ST_6		Female adults 15 years and over	

Ethanol as a Household Fuel in Madagascar - individual

Usability study– Part 2 – after each stove trial .

Part 2: **OPINION OF NEW STOVE & FUEL – to be asked after each stove is tried out (BQ contd)**						
BQ_6	Study household ID number (eg USER_07)	USER _				
BQ_7	Group	GROUP _				
BQ_8	Name of Interviewer					
BQ_9	Date of interview (DD/MMM/YYYY)	__ __/__ __ __ __/__ __ __ __				
BQ_10	**Type of stove used *(Interviewer please check)***					
For these questions, put a circle round the ***number*** attached to the response						
TEST STOVE QUESTIONS (TS)						
TS_1	How easy is it to cook on the stove?	Very easy	Easy	OK	A bit difficult	Very difficult
		1	2	3	4	5
TS_2	After training, how confident were you in using the stove?	Very confident	Confident	OK	A bit worried	Very worried
		1	2	3	4	5
TS_3	How much of the cooking did you do on this stove?	All	Most cooking	About half the cooking	A few cooking	No cooking at all
		1	2	3	4	5
TS_4	Did you use other stove / stoves as well?	Not at all	Occasionally	About half the cooking	Most cooking	All cooking
		1	2	3	4	5
TS_5	How did this stove compare to your usual cooking?	Much better	A bit better	About the same	A bit worse	Much worse
		1	2	3	4	5
TS_6	If you could afford it, would you buy this stove?	Definitely	Probably	Maybe	Probably not	Definitely not
		1	2	3	4	5
TS_7	About how much do you think this stove would cost to buy? (Ar)					
TS_8	Would you consider using credit to buy the stove, if available?	Definitely	Probably	Maybe	Probably not	Definitely not
		1	2	3	4	5

TS_9	Is the stove the right size for cooking meals?	Definitely big enough	Nearly big enough	OK	Too small	Much too small
10	How long did it take to prepare food compared to usual?	I saved at least 30 minutes	I saved between 10 and 30 minutes	About the same	It took between 10 and 30 minutes more	It took at least 30 minutes more
		1	2	3	4	5
TS_11	Did you save any time in other ways compared to usual? (eg cleaning pots, gathering firewood)	Saved a lot of time	Saved a bit of time	About the same	Had a bit less time	Had much less time
		1	2	3	4	5
TS_12	Please say in what ways you saved time					
TS_13	Did you have any problems using the stove? – if so, please describe them					
TS_14	Did anything on the stove break? If so, please describe					
ETHANOL FUEL QUESTIONS (ET)						
ET_1	How easy is it to cook using ethanol fuel?	Very easy	Easy	OK	A bit difficult	Very difficult
		1	2	3	4	5
ET_2	After training, how confident were you in using the ethanol fuel?	Very confident	Confident	OK	A bit worried	Very worried
		1	2	3	4	5
ET_3	About how much fuel did you use in total (litres)					
ET_4	About how many meals did you cook in total? *(only meals where people sit down at the table)*					
ET_5	Did you have any problems using ethanol? – if so, please describe *(write 'no problems' if OK)*					
ET_6	If any fuel was wasted, how did this happen? *(write 'none wasted' if OK)*					

ET_7	If you could afford to use ethanol would you do so?	Definitely	Probably	Maybe	Probably not	Definitely not
		1	2	3	4	5
ET_8	About how much would you pay for ethanol per litre? - Ar					
ET_9	Did you feel the ethanol fuel was safe to use?	Very safe	Safe	OK	Not safe	Very unsafe
		1	2	3	4	5
SAFETY (SF)						
SF_1	Did you feel the stove and fuel was safe to use?	Very safe	Safe	OK	Not safe	Very unsafe
SF_2	Please say why you feel that the stove is safe / unsafe *(Interviewer: Ask the question in the way that reflects the answer to SF_1)*					
SF_3	Did you burn or scald yourself at all using the ethanol stove & fuel?	1= Yes 2 = No (go to SF_4)				
SF_3	If Yes, how many times did you burn yourself?	Number of times				
SF_4	Please describe what happened					
SF_5	Did any of your children (under-5) get burnt or scalded during the time you had this stove?	1= Yes 2 = No				
SF_6	Please describe what happened					

See next page for final visit: Thank participant for time and interest in this study

Last visit – if more than one visit is made

List the stoves in FW_1 and enter a tick for each one they select. If the woman chooses two or three stoves, put a tick in each box

		Stove name	**Stove name**	**Stove name** *(Use column if 3 tried)*
FW_1	Which stoves did you try?			
FW_2	Which did you like best?			
FW_3	Which did you like least?			
FW_4	Which was fastest?			
FW_5	Which was the slowest?			
FW_6	Which was cleanest?			
FW_7	Were any stoves smoky?			
FW_8	Which would you buy if you had enough money?			
FW_9	Are there any that you would not wish to use?			

Please rank these features in order of importance to you if you were to buy a stove

(Interviewer: Ask people what they think is most important – put a '1' beside it – then what is next most important – put a '2' beside it, then a '3' by the next one etc.

If you need to read the list several times, leave out the ones that have already been selected.

FW_10	Cost of stove	
FW_11	Cost of fuel	
FW_12	Stove appearance	
FW_13	Speed of cooking	
FW_14	Ease of cooking	
FW_15	Easy access to buy fuel	
FW_16	Stove Safety	

FW_17	Less smoke	

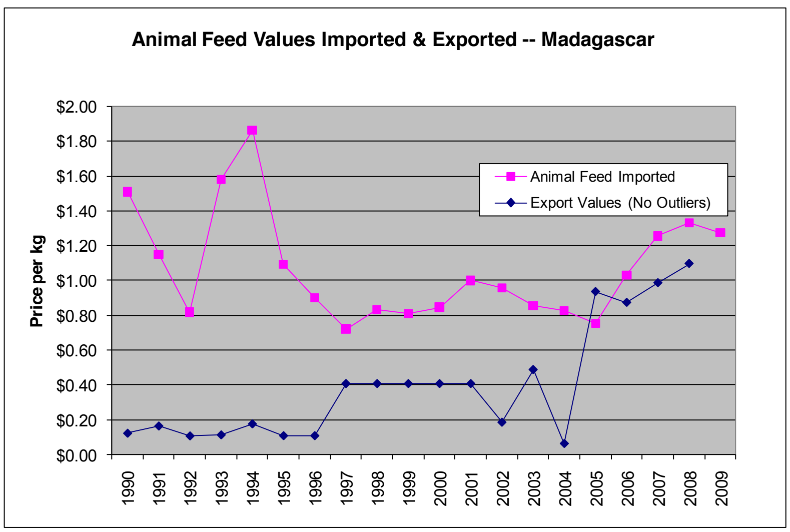
Annex 10

Annex 10.1 Importance of bi-products

Micro-distilleries do more than just produce fuel; they produce fuel and co-products, e.g. feeds and fertilizers. A new report by the FAO, 'Reducing poverty by growing fuel and food (February 2011) shows how integrated food and energy crops work for poor farmers. This report states that producing food and energy side-by-side may offer one of the best formulas for boosting countries' food and energy security while simultaneously reducing poverty[223].

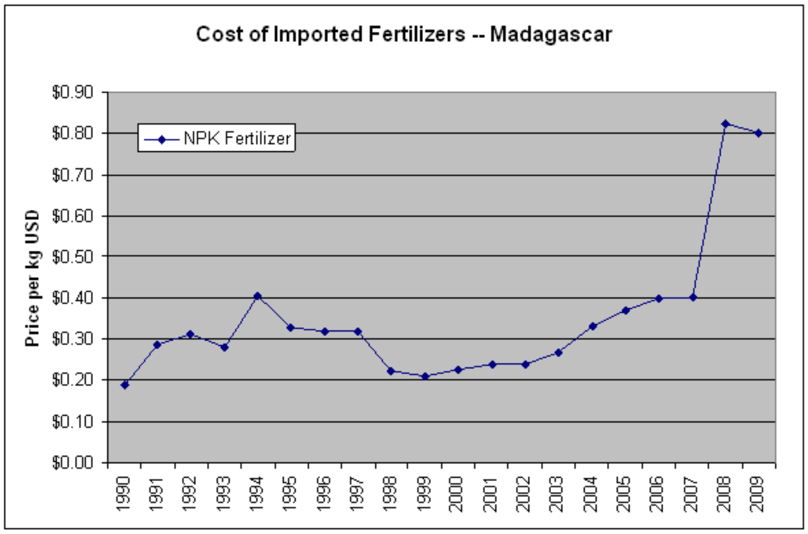
In the case of micro-distilleries in Madagascar, these are all value-added products that will sell for more than the original biomass cost to feed the plant. Yeasts and microbes break down the solids into ethanol and other products with value. For example, biomass that is not digestible to farm animals before distillation is converted into animal feed because the yeasts and microbes in the distillation process add protein and convert the solids into animal feed. Each litre of ethanol is associated with about five kilograms of solid fertilizer and five to ten litres of liquid fertilizer, depending on the type or raw feedstock, which can either be used on the farm, if the distillery is part of a farm complex, or sold. It will produce at least 5 kg of feed grade solids.

The graph below shows the prices of animal feed in Madagascar (Commodity Trade Statistical Database, FAO, Trade of goods, HS 1992, 23: Residues, wastes of food industry, animal fodder for Madagascar).



The data illustrates that a robust demand for fertilizers exists, with fertilizer prices range from $0.50 to over $1.00 per kilogram for a range of standard products. Prices have increased over the past decade as shown in the graph below.

[223] http://www.fao.org/docrep/013/i2044e/i2044e.pdf


Cost of Imported Fertilizers -- Madagascar
NPK Fertilizer
Price per kg USD
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

Annex 10.2 Alternative Ethanol Producing Feedstocks

Yield Table -- Conventional and Alternative Feedstocks	Yield Annual Liters/Ha	Notes	Liters * Hectares = Annual Yield Number of Households Served (liters/360 days) 10 Ha	50 Ha	100 Ha	500 Ha	5,000 Ha
Cattails in sewage with cellulose	93,500	Grows in waste water	935,000	4,675,000	9,350,000	46,750,000	467,500,000
Typha sp.			**2,597**	**12,986**	**25,972**	**129,861**	**1,298,611**
Cattails (starch only)	23,375	Spent mash is high in protein	233,750	1,168,750	2,337,500	11,687,500	116,875,000
			649	**3,247**	**6,493**	**32,465**	**324,653**
Cattails wild	10,051		100,513	502,563	1,005,125	5,025,625	50,256,250
			279	**1,396**	**2,792**	**13,960**	**139,601**
Sweet Sorghum (with cellulose)	32,725		327,250	1,636,250	3,272,500	16,362,500	163,625,000
			909	**4,545**	**9,090**	**45,451**	**454,514**
Sweet Sorghum cane	9,350	seedhead for flour or animal feed	93,500	467,500	935,000	4,675,000	46,750,000
			260	**1,299**	**2,597**	**12,986**	**129,861**
Grain Sorghum	2,338	seedhead for animal feed	23,375	116,875	233,750	1,168,750	11,687,500
			65	**325**	**649**	**3,247**	**32,465**
Cassava (U.S. yield value)	16,830	Spent mash is high in protein	168,300	841,500	1,683,000	8,415,000	84,150,000
			468	**2,338**	**4,675**	**23,375**	**233,750**
Cassava (Brazil yield value)	9,350	Yields DDS, high quality feed	93,500	467,500	935,000	4,675,000	46,750,000
			260	**1,299**	**2,597**	**12,986**	**129,861**
Nipa palms (managed, Phillipines)	20,009	Perennial; sap is harvested	200,090	1,000,450	2,000,900	10,004,500	100,045,000
Nypa fructicans			**556**	**2,779**	**5,558**	**27,790**	**277,903**
Nipa palm (wild)	6,078	Also Sugar and Raphia palms	60,775	303,875	607,750	3,038,750	30,387,500
Nypa & others			**169**	**844**	**1,688**	**8,441**	**84,410**
Sago palm (wild, New Guinea)	6,078	Trunk harvested;	60,775	303,875	607,750	3,038,750	30,387,500
Metroxylon sagus			**169**	**844**	**1,688**	**8,441**	**84,410**

		new sprouts					
Sugar cane (22 month crop)	8,415		84,150	420,750	841,500	4,207,500	42,075,000
			234	**1,169**	**2,338**	**11,688**	**116,875**
Molasses	1,477	9.5 tons of sugar also produced	14,773	73,865	147,730	738,650	7,386,500
			41	**205**	**410**	**2,052**	**20,518**
Tropical Sugar Beets	5,610	Mash provides animal feed	56,100	280,500	561,000	2,805,000	28,050,000
			156	**779**	**1,558**	**7,792**	**77,917**
Potatoes, starch only	3,740		37,400	187,000	374,000	1,870,000	18,700,000
			104	**519**	**1,039**	**5,194**	**51,944**
Sweet Potatoes	2,057		20,570	102,850	205,700	1,028,500	10,285,000
			57	**286**	**571**	**2,857**	**28,569**
Yams	879		8,789	43,945	87,890	439,450	4,394,500
			24	**122**	**244**	**1,221**	**12,207**
Corn	2,805	DDGS or cattlefeed from mash	28,050	140,250	280,500	1,402,500	14,025,000
			78	**390**	**779**	**3,896**	**38,958**
Melons	4,208	wild on semi arid lands	42,075	210,375	420,750	2,103,750	21,037,500
Cucurbitaceae			**117**	**584**	**1,169**	**5,844**	**58,438**
Buffalo gourd	8,415	pumpkin and melon family	84,150	420,750	841,500	4,207,500	42,075,000
Cucurbita			**234**	**1,169**	**2,338**	**11,688**	**116,875**
Prickly Pear Cactus, managed	8,415	Cattle food; the water plant	84,150	420,750	841,500	4,207,500	42,075,000
Opuntia polycanta			**234**	**1,169**	**2,338**	**11,688**	**116,875**
Prickly Pear wild	3,273	"Raketa" or "sakafon-drano"	32,725	163,625	327,250	1,636,250	16,362,500
			91	**455**	**909**	**4,545**	**45,451**
Mesquite, managed	3,188	mash produces food for humans	31,884	159,418	318,835	1,594,175	15,941,750
Prosopis			**89**	**443**	**886**	**4,428**	**44,283**
Castor bean (Jatropha)	3,029	sprouted	30,294	151,470	302,940	1,514,700	15,147,000

Jatropha curcas		bean is high in sugars	**84**	**421**	**842**	**4,208**	**42,075**
Rice, rough	1,870		18,700	93,500	187,000	935,000	9,350,000
			52	**260**	**519**	**2,597**	**25,972**
Coffee pulp	1,403	produces valuable by-products	14,025	70,125	140,250	701,250	7,012,500
			39	**195**	**390**	**1,948**	**19,479**
Pineapples	729		7,293	36,465	72,930	364,650	3,646,500
			20	**101**	**203**	**1,013**	**10,129**
Mangos	944	Fruits add water to the process	9,444	47,218	94,435	472,175	4,721,750
			26	**131**	**262**	**1,312**	**13,116**
Papayas	851		8,509	42,543	85,085	425,425	4,254,250
			24	**118**	**236**	**1,182**	**11,817**
Bananas	1,477		14,773	73,865	147,730	738,650	7,386,500
			41	**205**	**410**	**2,052**	**20,518**
Cashew apple (India)	486	co-product of the cashew nut	4,862	24,310	48,620	243,100	2,431,000
Anacardium			**14**	**68**	**135**	**675**	**6,753**

Annex 11

Establishing a market for ethanol in Madagascar to 2026

The methodology looks at the potential for the introduction of stoves, using different prices for both stoves and fuel, and observing the sensitivity of the price on uptake for both fuel and stoves. The methodology adopted is as follows:

- The number of households each year in rural/urban communities that use each fuel up to 2026 is projected, using current growth and migration patterns.
- The number of households involved, expected to reach 10 percent, 20 percent and 30 percent saturation level in 10 years in the two scenarios – rural and urban – is modelled using an S-curve for growth.
- This is compared with the number of 'charcoal & LPG' families which it has been shown in this report are virtually all these households are in the top quintile.
- Finally, the percentage uptake is considered, using the price and uptake of charcoal and LPG to give the ratio of uptake to annual fuel costs.

Saturation would occur over a number of years as people gradually adopted the stoves. The model assumes that the price of the stove is split over the years during which it is being used. **This is a major assumption** that requires soft loans or carbon finance to achieve. Thus it does not include the barrier of the upfront cost of the stove. Stove repair costs are not included for any of the stoves.

Population statistics

Population & Demographics

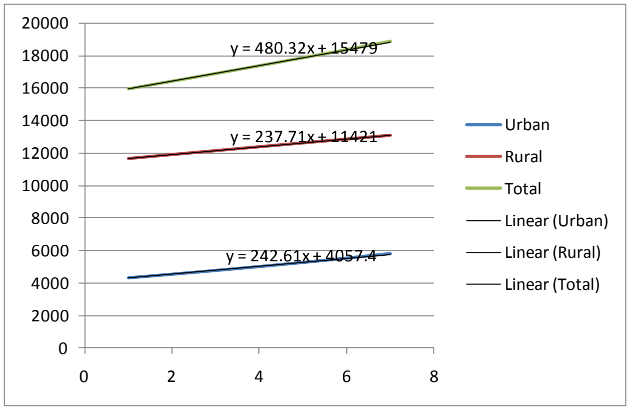
Population size in thousands of Madagascar by the projection with the medium variant (projection 1993)

		2002	2003	2004	2005	2006	2007	2008
People of Madagascar		15 981	16 441	16 908	15 382	17 865	18 359	18 866
including:	Women	8 003	8 211	8 461	8 696	8 935	9 179	9 430
	male	7 978	8 230	8 447	8 686	8 930	9 180	9 436
Urban population of Madagascar		4 327	4 544	4 770	5 005	5 252	5 511	5 786
including:	Women	2 203	2 313	2 427	2 546	2 670	2 801	2 939
	male	2 124	2 231	2 343	2 460	2 582	2 711	2 847
Rural Population of Madagascar		11 653	11 897	12 138	12 377	12 613	12 847	13 080
including:	Women	5 799	5 917	6 034	6 150	6 265	6 378	6 490
	male	5 854	5 980	6 104	6 226	6 348	6 469	6 589

Source: INSTAT, Directorate of Demography and Social Statistics

Updated on Monday, 06 Juillet 2009 14:07

Using linear regression to 2025



Using the Instat data, the trend in population to 2025 is calculated.

Projection of population to 2025:

	Year	Urban	Rural	Total
2002	1	4327	11653	15980
2003	2	4544	11897	16441
2004	3	4770	12138	16908
2005	4	5005	12377	17382
2006	5	5252	12613	17865
2007	6	5511	12847	18358
2008	7	5786	13080	18866
2009	8	5998	13323	19321
2010	9	6241	13560	19801
2011	10	6484	13798	20282
2012	11	6726	14036	20762
2013	12	6969	14274	21242
2014	13	7211	14511	21723
2015	14	5998	13323	19321
2016	15	6241	13561	19802
2017	16	6484	13798	20282
2018	17	6726	14036	20762
2019	18	6969	14274	21243
2020	19	7211	14512	21723
2021	20	7454	14749	22203
2022	21	9152	16413	25565
2023	22	9395	16651	26045
2024	23	9637	16888	26526
2025	24	9880	17126	27006

From demographic data, mean household size is assumed at around 5 persons per rural household, and 4 persons per urban household. This data is used to determine the growth in the number of households in rural and urban locations:

Projected number of households

Year		Urban	Rural	Total
2002	1	1082	2331	3412
2003	2	1136	2379	3515
2004	3	1193	2428	3620
2005	4	1251	2475	3727
2006	5	1313	2523	3836
2007	6	1378	2569	3947
2008	7	1447	2616	4063
2009	8	1500	2665	4164
2010	9	1560	2712	4272
2011	10	1621	2760	4380
2012	11	1682	2807	4489
2013	12	1742	2855	4597
2014	13	1803	2902	4705
2015	14	1500	2665	4164
2016	15	1560	2712	4272
2017	16	1621	2760	4381
2018	17	1682	2807	4489
2019	18	1742	2855	4597
2020	19	1803	2902	4705
2021	20	1863	2950	4813
2022	21	2288	3283	5571
2023	22	2349	3330	5679
2024	23	2409	3378	5787
2025	24	2470	3425	5895

Data from Demographic and Health survey 2003-04 for Madagascar on percentage urban/rural stove use. The survey for 2008 is not yet complete. This ratio can be revised when new data becomes available – however, as these are ratios, this data is considered acceptable.

Housing Characteristics Type of cooking fuel									
	Electricity	**LPG natural gas**	**Biogas**	**Kerosene**	**Coal, lignite**	**Charcoal**	**Firewood, straw**	**Dung**	**Other**
Urban	0.9	2.7	0.3	0.2	0.7	59.4	35.5	0.1	0.1
Rural	0.1	0.6	0	0.1	0.2	15.2	83.3	0.3	0
Total	0.3	1.1	0.1	0.1	0.3	25.2	72.4	0.3	0

Using these percentages to determine number of households using each fuel type in rural/urban situations for the BAU situation (ie with percentage by location of each type of fuel staying unchanged – there has been small reduction in urban household size with time – but around 4-5% and this is a forward projection so 4% retained):

Projected number of urban and rural households using each main fuel for the BAU situation

	BAU - HHx1000		BAU - HHx1000		BAU - HHx1000	
Year	UrbChar	RurChar	UrbWood	RurWood	UrbLPG	RurLPG
2003	675	362	409	1975	31	14
2004	708	369	429	2015	32	15
2005	743	376	450	2055	34	15
2006	780	383	473	2094	35	15
2007	818	391	496	2133	37	15
2008	859	398	521	2171	39	16
2009	891	405	540	2212	40	16
2010	927	412	562	2251	42	16
2011	963	419	584	2290	44	17
2012	999	427	605	2330	45	17
2013	1035	434	627	2369	47	17
2014	1071	441	649	2409	49	17
2015	1107	448	671	2448	50	18
2016	1143	456	693	2488	52	18
2017	1179	463	715	2527	54	18
2018	1215	470	736	2567	55	19
2019	1251	477	758	2606	57	19
2020	1287	484	780	2646	59	19
2021	1107	448	671	2448	50	18
2022	1359	499	824	2725	62	20
2023	1395	506	846	2764	63	20
2024	1431	513	867	2803	65	20
2025	1467	521	889	2843	67	21

This provides a BAU scenario for charcoal wood and LPG use to 2025.

Modelling use of ethanol growth within urban and rural communities

These analyses are adapted from a web-based document on Modelling Market Adoption by Juan Carlos Mendez Garcia.

http://8020world.com/jcmendez/2007/04/business/modeling-market-adoption-in-excel-with-a-simplified-s-curve/

The model is applied to the total population, and uses a well-recognised s-curve for growth, and uses three parameters:

- Saturation [saturation]– The maximum expected penetration after the product becomes mainstream i.e. what is the value that the top of the s-curve will reach?
- Start of fast growth [rapid] – By this year, the penetration will be 10 percent of the saturation value, and it will start to grow rapidly. (10 percent was an arbitrary choice –it is a reasonable choice in most cases).
- Takeover time [steady] – the time it takes for the product to “catch on” – The operational assumption in the formula is that this number of years after the start of fast growth, the product

would have reached 90percent of the saturation value and will start to slow down. This again is a reasonable choice.

The s-curve model focuses in the early phases of the product lifecycle, until maturity is reached. Penetration decay is not covered by this model, so adverse factors are not considered (eg the supply of stoves or ethanol being insufficient).

The formula for each year’s penetration is given by:

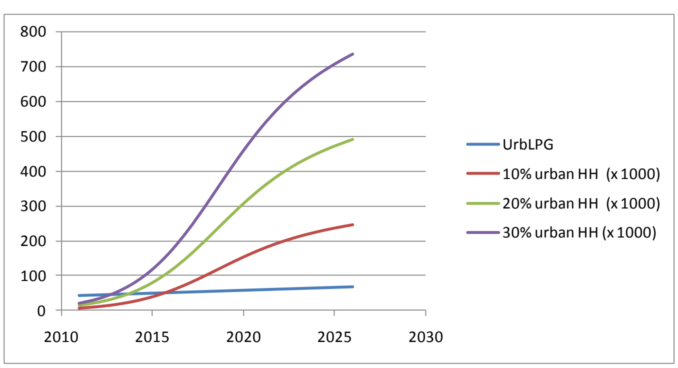
Penetration at year (x) = saturation/(1+81^((rapid+steady/2-year)/steady))

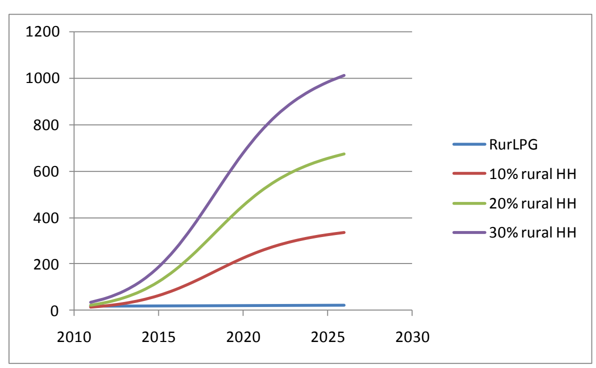
Examples in this case:		
Base year	Base 2010	(start of growth)
Saturation %	Saturation	10%, 20%, 30% (size of anticipated market at steady state)
Rapid growth	Rapid 2012	(rapid growth starts – year)
Steady demand	Steady	15 (years)

For each case, the BAU model for LPG, charcoal, and charcoal+LPG use is compared to the households that would use ethanol within the total population. This number of households is compared to those already using charcoal and LPG.

LPG

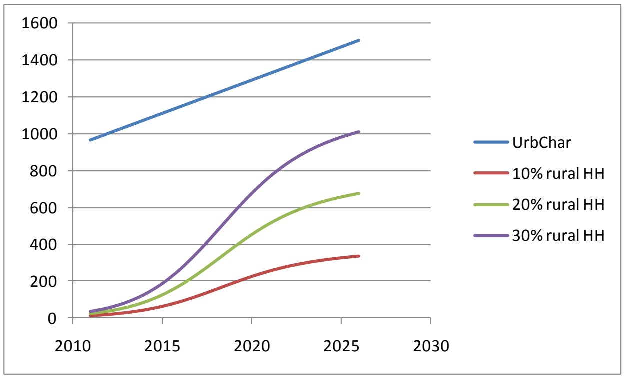
It can be seen that there is already a market for LPG, which could provide a potential market for up to 6 years (10 percent saturation) if we assume that both stove and fuel are less expensive for ethanol and that households would wish to switch. However, LPG stoves may be considered more ‘desirable’ if they are the sort of stoves available in the industrialised world, with several burners and an oven. Nonetheless, in terms of affordability, they are a market. The market in rural communities would need to start at 100 percent of all LPG users moving to ethanol if even a 10 percent saturation was to be reached. This target market seems non-feasible.

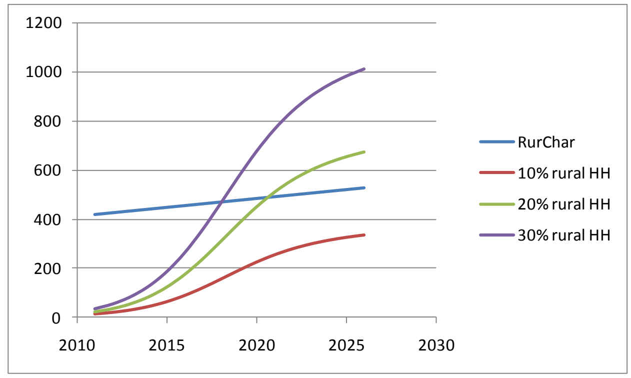




Charcoal

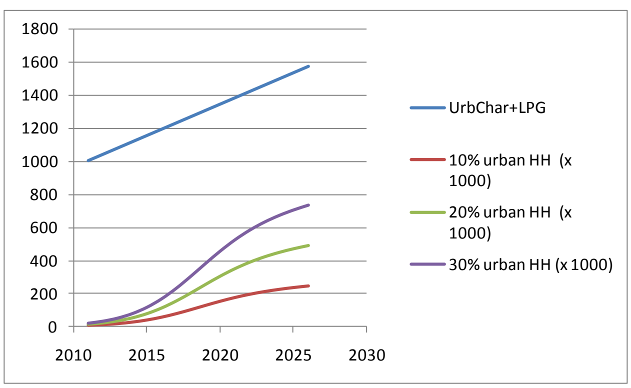
The urban charcoal market is very large in Madagascar, but most users fall within the top and second wealth quintile – ie 40 percent of the population. Despite this, even with a penetration of 30 percent, only around 49 percent of these charcoal users would be reached within 15 years. Within the rural context, market saturation would occur within around 2018 if 30 percent saturation is achieved, and around 2021 for 20 percent saturation. This still provides a substantial market.

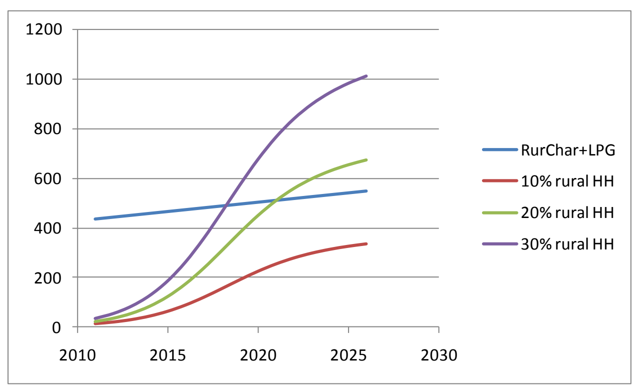




Charcoal + LPG

Combining both these fuels it can be seen that there exists a very substantial growth potential and market if one can provide an environment where ethanol can compete with charcoal and LPG. If both these market sectors are taken together it can be seen that the maximum percentage of urban LPG and/or charcoal users that would have to adopt would be 47 percent by 2025 in order to reach 30 percent of the total urban population. In rural communities, it can be seen that even in the rural market, a growth pattern of 10 percent saturation in 10 years would not reach the total number of households using LPG and charcoal and for 20 percent and 30 percent, this saturation would be reached by 2020 and 2018 respectively.





What price is needed to achieve ethanol markets of this size?

From the DHS data for 2003 it can be seen that the major fuels are charcoal, firewood and in urban areas, LPG is used by 2.7 percent of the urban population. In the following analysis, only data for two of the three main fuels is considered - namely LPG and Charcoal. Although the usage figures for fuelwood are included, it is assumed that the ethanol market will lie within the groups that can pay for fuel, and can afford the marginally more expensive and cleaner fuels. The other fuels are not considered as they are only used by very small percentages of the population.

Urban / Rural split – DHS survey 2003-04

	Housing characteristics									
	Type of cooking fuel									
	Electricity	LPG, natural gas	Biogas	Kerosene	Coal, lignite	Charcoal	Firewood, straw	Dung	Other	Missing
Madagascar 2003-04										
Residence										
Urban	0.9	2.7	0.3	0.2	0.7	59.4	35.5	0.1	0.1	0.0
Rural	0.1	0.6	0.0	0.1	0.2	15.2	83.3	0.3	0.0	0.1
Total										
Total	0.3	1.1	0.1	0.1	0.3	25.2	72.4	0.3	0.0	0.1

Source: Macro International Inc, 2010. MEASURE DHS STATcompiler. http://www.measuredhs.com, April 4 2010.

The approach adopted is to determine the price per annum for fuels and stoves in 2010, for charcoal and for LPG in both the rural and urban situations. We know the adoption rate of each of these forms of cooking, and a linear relationship is assumed to relate the annual cost of cooking with the percentage of households which could afford that form of cooking. These are shown on the graph below, using linear regression.

Knowing the cost of the ethanol stove used in the study, and the cost per annum for fuel at various prices per litre, one can predict the percentage of the population that could afford to use it in rural and urban areas. This percentage would describe when saturation was reached, with the stove being gradually adopted over a period of years and reflects the *market potential* for ethanol – ie the number of people who *could* adopt. This forms the second part of the analysis.

This calculation is based on a number of assumptions as given below:

Stoves:

- Current cost of LPG stove = $40 with 10 year lifetime (LPG is problematic as the bottles are swapped, so do not need to be replaced. This is the approximate cost of a basic stove + bottle in Kenya)
- **Cost per annum for LPG stove = $4 = 8332 Ariary per annum**

- Cost of ethanol stove = $55 with 10 year lifetime.
- **Cost per annum for ethanol stove = $5.5 =11500 Ariary per annum**

- Price of stove was the median value on a per annum basis from the first round of the project survey = 3500 Ariary – stoves are assumed to last around 1 year
- **Cost per annum for charcoal stove = 3500 Ariary per annum**

Fuel prices

Unit prices of fuel (2010):

Figure 1 – unit cost of fuel (MGA)					
	Da Source	Unit	Unit Price/ MGA/unit	D Daily price of fuel (Ariary / unit)	Date
Ch Charcoal	INSTAT*	kg	272	300**	2010
L LPG (12.5kg bottle prices)	Vitogaz - Madagascar	kg	3313	1656	2010

N.B.: Recent data indicate that the retail price of charcoal in Antananarivo purchased by large bag is MGA 372 per kilogram and purchase in small sacks of 0.5 to 1 kg may be MGA 400.

The price of LPG is now MGA 4,500 or $2.25 per kg, when purchased in a 9 kg or 12.5 kg bottle (Virogaz).

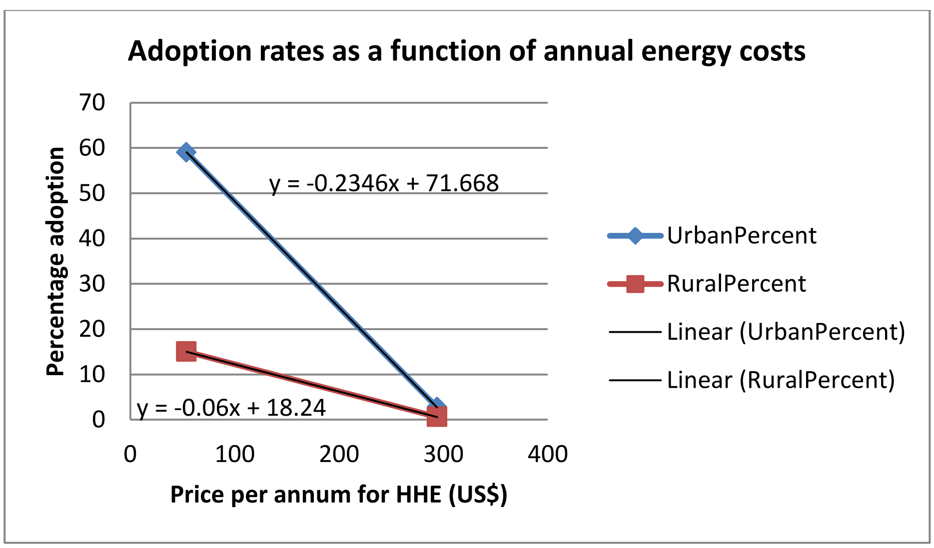
*National Institute of Statistics – INSTAT

**Project data

Total price per annum for each stove-fuel combination

= (Total cost stove /stove life) + total fuel cost per annum

	Ariary	Dollars
LPG	612772	294
Charcoal	113000	54



Calculating for urban adoption

Stove price is taken as project stove at $55US and life of 10 years percent adoption = - (0.2346 x Price per annum for energy) + 71.668

percent adoption required	Stove price US$	Stove life Years	Ethanol price/day Cents - US	Ethanol price/day Ariary
10.00	**55.00**	**10.00**	71	1440
20.00	**55.00**	**10.00**	59	1200
30.00	**55.00**	**10.00**	47	950

Calculating for rural adoption

Even if the fuel is free, the analysis indicates that only 18 percent would adopt if they had to pay for the stove.

percent adoption = - (0.06 x Price per annum for energy) + 18.24

percent adoption required	Stove price US$	Stove life Years	Ethanol price/day Cents - US	Ethanol price/day Ariary
5	**55**	**10**	59	1200
10	**55.00**	**10.00**	36	740

Effect of ethanol prices

Indicative prices of ethanol manufactured in different ways are as follows. These prices are being refined at present through further research.

Urban potential

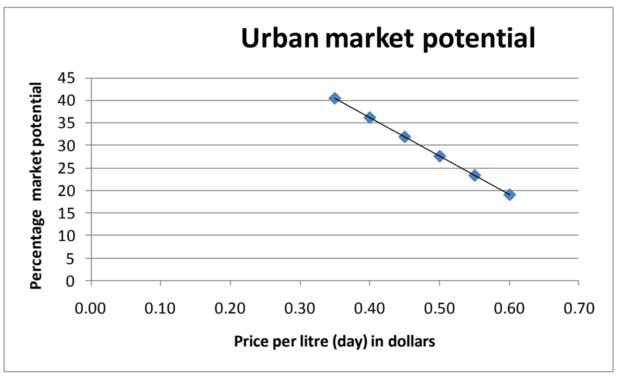
Ethanol Price per day US$ (Ariary)	Stove price US$	Stove life Years	Ethanol source	percent urban potential
0.35 (730)	55.00	10.00	Industrial	40
0.45 (935)	55.00	10.00	Imported	32
0.50 (1040)	55.00	10.00	Micro-scale	28

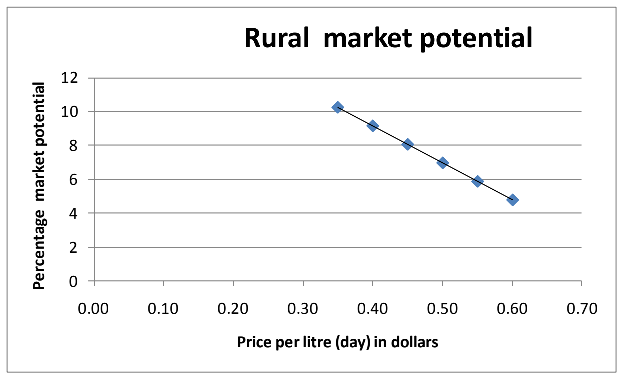
0.60 (1250)	55.00	10.00	Artisanal	19

Rural potential

Ethanol Price per day US$ (Ariary)	Stove price US$	Stove life Years	Ethanol source	percent rural potential
0.35 (730)	**55.00**	**10.00**	Industrial	10
0.45 (935)	**55.00**	**10.00**	Imported	8
0.50 (1040)	**55.00**	**10.00**	Micro-scale	7
0.60 (1250)	**55.00**	**10.00**	Artisanal	5

Sensitivity analysis on price of ethanol

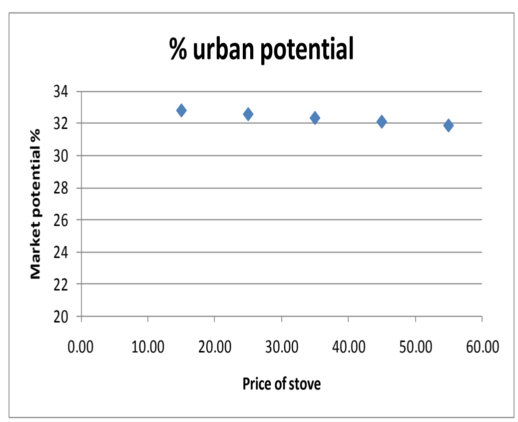




This urban curve suggests that within this range, for every 10 cents increase in the cost per litre of ethanol, around 8 percent of the potential urban market for ethanol is lost. A similar calculation for rural areas suggests that around 2.2 percent of a very small market is lost.

Sensitivity analysis on price of stove

The effect of changing the price of the stove is illustrated by fixing the ethanol price at $0.45US per litre. The price of the stove is set to $45, $35, $25, and $15.



This demonstrates that it is the price of the *fuel* that is most critical in determining the levels of adoption, provided that the capital cost of the stove is spread over its life through some form of affordable finance, as in the model. The rationale for this is that even if the stove costs $50, this is equivalent to $5 per year – or around 1.4 cents per day. For a stove of $20, the cost of the stove per day is ~0.5cents. For those using LPG, the fuel cost alone is around 80 cents per day, so this fraction is small.

Annex 12

Alternative Ethanol Producing Feedstocks

Yield Table -- Conventional and Alternative Feedstocks	Yield Annual Liters/Ha	Notes	Liters * Hectares = Annual Yield / Number of Households Served (liters/360 days)				
			10 Ha	50 Ha	100 Ha	500 Ha	5,000 Ha
Cattails in sewage with cellulose	93,500	Grows in waste water	935,000	4,675,000	9,350,000	46,750,000	467,500,000
Typha sp.			**2,597**	**12,986**	**25,972**	**129,861**	**1,298,611**
Cattails (starch only)	23,375	Spent mash is high in protein	233,750	1,168,750	2,337,500	11,687,500	116,875,000
			649	**3,247**	**6,493**	**32,465**	**324,653**
Cattails wild	10,051		100,513	502,563	1,005,125	5,025,625	50,256,250
			279	**1,396**	**2,792**	**13,960**	**139,601**
Sweet Sorghum (with cellulose)	32,725		327,250	1,636,250	3,272,500	16,362,500	163,625,000
			909	**4,545**	**9,090**	**45,451**	**454,514**
Sweet Sorghum cane	9,350	seedhead for flour or animal feed	93,500	467,500	935,000	4,675,000	46,750,000
			260	**1,299**	**2,597**	**12,986**	**129,861**
Grain Sorghum	2,338	seedhead for animal feed	23,375	116,875	233,750	1,168,750	11,687,500
			65	**325**	**649**	**3,247**	**32,465**
Cassava (U.S. yield value)	16,830	Spent mash is high in protein	168,300	841,500	1,683,000	8,415,000	84,150,000
			468	**2,338**	**4,675**	**23,375**	**233,750**
Cassava (Brazil yield value)	9,350	Yields DDS, high quality feed	93,500	467,500	935,000	4,675,000	46,750,000
			260	**1,299**	**2,597**	**12,986**	**129,861**
Nipa palms (managed, Phillipines)	20,009	Perennial; sap is harvested	200,090	1,000,450	2,000,900	10,004,500	100,045,000
Nypa fructicans			**556**	**2,779**	**5,558**	**27,790**	**277,903**

Nipa palm (wild)	6,078	Also Sugar and Raphia palms	60,775	303,875	607,750	3,038,750	30,387,500
Nypa & others			**169**	**844**	**1,688**	**8,441**	**84,410**
Sago palm (wild, New Guinea)	6,078	Trunk harvested; new sprouts	60,775	303,875	607,750	3,038,750	30,387,500
Metroxylon sagus			**169**	**844**	**1,688**	**8,441**	**84,410**
Sugar cane (22 month crop)	8,415		84,150	420,750	841,500	4,207,500	42,075,000
			234	**1,169**	**2,338**	**11,688**	**116,875**
Molasses	1,477	9.5 tons of sugar also produced	14,773	73,865	147,730	738,650	7,386,500
			41	**205**	**410**	**2,052**	**20,518**
Tropical Sugar Beets	5,610	Mash provides animal feed	56,100	280,500	561,000	2,805,000	28,050,000
			156	**779**	**1,558**	**7,792**	**77,917**
Potatoes, starch only	3,740		37,400	187,000	374,000	1,870,000	18,700,000
			104	**519**	**1,039**	**5,194**	**51,944**
Sweet Potatoes	2,057		20,570	102,850	205,700	1,028,500	10,285,000
			57	**286**	**571**	**2,857**	**28,569**
Yams	879		8,789	43,945	87,890	439,450	4,394,500
			24	**122**	**244**	**1,221**	**12,207**
Corn	2,805	DDGS or cattlefeed from mash	28,050	140,250	280,500	1,402,500	14,025,000
			78	**390**	**779**	**3,896**	**38,958**
Melons	4,208	wild on semi arid lands	42,075	210,375	420,750	2,103,750	21,037,500
Cucurbitaceae			**117**	**584**	**1,169**	**5,844**	**58,438**
Buffalo gourd	8,415	pumpkin and melon family	84,150	420,750	841,500	4,207,500	42,075,000
Cucurbita			**234**	**1,169**	**2,338**	**11,688**	**116,875**
Prickly Pear Cactus, managed	8,415	Cattle food; the water plant	84,150	420,750	841,500	4,207,500	42,075,000
Opuntia polycanta			**234**	**1,169**	**2,338**	**11,688**	**116,875**
Prickly Pear wild	3,273	"Raketa" or "sakafon-	32,725	163,625	327,250	1,636,250	16,362,500
			91	**455**	**909**	**4,545**	**45,451**

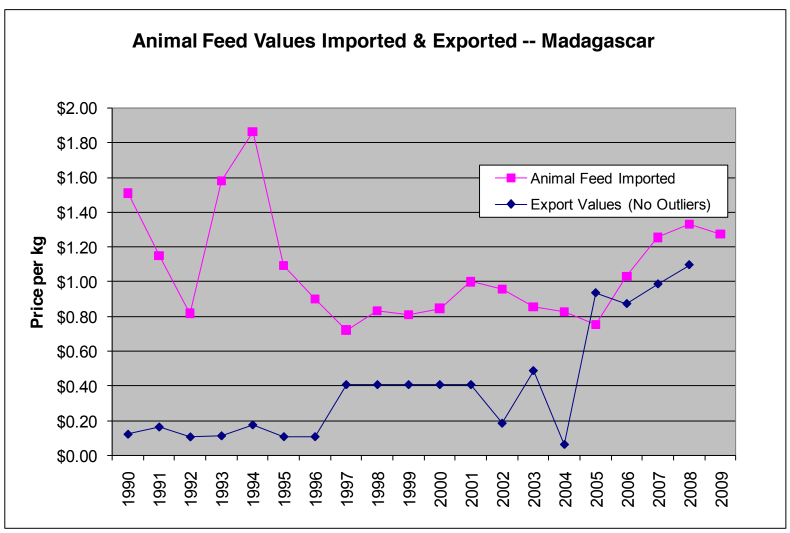
		drano"					
Mesquite, managed	3,188	mash produces food for humans	31,884	159,418	318,835	1,594,175	15,941,750
Prosopis			**89**	**443**	**886**	**4,428**	**44,283**
Castor bean (Jatropha)	3,029	sprouted bean is high in sugars	30,294	151,470	302,940	1,514,700	15,147,000
Jatropha curcas			**84**	**421**	**842**	**4,208**	**42,075**
Rice, rough	1,870		18,700	93,500	187,000	935,000	9,350,000
			52	**260**	**519**	**2,597**	**25,972**
Coffee pulp	1,403	produces valuable by-products	14,025	70,125	140,250	701,250	7,012,500
			39	**195**	**390**	**1,948**	**19,479**
Pineapples	729		7,293	36,465	72,930	364,650	3,646,500
			20	**101**	**203**	**1,013**	**10,129**
Mangos	944	Fruits add water to the process	9,444	47,218	94,435	472,175	4,721,750
			26	**131**	**262**	**1,312**	**13,116**
Papayas	851		8,509	42,543	85,085	425,425	4,254,250
			24	**118**	**236**	**1,182**	**11,817**
Bananas	1,477		14,773	73,865	147,730	738,650	7,386,500
			41	**205**	**410**	**2,052**	**20,518**
Cashew apple (India)	486	co-product of the cashew nut	4,862	24,310	48,620	243,100	2,431,000
Anacardium			**14**	**68**	**135**	**675**	**6,753**

Importance of bi-products

Micro-distilleries do more than just produce fuel; they produce fuel and co-products, e.g. feeds and fertilizers. A new report by the FAO, 'Reducing poverty by growing fuel and food (February 2011) shows how integrated food and energy crops work for poor farmers. This report states that producing food and energy side-by-side may offer one of the best formulas for boosting countries' food and energy security while simultaneously reducing poverty[224].

In the case of micro-distilleries in Madagascar, these are all value-added products that will sell for more than the original biomass cost to feed the plant. Yeasts and microbes break down the solids into ethanol and other products with value. For example, biomass that is not digestible to farm animals before distillation is converted into animal feed because the yeasts and microbes in the distillation process add protein and convert the solids into animal feed. Each litre of ethanol is associated with about five kilograms of solid fertilizer and five to ten litres of liquid fertilizer, depending on the type or raw feedstock, which can either be used on the farm, if the distillery is part of a farm complex, or sold. It will produce at least 5 kg of feed grade solids.

The graph below shows the prices of animal feed in Madagascar (Commodity Trade Statistical Database, FAO, Trade of goods, HS 1992, 23: Residues, wastes of food industry, animal fodder for Madagascar).



The data illustrates that a robust demand for fertilizers exists, with fertilizer prices range from $0.50 to over $1.00 per kilogram for a range of standard products. Prices have increased over the past decade as shown in the graph below.

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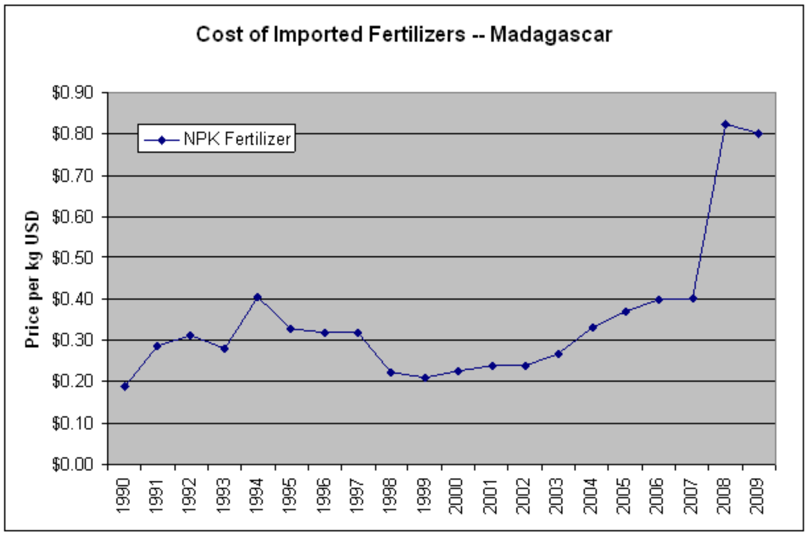
224 http://www.fao.org/docrep/013/i2044e/i2044e.pdf



Cost of Imported Fertilizers -- Madagascar
Price per kg USD
$0.90
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
NPK Fertilizer
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

Annex 13

Financial Analysis of Imported Stove – Urban, Ethanol Price of $0.35/l, Charcoal price of $0.17/kg

		Year									
IMPORTED STOVE		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cost											
Investment cost	USD/yr	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr										
Total	*USD/yr*	*50.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Benefits											
Fuel savings	USD/yr	13.71	13.71	13.71	13.71	13.71	13.71	13.71	13.71	13.71	13.71
Saving of investment costs	USD/yr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr										
Total	*USD/yr*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*	*13.71*
Cash flow	USD/yr	**-36.29**	**13.71**	**13.71**	**13.71**	**13.71**	**13.71**	**13.71**	**13.71**	**13.71**	**13.71**

Financial Analysis of Imported Stove – Rural Market, Ethanol Price of $0.35/l, Charcoal price of $0.10/kg

		Year									
IMPORTED STOVE		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cost											
Investment cost	USD/yr	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr										
Total	*USD/yr*	*50.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Benefits											
Fuel savings	USD/yr	-22.20	-22.20	-22.20	-22.20	-22.20	-22.20	-22.20	-22.20	-22.20	-22.20
Saving of investment costs	USD/yr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD/yr										
Total	*USD/yr*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*	*-22.20*
Cash flow	USD/yr	**-72.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**	**-22.20**

Financial Analysis of Micro-distilleries – sugarcane, with byproducts, ethanol price $0.35, 30-year penetration period

Please note that only years 1 to 10 (out of 30 years) are reported here due to the volume of data.

Sugarcane		year 1	year 2	year 3	year 4	year 5
Costs						
Operational costs						
Production cost for raw material	USD/yr	0	0	0	0	0
Management costs	USD/yr	0	0	0	0	0
Subtotal - Sugar cane production	USD/yr	*0*	*0*	*0*	*0*	*0*
Raw material	USD/yr	7,425	7,425	7,425	7,425	7,425
Chemicals	USD/yr	554	554	554	554	554
Labour	USD/yr	2,772	2,772	2,772	2,772	2,772
Miscellaneous	USD/yr	0	0	0	0	0
Power	USD/yr	396	396	396	396	396
Administration	USD/yr	1,188	1,188	1,188	1,188	1,188
Subtotal - Operational costs of destillery	USD/yr	*12,335*	*12,335*	*12,335*	*12,335*	*12,335*
Subtotal - Operational costs	USD/yr	***12,335***	***12,335***	***12,335***	***12,335***	***12,335***
Fixed costs						
Investment	USD/yr	7,055	0	0	0	0
Credit costs	USD/yr	5,559	5,559	5,559	5,559	5,559
Depreciation	USD/yr	1,425	1,425	1,425	1,425	1,425
Maintenance	USD/yr	792	792	792	792	792
Insurance	USD/yr	0	0	0	0	0
Subtotal - Fixed costs	USD/yr	***14,832***	***7,776***	***7,776***	***7,776***	***7,776***
Total - Costs	USD/yr	**27,167**	**20,112**	**20,112**	**20,112**	**20,112**
Benefits						
Sales of ethanol	USD/yr	13,860	13,860	13,860	13,860	13,860
Sales of primary co-products	USD/yr	3,960	3,960	3,960	3,960	3,960
Sales of secondary co-products	USD/yr	1,980	3,960	3,960	3,960	3,960
Total - Benefits	USD/yr	**19,800**	**21,780**	**21,780**	**21,780**	**21,780**
Cash flow	USD/yr	**-7,367**	**1,668**	**1,668**	**1,668**	**1,668**

year 6	year 7	year 8	year 9	year 10
0	0	0	0	0
0	0	0	0	0
0	*0*	*0*	*0*	*0*
7,425	7,425	7,425	7,425	7,425
554	554	554	554	554
2,772	2,772	2,772	2,772	2,772
0	0	0	0	0
396	396	396	396	396
1,188	1,188	1,188	1,188	1,188
12,335	*12,335*	*12,335*	*12,335*	*12,335*
12,335	***12,335***	***12,335***	***12,335***	***12,335***
0	0	0	0	0
0	0	0	0	0
1,425	1,425	1,425	1,425	1,425
792	792	792	792	792
0	0	0	0	0
2,217	***2,217***	***2,217***	***2,217***	***2,217***
14,553	**14,553**	**14,553**	**14,553**	**14,553**

Economic Analysis of Ethanol Programme, Sugarcane distillery, with byproducts, ethanol price $0.35, 30-year penetration period

Please note that only years 1 to 10 (out of 30 years) are reported here due to the volume of data.

IMPORTED STOVE and Sugarcane		Year 1	Year 2	Year 3
Costs				
Ethanol production	USD/yr	*12,163,405*	*11,229,091*	*13,423,477*
Ethanol transport/distribution	USD/yr	652,058	771,428	920,311
Investment cost stoves	USD/yr	2,427,001	444,302	554,151
Stove dissemination costs	USD/yr	658,170	120,489	150,278
Total - Costs	USD/yr	**15,900,633**	**12,565,310**	**15,048,217**
Benefits				
Sales of ethanol	USD/yr	6,200,987	7,336,178	8,752,033
Sales of direct co-products	USD/yr	1,771,710	2,096,051	2,500,581
Sales of secondary co-products	USD/yr	1,771,710	2,096,051	2,500,581
Fuel savings	USD/yr	-2,465,833	-2,917,243	-3,480,261
Saving of investment costs	USD/yr	0	0	0
Wood savings/Avoided deforestation	USD/yr	6,666,460	7,886,863	9,408,999
Avoided reforestation costs	USD/yr	0	0	0
CO2 emmission reductions of stoves	USD/yr	0	0	0
Avoided DALYs	USD/yr	705,238	834,343	995,368
Time Savings	USD/yr	7,574,062	8,960,617	10,689,984
Total - Benefits	USD/yr	**22,224,335**	**26,292,859**	**31,367,286**
Cash flow	USD/yr	**6,323,701**	**13,727,549**	**16,319,069**

Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
15,311,941	*17,945,772*	*17,882,264*	*20,700,255*	*24,066,867*	*28,969,018*	*34,203,698*
1,060,235	1,237,662	1,414,058	1,635,368	1,904,400	2,265,441	2,676,616
520,807	660,394	656,557	823,731	1,001,354	1,343,816	1,530,421
141,236	179,090	178,049	223,385	271,554	364,425	415,029
17,034,219	**20,022,917**	**20,130,927**	**23,382,738**	**27,244,174**	**32,942,699**	**38,825,763**
10,082,694	11,770,000	13,447,502	15,552,135	18,110,594	21,544,043	25,454,267
2,880,770	3,362,857	3,842,144	4,443,467	5,174,455	6,155,441	7,272,648
2,880,770	3,362,857	3,842,144	4,443,467	5,174,455	6,155,441	7,272,648
-4,009,400	-4,680,360	-5,347,422	-6,184,332	-7,201,708	-8,567,024	-10,121,932
0	0	0	0	0	0	0
10,839,546	12,653,507	14,456,931	16,719,546	19,470,054	23,161,233	27,364,976
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1,146,704	1,338,601	1,529,384	1,768,743	2,059,717	2,450,203	2,894,912
12,315,291	14,376,214	16,425,164	18,995,822	22,120,796	26,314,509	31,090,569
36,136,374	**42,183,677**	**48,195,846**	**55,738,848**	**64,908,364**	**77,213,845**	**91,228,088**
19,102,156	**22,160,760**	**28,064,918**	**32,356,110**	**37,664,190**	**44,271,146**	**52,402,325**