Bioenergy in Africa: opportunities and risks of jatropha and related crops

Production, policy & trade opportunities for biofuels in Eastern Africa

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Research Report

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The analysis and interpretations in this report, however, are those of the authors. They are not necessarily the views of our partners, colleagues, funder, nor the Overseas Development Institute. The authors remain solely responsible for whatever errors and omissions have crept into this report.

Abbreviations

Units of measurement

Km	Kilometre
Kg	Kilogram
t	Metric ton, tonne
M	Million
k	Thousand
ha	Hectare

Other abbreviations

ACFC	Agro Chemical and Food Corporation, Kenya
BIA	Bioenergy in Africa (BIA)
CGE	Computable General Equilibrium
EBA	Everything But Arms
EIA	Environmental Impact Assessment
EISA	Energy Independence and Security Act, US
ERA ARD	European Research Area, Agriculture for Development
ESA	Eastern & Southern Africa
	Eastern Africa: refers to the UN region of 19 countries, running from Eritrea to Mozambique
ESIA	Environmental and Social Impact Assessment
EU	European Union
GHG	Greenhouse Gas
GSP	Generalised System of Preferences

GTP	Growth & Transformation Plan, Ethiopia
IEPA	Interim Economic Partnership Agreement
IPCC	Intergovernmental Panel on Climate Change
KCFC	Kenya Chemical and Food Corporation
KEBS	Kenya Bureau of Standards
LDC	least developed countries
NBC	National Biofuels Commission, Mozambique
NBPS	National Biofuels Policy and Strategy, Mozambique
OECD	Organisation for Economic Cooperation and Development
REC	Regional Economic Commission
RFS	Renewable Fuel Standard , US
RSB	Roundtable on Sustainable Biofuels
SAM	Social Accounting Matrix
STAGE	Static Applied General Equilibrium
SVO	straight vegetable oil
TIC	Tanzania Investment Centre
UNFCCC	UN Framework Convention on Climate Change
US EPA	US Environmental Protection Agency
WTO	World Trade Organisation

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Summary

Research aims and methods

This research is about the possibilities for production and trade in biofuels in eastern Africa. It arises from the growing interest in biofuels, triggered by rising oil prices, and the desire to replace fossil fuels by renewables as a way to cut greenhouse gas emissions. For developing countries biofuels represent an opportunity to create new industries, jobs, and to reduce the increasingly costly imports of petroleum products.

The research has been carried out as part of the programme of a consortium, Bioenergy in Africa (BIA) — opportunities and risks of jatropha and related crops. Led from the Institute of Geography in the University of Bern, the BIA consortium includes EMPA [materials science and technology] (CH), Plant Research International, Wageningen Agricultural University (NL), Austrian Bioenergy Centre, Roundtable on Sustainable Biofuels, CIRAD [F], Overseas Development Institute (ODI) [UK]; together with partners from Belize, Ethiopia, Kenya, Mexico, Mozambique and Tanzania.

The overall objectives of the research consortium are:

> To provide an enhanced information and knowledge basis upon which sustainable and pro-poor bioenergy development strategies and policies can be designed and implemented by developing country policy makers, development partners and governments.

The research has been divided by theme, with ODI leading on global policy and trade, where the overall aims are:

- To inform developing country policy makers within Eastern Africa and more widely, as to the available opportunities and limitations of biofuel trade in international, regional and national markets; and,
- To review critically the global discourse on biofuels and analyse the impact of global trade, policies and certification of biofuels on bioenergy production.

The specific research questions set are as follows:

- Markets and trade. What is known about current and recent trends, plus projections, for transport fuels in Eastern Africa? What opportunities exist for exporting biofuels or feedstock?
- Trade policy for biofuels & biofuels feedstock. What are the arrangements for biofuel and feedstock in the trade policies that affect Eastern Africa countries?
- Production. What is the economic potential for production of biofuel feedstock in Eastern Africa?
- Government and regional (RECs) policies, public investment programmes, and regulations on biofuels. What policies are being developed within Eastern Africa and in potential importing countries for biofuels, and their implications? and,
- Certification schemes. How are schemes for certification and sustainability indicators that apply to biofuel production and processing evolving and how are they likely to progress? What are the implications for producers, processors and potential exporters?

The research was carried out between July 2010 and June 2011 in three stages: a literature review; collection of data and analysis in four countries of Eastern Africa where the consortium has been most active: Ethiopia, Kenya, Mozambique and Tanzania; and synthesis of these results culminating in this report. A core team from ODI led the work, in partnership with researchers based in the four countries. There are separate, detailed reports for each of the countries.

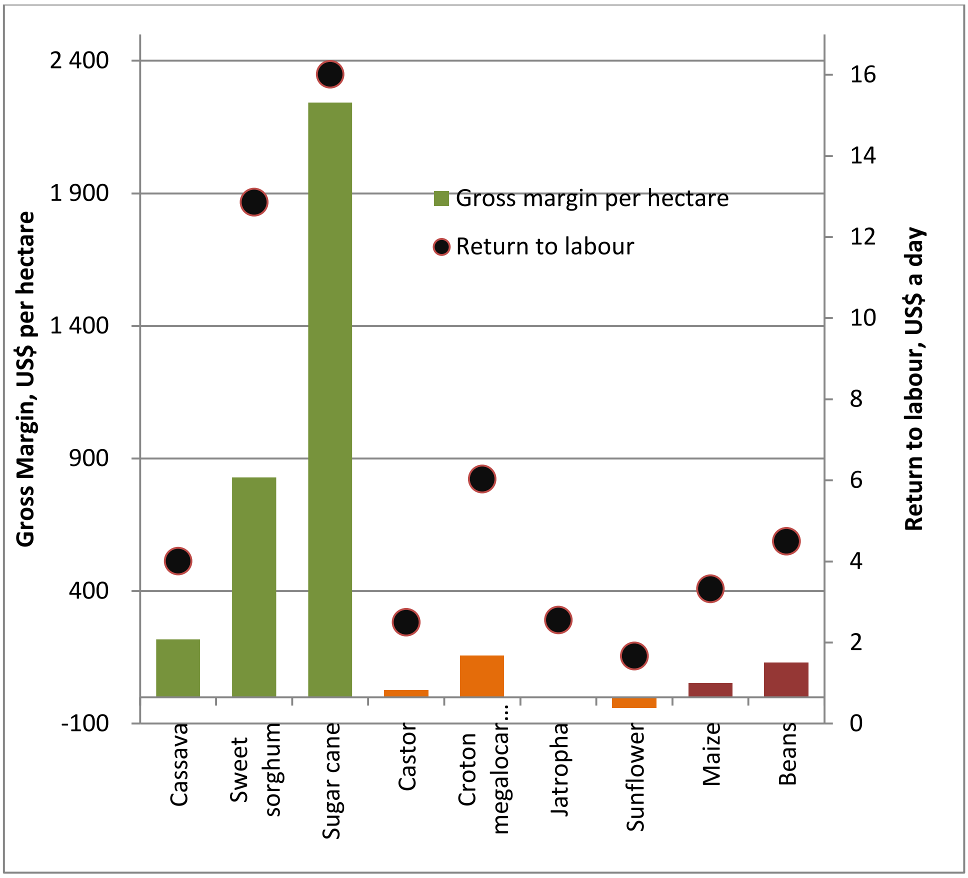
Main findings

Potential for biofuels

Eastern Africa includes countries that have abundant land. Of the four countries studied, Mozambique and Tanzania have very large areas of land currently little used that might be cultivated to grow feedstock. Ethiopia also has land to develop, although currently parts of this are remote and access is costly. Kenya has the least unused agricultural land, but possesses large areas of semi-arid land that might be used to grow feedstock adapted to such conditions.

Economic returns to biofuel feedstock, assuming oil prices of US$90 a barrel or more, can be high for some potential feedstock, notably sugar cane and sweet sorghum — generating returns to labour of US$12 a day or more — see Figure A.

Figure A: Returns to growing biofuel feedstock in Eastern Africa



Source: Data from country studies, mainly Kenya

These two crops are already cultivated widely across the region: sweet sorghum, moreover, can be grown in semi-arid areas making it particularly attractive. There would thus appear to be great scope to develop ethanol plants using these feedstock, sourced probably from outgrowers, perhaps with a nucleus estate. The resulting biofuel could then be blended into transport fuels, as well as replacing some of the kerosene currently consumed for cooking — predominantly in urban areas — and for lighting in rural areas lacking electricity.

Returns to growing oil crops that might be used to make biodiesel are far less attractive. Indeed, of the four oil feedstock considered here, only croton megalocarpus seems able to generate reasonable returns — US$6 a day — to labour. Castor and sunflower have much lower returns. But then again, their oil is more valuable for industry and cooking, respectively, so that they are unlikely to be grown for biofuels. Jatropha curcas, a crop that has been highly touted as a biodiesel feedstock on account of its ability to grow in semi-arid conditions, shows marginal returns.

At first sight, then, the prospects for biodiesel are far less than for ethanol. But that needs qualification. Costs of production of croton and jatropha seed fall when these plants are grown for other purposes, as shade trees and hedges, respectively. For the rural poor, collecting oil seeds from these plants might be laborious, but may generate cash income that they could not otherwise realise. Moreover, the value of these oils will be higher when used locally, either as straight vegetable oil or processed to biodiesel, to power diesel engines and motors, than when sold for blending with diesel. The more remote the location and the higher the costs of transport to ports and major cities, the more attractive growing oilseeds for biofuel becomes.

Development of biofuels so far in Eastern Africa

Biofuels had been only slightly developed in the region prior to the higher oil price. Some sugar mills, although surprisingly not all, distilled the molasses by-product of sugar refining to ethanol — largely for industrial use rather than for transport fuels.

Since the cost of imported fossil fuels has risen, great interest has been shown by private enterprise and some non-governmental organisations in producing biofuels. In all four countries, but especially in Mozambique and Tanzania, investors have filed numerous applications for biofuels projects, often involving production of feedstock on large estates. To date, few of these investments are operating at scale: most are running trials on small fractions of any land they have been granted. Some have run into problems in obtaining the land they were granted, or in producing feedstock: consequently some have been abandoned. It remains to be seen whether the current low realisation of such projects is temporary, as they start up and expertise is developed; or whether there are serious obstacles to realising the plans.

NGOs have been similarly active with trial programmes, usually looking to assist small farmers to grow feedstock for local processing and use. Again, few if any of these have yet gone to significant scale.

Policy for biofuels

To some extent, private initiatives have not had much support from the state. Governments have been running behind the pace of private investments in defining national strategies for biofuel development, in setting rules and regulations to guide the infant biofuel industry, and in considering what public support is needed and justified. The delay in establishing official positions on biofuels has added to the uncertainties faced by large-scale investors, small farmers and industrialists contemplating investments in feedstock and processing plants.

It is easy to see why policy development has been slow. Biofuel policy crosses at least four administrative remits: those of agriculture, energy, land tenure and environmental matters. The potential for policy incoherence is high. Moreover, there are uncertainties over the impacts of biofuels development: uncertainties that are matched by the degree of concern by civil society about the potential harm that unwise development could bring to the physical environment, to rights of poor rural people to land, to food production and security.

Governments have been trying to catch up: in the last two or three years policies have been drafted in the four countries. Generally these have laudable and attractive objectives of stimulating growth and jobs. In content, however, many policies consist of regulations designed to prevent undesirable developments that stress prior approval and imply control and monitoring. There is less than might be expected in setting out a framework for the development of biofuels. Policy also seems to focus on large-scale investors and correspondingly to say less about smaller-scale initiatives. It seems that large-scale investors are to be favoured, on account of their capital and know-how.

One particular aspect of policy that has lagged is the definitions of standards to be met if the countries were to export feedstock or biofuel to OECD countries, and the European Union in particular. Fortunately, there are signs that forums such as the Roundtable on Sustainable Biofuels may be able to develop standards and methods of certification that would meet the demanding standards that the EU is likely to demand for imports.

Civil society in all four countries is taking considerable interest in the development of biofuels, partly to act as a watchdog against possible abuses by large-scale investors. The issues that biofuels raise, however, are as contentious as they are substantial; made all the more so by the complexity of the systems within which biofuel developments take place that results in uncertainty over the impacts of different forms and degrees of development of biofuels. Public debates on biofuels are thus always likely to be divisive: finding ways to create a broad public consensus on these matters is a challenge.

Markets and trade

For the moment it seems that developing biofuels in eastern Africa will be focused on domestic use, to replace increasingly costly fossil fuel imports. That said, the European market is growing, especially since to produce much more than is currently produced in the Union is likely to be at high cost. Most of Eastern Africa enjoys preferential access to this market, for example under the tariff-free privileges of the Everything-but-Arms initiative: competing producers of tropical biofuels such as Brazil, Malaysia and Indonesia do not have such access. Given the high tariffs that are otherwise applied to ethanol imports, there is real potential for exports of ethanol — a prospect for Mozambique and Tanzania that have considerable areas that might be developed for biofuels.

Discussion

Two interlinked points arise from these findings: one is the need for more precise information; the other is for policy-making to catch up with events on the ground — that would be facilitated with more and better information.

Information. Although much public debate on biofuels unsurprisingly focuses on prominent issues such as land rights and food security, technical understanding about agronomy, economics and markets is incomplete. The agronomy of promising feedstock such as sweet sorghum and croton megalocarpus needs testing, adaptation and dissemination: more extensive trials in different areas on farmers' fields are needed to confirm their potential. Economic and market analysis is needed that has precise data relevant for particular countries and locations within them. Most analysis to date — including that reported here — is indicative, generating estimates that may be no better than plus or minus 25% accurate: that needs improvement.

Policy: once more and accurate information is available, it should be easier for policy makers and stakeholders to discuss the options and reach agreement. The priority is to set out consistent, clear and credible strategy for biofuel development: one that indicates the degree to which biofuels might be used for transport and other energy uses, the ambitions if any for exports, and measures such as taxes, subsidies and trade rules that will be used to encourage this.

Once a framework is in place, the detail needs defining. Mitchell (2011) expands on this when considering the policies needed to development biofuels for domestic use:

> Biofuel standards would need to be defined, monitored, and enforced. Regulations would need to be developed on handling, storage, transport, and distribution. Blending facilities would be needed, and procedures, regulations, and investment incentives would need to be agreed on. Pricing, taxing, and tariff policies would be needed. Limits on blending levels of biofuels with fossil fuels must be established.

A clear framework would not only help stimulate development of biofuels; but it would also help clarify the risks that such developments run, and indicate how these could be monitored and minimised. The current situation of schemes for certification that try to address a wider range of risks, with little or no distinction between the more or less likely and the more or less serious, arguably creates unnecessary work and contributes to confused debate over the issue.

These measures would help Eastern African countries to take advantage of what this research suggests may be a major opportunity to develop new industry, to create jobs, to improve the trade balance and to reduce dependence on imported energy.

1 Introduction: research objectives and methods

1.1 Background

Interest in biofuels has risen dramatically in the new century stimulated by the rise in oil prices, and by the desire to replace fossil by renewable fuels to reduce greenhouse gas (GHG) emissions. OECD countries, especially the United States and the European Union, have adopted policies to replace fuels from fossil sources for transport by renewable fuels — of which the only ones that are technically and financially viable are biofuels. These policies are implemented through mandates that set either a fraction of transport fuels to come from renewable sources, or a quantity of renewable fuels to be used, by a given date, as well as through subsidies to producers of biofuels.

Biofuel production has thus increased dramatically during the 2000s. Worldwide, production of ethanol has risen from around 30 billion litres in 2000 to 70 billion litres in 2010; while biodiesel production has grown from 2.2M tonnes in 2002 to 11.1M tonnes in 2008.

Some developing countries also have policies to stimulate biofuels, most notably Brazil that now has a very large industry producing ethanol from sugar cane. For developing countries, especially those with relatively abundant land, biofuels represent opportunities to produce fuels domestically and thereby cut back on increasingly costly imports of petroleum products. Some may even be able to export biofuels, or feedstock, to OECD countries: it is far from clear that the European Union can produce the biofuels mandated from domestic production without incurring high costs and displacing other crops.

The potential scope for producing biofuels in developing countries is very large indeed. In 2009, 3,837M tonnes of petroleum products were consumed worldwide, of which 23.3%, or 3 trillion litres[1], were motor gasoline. To produce that quantity of fuel in tropical areas, at a rate of 5,000 litres per hectare — as can be achieved by when growing sugar cane for ethanol — would require no less than 500M ha to be devoted to feedstock: a figure that can be compared to 1.5 billion ha currently under arable and permanent crops across the world.

There are thus great opportunities in biofuels to develop new industries, create jobs, and earn or save foreign exchange. Much interest has been aroused by the possibilities of growing jatropha curcas: a bushy plant whose fruits contain oil that can be used as straight vegetable oil (SVO) or processed to make biodiesel, jatropha can be grown in semi-arid lands that have low opportunity cost.

Yet there are significant concerns over large-scale development of biofuels. To produce biofuel feedstock, either current land use would need to be intensified to maintain current production plus biofuels, thereby driving up costs of production; or large swathes of land not currently under cultivation would have to be converted to feedstock, with tropical forests an inviting target.

Development of biofuels thus could lead to land being converted from valued habitats such as forest, peat and wetlands to crops; with loss of biodiversity, environmental services, and high greenhouse gas (GHG) emissions during conversion. Land acquisition may mean that current land users, especially those who are poor and with little political power, lose access to land that underwrites their livelihoods. Large-scale replacement of current crops by feedstock would almost certainly drive up the real cost of food: while this might benefit some farmers, it would hurt low income consumers in a world that is increasingly urban, and potentially increase the numbers who

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[1] At roughly 1,400 litres of gasoline per metric tonne.

are food insecure. There are, moreover, concerns over the treatment of labour in feedstock production and processing to biofuels.

This background, then, is the motivation for this study: to examine in more detail the possibilities for production and trade in biofuels in Eastern and Southern Africa.

1.2 Research objectives and questions

The research has been carried out as part of the programme of a consortium, Bioenergy in Africa (BIA) — opportunities and risks of jatropha and related crops. This, in turn, forms part of the European Research Area, Agriculture for Development (ERA ARD) programme. Led from the Institute of Geography in the University of Bern, the BIA consortium includes as European partners:

- EMPA [materials science and technology] (CH),
- Plant Research International, Wageningen Agricultural University (NL),
- Austrian Bioenergy Centre,
- Roundtable on Sustainable Biofuels,
- CIRAD [F],
- ODI [UK]; together with
- Southern partners from Belize, Ethiopia, Kenya, Mexico, Mozambique and Tanzania.

The overall objectives of the research consortium are:

> To provide an enhanced information and knowledge basis upon which sustainable and pro-poor bioenergy development strategies and policies can be designed and implemented by developing country policy makers, development partners and governments.

More specifically, the consortium aims to conduct high quality research on bioenergy production in Eastern and Southern Africa (ESA) within four work programmes — see Figure 1.1:

- Work Programme 1: Analysis of technical aspects and feasibility of bioenergy production with Jatropha;
- Work Programme 2: Analysis of socio-economic and environmental impacts of bioenergy production;
- Work Programme 3: Analysis of global trade and policies on bioenergy production; and
- Work Programme 4: Regional assessment of bioenergy potentials in ESA in a multi-objective decision-support system for the elaboration of development strategies and the definition of policies in relation to the production of bioenergy.

ODI leads Work Programme 3, Global Policy & Trade; and in particular Tasks 3.2 and 3.3.

Work Programme 3 aims:

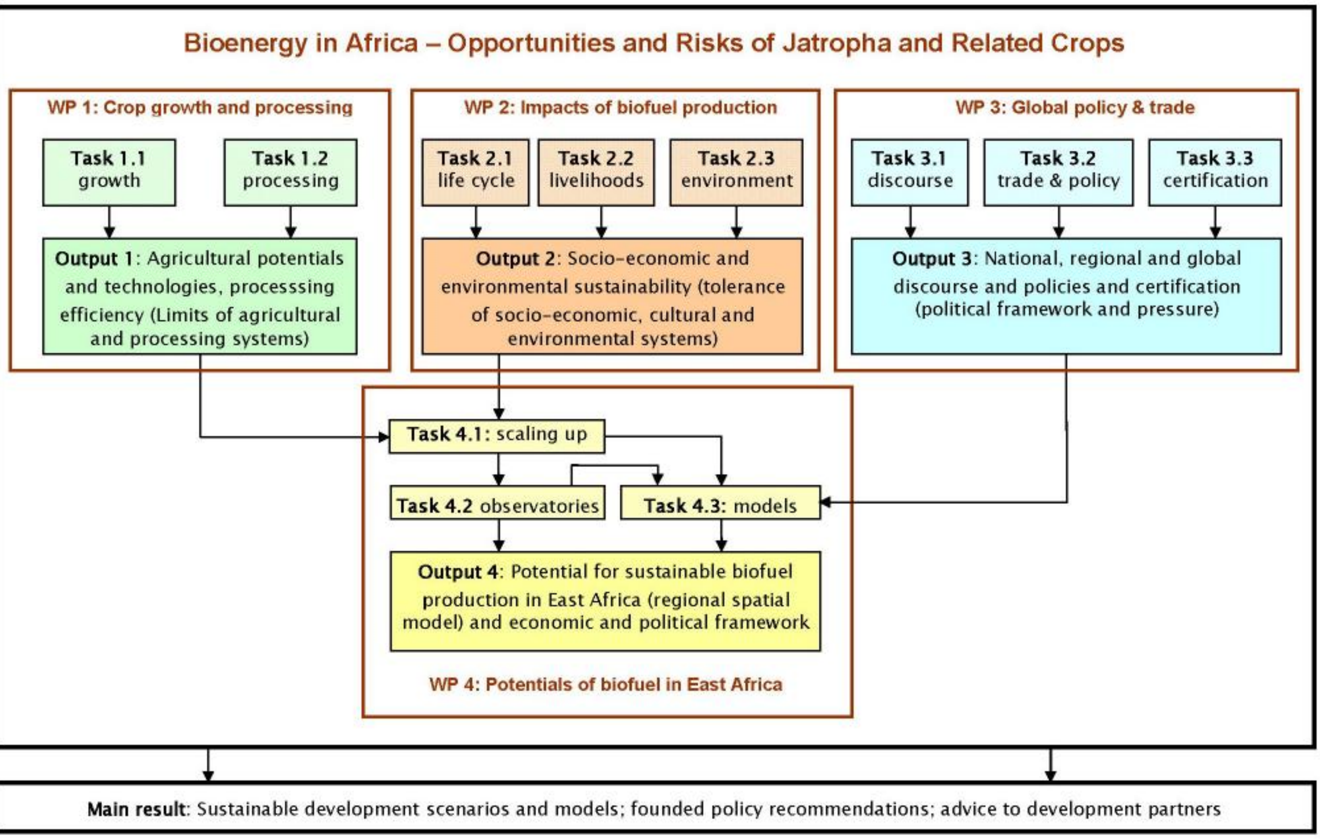
- To inform developing country policy makers within the ESA region and more widely, as to the available opportunities and limitations of biofuel trade in international, regional and national markets; and,
- To review critically the global discourse on biofuels and analyse the impact of global trade, policies and certification of biofuels on bioenergy production.
- Specifically, this part of the consortium's programme has the following objectives:

- ***Task 3.1: Analysis of the global discourse on biofuels***; the objective being to understand the basis of national biofuels policy in larger markets (EU and US) and the selected ESA country case studies (Kenya, Tanzania, Ethiopia and Mozambique). A comparison will be provided with Central America (Belize and Mexico).

- ***Task 3.2: Analysis of global trade in biofuels;*** the objective being to assess the potential of biofuels export/import in ESA countries and regional trade; in addition to the implications of the EU sugar market reform for ESA countries.

- *Task 3.3: Analysis of biofuels certification* (national, regional and international level); the objective being to understand the implications of compliance costs and enforcement mechanisms of schemes for different markets and products, and associated upgrading opportunities for biofuel producers in the ESA countries.

Figure 1.1: BIA consortium work programmes



ODI has interpreted these objectives for Eastern and Southern Africa as providing an understanding of the policy framework within which Eastern & Southern African countries can develop biofuel industries, and especially those that intend to export to world markets. The specific research questions set are as follows:

- Markets and trade. What is known about current and recent trends, plus projections, for transport fuels in ESA? What opportunities exist for exporting biofuels or feedstock?
- Trade policy for biofuels & biofuels feedstock. What are the arrangements for biofuel and feedstock in the trade policies that affect ESA countries?
- Production. What is the economic potential for production of biofuel feedstock in ESA?
- Government and regional (RECs) policies, public investment programmes, and regulations on biofuels. What policies are being developed within ESA and in potential importing countries for biofuels, and their implications? And,
- Certification schemes. How are schemes for certification and sustainability indicators that apply to biofuel production and processing evolving and how are they likely to progress? What are the implications for producers , processors and potential exporters?

1.3 Research methods

The work was carried out in three main stages, as follows:

- Existing literature and data was reviewed to identify key issues already recognised, and ensure that nothing significant was overlooked before undertaking more detailed study;
- Collection of data in the four countries of ESA where the consortium has been most active: Ethiopia, Kenya, Mozambique and Tanzania. Data were assembled and analysed in four country reports[2]; and,
- Synthesis of the insights from the country studies during a two-day workshop held in London 14 and 15 April 2011 that brought together country partners with the ODI team.

The ODI research team consisted of: Jodie Keane, Jane Kennan, Henri Leturque, Chris Stevens, and Steve Wiggins as co-ordinator. The country studies were carried out by the following teams:

- Ethiopia: Aklilu Amsalu, University of Addis Ababa;
- Kenya: Geoffrey Ndegwa, Violet Moraa, and Miyuki Iiyama, World Agroforestry Centre (ICRAF);
- Mozambique: Boris Atanassov, Lara Machuama, Andrew Gordon-Maclean, Stockholm Environmental Institute; and,
- Tanzania: Andrew Gordon-Maclean, Jacqueline Senyagwa and Anders Arvidson, Stockholm Environmental Institute.

2 The potential for biofuels in Eastern and Southern Africa: supply

2.1 Land availability

How much land is available in in the region, and in the four countries studied? Available statistics from FAO are shown in Table 2.1 for the four countries and for Eastern Africa.[3] The four countries are relatively abundant in agricultural land: while 36M ha is under arable and permanent crops,

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[2] Shortly be made available on the website of Bioenergy in Africa: http://www.bioenergyinafrica.net/

[3] Eastern Africa corresponds to the UN definition: it runs from Eritrea in the north to Mozambique and Zimbabwe in the south. The western boundary is marked by the borders with Sudan, DR Congo, Angola, Namibia, Botswana.

estimates of the area suitable for agriculture range from 129M ha to 190M ha. Hence 154M ha, equivalent to 93M ha of very suitable land, may be physically available.

In all four countries the equivalent potential arable area is large: 70% of the existing arable and permanent cropped area in Kenya, double that area for Ethiopia, three times the area for Tanzania, and more than ten times the area for Mozambique.

Table 2.1: Land availability in Ethiopia, Kenya, Mozambique, Tanzania and Eastern Africa, '000 ha

	2006/08 estimates				1994 assessment			
'000 ha	Land area	Agricultural area	Arable & Permanent Crops	Area equipped for irrigation	Potential Arable	Equivalent potential arable	Apparent available arable	Equivalent apparent available arable
Ethiopia	100,000	34,603	14,603	290	42,945	29,220	28,342	14,617
Kenya	56,914	27,085	5,785	103	15,845	9,806	10,060	4,021
Mozambique	78,638	48,767	4,767	118	63,544	44,002	58,777	39,235
Tanzania	88,580	34,867	10,867	184	67,285	45,911	56,418	35,044
Total	*324,132*	*145,321*	*36,021*	*695*	*189,619*	*128,939*	*153,598*	*92,918*
Eastern Africa	605,338	300,239	61,590	2,465	379,238	257,878	317,648	196,288

Sources: Estimated land areas and uses for 2006/08 from FAOSTAT; 1994 assessment of potential arable and its equivalent from TERRASTAT.

Notes: Eastern Africa data exclude those for Indian Ocean islands of Comoros, Mauritius, Mayotte, Reunion & Seychelles.

'Equivalent potential arable' aims to correct for quality of land, as follows. 'The potential arable land was adjusted for its quality by giving a weighting to the suitability classes as follows: Suitable x 0.7, Moderately Suitable x 0.5, Marginal x 0.3. Thus the weighted values give the equivalent areas of Very Suitable land.'

Apparent available arable land = potential arable minus arable and permanent crops; Equivalent apparent available arable land = equivalent potential arable minus arable and permanent crops

At first sight, then, there is ample land in these countries to use for additional crops of feedstock for biofuels. That said, some sizeable deductions need to be made to remove land allocated to nature and wildlife reserves, forests, other areas of high biodiversity that should not be converted to farmland, and areas with slopes steep enough to risk erosion. National estimates of the land that might be planted to biofuel feedstock are thus often smaller:

- In Ethiopia, 23.3M ha are estimated suitable for planting an oil crop such as jatropha, while 1.4M ha could produce irrigated sugar cane for ethanol;
- For Kenya, estimates of areas suitable for different feedstock can be seen in Table 2.2. Large differences exist between the total area that could be used to grow the feedstock, and the areas suitable in zones not already cultivated. Even so, the areas assessed are larger than the remaining undeveloped arable land for some feedstock, especially those that can be grown in semi-arid areas.

Table 2.2: Estimated area suitable for biofuel feedstock in Kenya

'000 ha	General suitability	Suitable within non-cultivated areas
Jatropha	22,194	11,534
Castor	24,049	12,124
Croton	6,277	865
Sunflower	14,000	6,346
Sweet sorghum	26,397	14,926
Sugar cane	1,733	146
Cassava	10,304	3,875

Source: Kenya country study, from Muok et al. 2010

- In Mozambique, the government assessed the country's agro-ecological zones, on the basis of agro-climatic suitability and availability of land. It came to the conclusion that there were almost 7M ha that would be suitable for agricultural expansion (Mozambique country study). [4]
- Tanzania also has large areas suitable for biofuels not presently cultivated, as Table 2.3 reports. Depending on the crop, between 7M and 31M ha may be suitable for feedstock in areas not yet tilled.

Table 2.3: Estimated area suitable for biofuel feedstock in Tanzania

'000 ha	General suitability	Suitable outside cash & food crop area
Jatropha	65,914	27,331
Castor	69,372	28,456
Croton	20,964	7,399
Sunflower	42,388	17,775
Sweet sorghum	78,623	31,508
Sugar cane	47,427	18,955
Cassava	78,623	22,796

Source: Tanzania country study, from World Bank data

Land suitability is further complicated by the potential for irrigation: if semi-arid areas can be watered, they may change from marginal lands to prime agricultural land on which biofuel feedstock — and other crops may be grown.

Access may limit the use of land: some areas suitable for cropping may lack reasonable road access, and hence not be economically useful until roads have been built. This particularly affects Ethiopia and Mozambique that both have relatively few roads, leaving large areas of medium to high potential arable land with poor physical access.

Nevertheless, in sum, these four countries all have land that currently is not cultivated that might be used to grow biofuel feedstock. Mozambique and Tanzania, in particular, have very large areas that might be so developed.

2.2 Costs of production and returns

Data were collected for some of the country studies, most notably Kenya, that allows a broad estimate of the costs of production of some biofuel feedstock in eastern and southern Africa. Table 2.5 reports the estimates made: details appear in Appendix B.

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[4] There were concerns that the scale of mapping , at 1:1M, was too broad; so that revised exercise using maps at 1:250k has been ordered.

Table 2.5: Costs of production of biofuel feedstock

Feedstock	Cost production feedstock, US$ per tonne	Cost of biofuel, US% per litre
Ethanol:		
• Cassava	63.8	0.53
• Sweet sorghum	11.5	0.40
• Sugar cane	23.7	0.42
• Molasses	-	0.11
Biodiesel:		
• Castor	198.8	0.63
• Croton megalocarpus	95.1	0.55
• Jatropha	150.1	0.76
• Sunflower	177.1	0.80

Source: Mainly data from Kenya, see Appendix B

Unit costs vary greatly depending on the yields achieved and the cost of labour: these cases assume middle range yields and value labour at US$2.5 a day — a low valuation for labour.

It is clear that the lowest cost sources of feedstock are those for ethanol. In the case of molasses, a by-product of sugar cane processing that has few alternative uses and may thus be valued as zero, the cost of ethanol becomes very low indeed. Sugar cane and sweet sorghum have similar costs of production, with cassava a little more costly.

Biodiesel feedstock costs more to produce. These costs might fall when feedstock are grown for other purposes, so that the only additional cost for biofuel use is harvesting the feedstock. This would apply to the cases of croton m., that may be grown as a shade tree, and to jatropha that is commonly used for hedgerows.

How do these costs compare to the potential returns? Gross margins have been calculated for these crops, assuming that the value of ethanol is that of replacing gasoline, and that of biodiesel is that of replacing diesel. In OECD countries the value of these hydrocarbons varies very closely with the price of crude oil. If a level of US$90 a barrel were assumed as the minimum price likely apply in 2011 and over the next few years, then the cost of gasoline can be expected to be around US$0.79 a litre, diesel at US$0.85, at the pump, net of any taxes in OECD countries. It is unlikely that these prices would be any less in eastern and southern Africa: given high costs of transport, fuel prices inland are likely to be substantially higher.

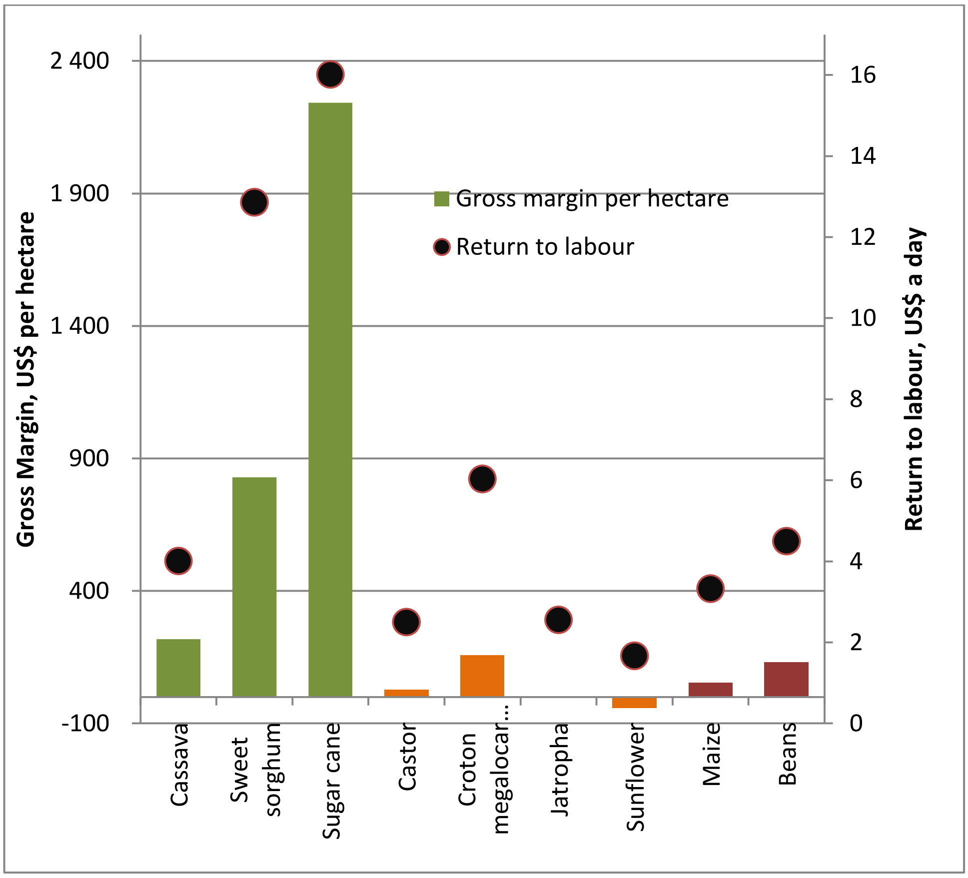
Comparing these costs of fossil fuels to the costs of production of biofuels shows that in all cases, biofuels look competitive, even allowing for costs of transport of the biofuel to transport fuel warehouses. This impression is confirmed by computing gross margins per hectare, and in some cases, the return to labour from producing biofuel feedstock, see Table 2.6 and Figure 2.1.

Table 2.6: Gross margins and returns to labour from growing biofuel feedstock

Ethanol:	Gross margin, US$ per ha	Return to labour, US$ per day
• Cassava	218	4.0
• Sweet sorghum	829	12.9
• Sugar cane	2,242	16.0
• Molasses	NA	NA
Biodiesel:		
• Castor	26	2.5
• Croton megalocarpus	158	6.0
• Jatropha	1.7	2. 6
• Sunflower	- 42	1.7
Food crops: for comparison		
• Maize	54	3.3
• Beans	130	4.5

Source: Mainly data from Kenya, see Appendix B

Figure 2.1: Gross margins and returns to labour from growing biofuel feedstock



Source: Table 2.5

Again, it clear that the returns to growing feedstock for ethanol are better than those for growing oilcrops for biodiesel. Returns to the two sugar crops, cane and sweet sorghum, are extraordinarily high for developing countries, whether measured by returns to land or labour. Growing cassava for ethanol is less valuable, but even so offers quite attractive returns.

Returns to oilcrops for biodiesel, on the other hand, are low: only in the case of croton m. are they higher than those to food crops such as beans and maize.

Two qualifications apply to the biodiesel feedstock. One, as mentioned, is that some of these crops may be grown as hedges or shade trees, so that their costs as feedstock can be considered just those of collection of seeds from the plants. Two, the value of the oilcrops has been assessed as that of replacing imported diesel fuel. If, however, the oil were used as straight vegetable oil for cooking, lighting, or running small diesel engines in rural areas, their value would rise — for the simple reason that imported diesel would have to bear transport costs that can be substantial, especially in remote areas.

2.3 Development of biofuels to date

Biofuels are being produced industrially in the region in small quantities, as follows:

- Ethiopia: ethanol produced from molasses at the Fincha'a sugar factory, 8M litre capacity. The ethanol has been exported;
- Kenya: began ethanol production in 1977 and adopted blending into transport fuels in 1984. This was later abandoned in 1995 after liberalisation of the industry. Currently ethanol is distilled from molasses by two companies namely; Agro-Chemical and Food Company Limited and Specter International Limited, with a combined capacity of 125,000 litres a day but produce only 57,400 litres a day (Kenya country study citing MOE/GTZ, 2008). Ethanol is used industrially: solvents, beverages and pharmaceuticals, rather than for energy ;
- Mozambique: just one ethanol distillery operates, in Buzi District, Sofala province, producing 10,000 litres a day for the beverage and pharmaceutical markets. There are a few biodiesel processing plants, of which the Ecomoz facility is the most significant. In operation since 2007, it can refine up to 100,000 litres a day. Biodiesel is sold to Petromoc, the state oil company, who use it to run their own vehicles (Mozambique country study, citing Schut et al, 2010); and,
- Tanzania: it is believed that some ethanol is produced from molasses at sugar cane mills, most notably that of Kilombero, since 2007.

In addition, there are other cases of biofuels being produced on a small scale as part of industrial research and as pilot projects, especially by NGOs.

Not only has production to date been small, but also little of this has been supplied for blending of transport fuels. It seems that Malawi may be the only country in eastern Africa that blends ethanol into petrol.

Since 2007 and the rise in oil prices, however, there has been a surge of interest in developing biofuels to replace imported fossil fuels. Two sets of actors have been prominent:

- private investors, either foreign or foreign in partnership with domestic concerns, seeking to produce biofuels on a large scale from feedstock grown on land they control, or sometimes with the intention of buying feedstock from smallholders. The biofuel is intended to replace imported fossil fuels, mainly for transport. In Ethiopia state companies have shown interests in similar investments;
- NGOs that have set up plants to crush oilseeds, refine the oil, and in some cases to process further to biodiesel. The oilseeds are to be bought from smallholders with the intention of stimulating agriculture and improving farmer incomes. The oil or biodiesel produced will be

used either for local manufacture to soap, or for local energy use in lighting, cooking and running diesel engines, including generators for electricity.

Table 2.7: Planned investments in biofuels in the four countries summarised

Country	Plans announced
Ethiopia	Plans to increase capacity to distil ethanol from cane and molasses: Fincha'a sugar factory to boost ethanol production capacity from 8M to 18M litres; Wonji and Matahara sugar mills building ethanol distilleries with annual production capacity of 20.5Mand 35.6M litres respectively. Government building another sugar mill (Tendaho) in Afar region, to produce 50.6M litres of ethanol a year by 2013. A Pakistani company, Habesha sugar, is building a mill and ethanol distillery in Wollega zone of Oromia region. All told, capacity to distil ethanol is planned to rise from the current 8m to 124M litres by 2014/15. Government providing land to grow biofuel feedstock to foreign and local companies as well as private and non-private investors. Since 2010, 18 investors and enterprises, with over 3 billion birr [c. US$187M] combined capital, are developing biodiesel on 207,180 ha — with promises of 109,543 jobs (The Ethiopian Herald, Dec. 29 2010).
Kenya	To the 9 current sugar mills, another 4 are planned to be built within the next few years. It likely that most if not all additional sugar will be bought in from small-scale outgrowers. Two companies plan ethanol distilleries: Mumias with 80k l a day, and Kwale International with 30k l a day. Total installed capacity will then reach 235k l a day. Specter international has imported sorghum seed from India, bulking this to distribute to farmers to grow sweet sorghum. Some foreign companies have expressed interest in Jatropha curcas plantations for biodiesel production on semi-arid land owned by government or large private ranches. The latest involves Bedford Biofuels, a foreign company that plans to invest about US$3.6M to develop an estimated 64,000 ha of jatropha in the Tana Delta (Bedford biofuels, 2010, cited in Kenya country report) — a plan that has attracted much concern from conservationists.
Mozambique	By 2009, investors had requested 12M ha for biofuel feedstock. Of these, 2M ha were seen as credible by the government. Country study surveyed 48 biofuel projects: 16 active, 4 beginning, 3 ended, 4 paralysed, the rest with unclear status. 11 are to produce ethanol: 9 with cane, 2 with sweet sorghum. Most are large scale: the average request for land is 23,000 ha, the area granted 20,000 ha. Average production planned is 163M litres, with an investment of US$252M, expected to create 3,000 jobs each on average. 37 projects aim to produce biodiesel: 33 with jatropha, 2 from coconut, 2 from sunflower. Scale is also large: on average, land request 13,000 ha, granted 8,000 ha, average investment of US$23M. Land development to date a tiny fraction of areas granted: 41 ha for ethanol projects, 481 ha for biodiesel projects.
Tanzania	17 large-scale projects are registered with investment centre: most are requests that have yet to be granted. More than 4M ha were requested for biofuels in 2009, but only 100,000 ha had been granted formal rights. (Sulle & Nelson 2009) 7 large-scale, privately-funded projects have been started: including 140,000 ha of sugar cane and sweet sorghum to distil ethanol; 63,500 ha of jatropha, croton m., and palm oil. One of these, growing jatropha, went bankrupt/ Another 5 projects intend to buy jatropha from outgrowers.

Sources: Compiled from country reports

The former investments have often included plans to acquire very large estates to grow feedstock, thus prompting fears over existing land users losing their rights to land — either through expropriation or purchase at a low price. Table 2.7b summarises some the main large-scale developments planned for the four countries.

There are considerable gaps between plans for large, sometimes very large, scale development of estates for growing feedstock, and subsequent developments. Mozambique provides good examples: for the ethanol projects, where the average area granted was 20,000 ha, from the few reports of progress, the average area actually developed was 41 ha; of the biodiesel investments, for which on average 8,000 ha lots had been granted, on average less than 500 ha had been developed — again, however, from relatively few reports. In Ethiopia, around 200 investors applied for licences to develop biodiesel since 1992: a review of these in 2010 showed that only eight were in operation, the rest having been abandoned.

It may be that for some investments, these are early days and in a few years' time the areas planned will be in production. It was expected that trials would be run before main development in some cases. But in other cases the delays have arisen since problems have arisen: in getting access to land, agreement with local authorities, or higher costs in developing the land than expected. It remains to be seen just how far the large-scale projects will progress.

3 Policy for biofuels development

In general, policy-making has lagged behind the pace of private initiatives in biofuels, even to the point where governments in Mozambique and Tanzania have announced moratoriums on approvals of large-scale investments while policies are debated, decided and frameworks put in place. Biofuels development, in fairness, presents stiff challenges to policy makers in eastern Africa: biofuels are both energy and agricultural and so fall within the remits of different ministries; the intended investments often involve land acquisition in countries where the state struggles to make working policies that protect land rights of users while ensuring effective and efficient use of land; the use of land to produce fuels raises questions about food production and security; and there are important questions about the environmental impacts of expanding the cultivated area to accommodate biofuel feedstock.

The situation in early 2011 for each of the four countries is set out in the next section.

3.1 National policies affecting biofuels

Ethiopia

The Plan for Accelerated and Sustainable Development to End Poverty (PASDEP) that ran from 2004/05 to 2009/10, included the aim of promoting palm oil, with biodiesel production as a line of industrial development; set a target of 143M litres of ethanol to be distilled by 2009/10 for the sugar industry; and in general aimed to develop biomass for food, feed and household energy. Subsequently, the Growth and Transformation Plan (GTP) for 2010/11 to 2014/15 sets more specific goals for biofuels, aiming to increase ethanol production to 195M litres, biodiesel production to 1.6M litres, and establish 8 more blending facilities for ethanol and 72 more for biodiesel.

The energy policy of 1994 declared the goal of decreasing the use of petroleum imports by switching to alternative transport fuels. In 2007, the Ministry of Mines and Energy set out the strategy for biofuels. This recognises the need to reduce imports as world oil prices rise, the desirability of lessening dependence on imports from countries affected by unrest, the need to reduce Greenhouse Gas (GHG) emissions on the one hand; and on the other, the need to make full use of Ethiopia's land and labour force. Biofuel development is thus seen as a way to promote growth and rural development, to improve the balance of trade, and to conserve the environment.

Agricultural development remains central to the country's development strategy, through raising the productivity of smallholders. In addition, private investments are welcomed with a total of 3M ha of land to be made available to investors, land mainly in the lowlands. In the highlands, close to the main cities, the aim is to encourage outgrower schemes.

Environmental policy in Ethiopia since 2002 requires that Environmental Impact Assessments (EIA) be carried out prior to approval of investments. Implementation of this has been limited. None of the companies operating in the biofuel sector made an EIA of their projects, except for one belatedly did so long after it started its biofuel development.

Kenya

Sessional Paper No. 4 of 2004 encourages renewable energy. It recognizes the potential to produce of biofuel from crops, the need to set aside land to grow energy crops while harmonising land use and energy policies, and the need to formulate frameworks to facilitate blending biofuels into transport fuels.

The Energy Act of 2006 mandates the government to pursue and facilitate the production of biofuels, even if it does not provide detail on how this will be done. It is, for example, unclear on whether biofuels can be produced or sold in the absence of clear standards from the Kenya Bureau of Standards that is directed to set fuel quality and blending standards for biofuels.

At the moment, some detail is being added in the drafts of the *Strategy for Developing the Bio-Diesel Industry in Kenya; 2008–2012* and the *Proposed National Biofuel Policy, 2010.* These legislations should act as a legal framework within which the sector will operate. For the time being, however, they remain in draft.

Under environmental regulations of 1999 and 2003, all projects have to pass through an EIA before they start.

Agricultural policy, as set out in the Strategy for Revitalizing Agriculture 2004–2014 recognises the need to support agro-processing and improve linkages between producers, suppliers, processors and market. It also recognizes the importance of new and emerging crops including biofuel feedstock. The Arid and Semi-Arid Lands policy of 2005 notes that biofuels may be produced in these areas.

Mozambique

> In May, 2009, the Mozambican government approved the National Biofuels Policy and Strategy (NBPS, 2009), and at present it is the only specific document which lays down the government's intentions for the production, consumption, and trade of biofuels and their feedstock in the country. The document is a result of government's efforts for the promotion of its vision in developing the biofuels sector in "response to the challenges" brought about due to dependency on imported fuel, and in line with the country's long-term poverty reduction strategy (NBPS, 2009: 5). Some of the motivating factors for the approval of biofuels policy are said to have been the need for the country to safeguard energy security; the advantageous agriculture conditions; and the need to promote sustainable development (ICTSD, 2009). [Mozambique country study]

The 2010 National Energy Strategy aims for sustainable and diversified energy sources. Developing biofuels fits with this. Agricultural development is central to overall development efforts, given that the large majority of the population live rurally and depend to some degree on farming for their livelihoods.

In May 2009 a National Biofuels Policy and Strategy (NBPS) was approved. It intends to promote agro-energy resources, drawing on some 450,000 ha identified as available for feedstock, aiming for energy security and sustainable development, as well as to respond to fuel price instability, unpredictability and volatility, and to reduce dependence on oil imports. Biofuels are seen as a way to reduce poverty, and to raise agricultural production and productivity.

Biofuels are intended to be produced first and foremost to replace fossil fuels in domestic production. It contemplates mandatory blending of 10% for ethanol and 5% for biodiesel for the pilot phase — not yet in force— with a possible increase to 20% for each component from 2015 to 2021, and to 100% from 2021 onwards. After that, the aim is to export, especially to SADC members in southern Africa.

The Strategy identifies land on the basis of agro-ecological mapping, although that needs to be carried out at more detailed scale.

The strategy includes some quite precise assessments of the impacts that might be generated by biofuels: reducing petroleum imports by US$15M to 20M a year, loss of revenues from tariffs and taxes of US$12M but offset by increase of around US$7M, creation of another 150,000 jobs, and the potential to export biofuels that could be worth US$450M.

Implementing, coordinating and supervising the NBPS is to be undertaken by a National Biofuels Commission (NBC) that has yet to be established. The Strategy is to be implemented in stages.

> The first is the Pilot Stage from 2009 to 2015; the main activities in this phase include sale of biofuels from national producers by the Biofuels Purchase Program. The second phase, the Operational Phase, is to begin in 2015 onwards and it will focus on consolidating the sector and increasing the blending levels. And the third stage, Extension Phase from 2011 onwards, the government envisions *"the development of separate, parallel distribution networks for vehicles that use higher percentages…"* of biofuels (NPBS, 2009). [Mozambique country study]

Although some detail has been set out, specific biofuels legislation is still required. A particular concern is the lack of legislation on blending requirements, although it is understood that a draft for this was ready in March 2011.

Mozambique illustrates how many agencies need to co-ordinate their policies for biofuels. Thus,

> the Ministry of Energy, through the National Directorate for New and Renewable Energy, is the coordinator for the National Biofuels Task Force. It is also responsible for biofuels use and blending regulations. The Ministry of Agriculture through the National Directorate for Agriculture Investment Promotion (CEPAGRI) is responsible for some project approvals, land allocation, and investment analysis; and the National Directorate for Land and Forest (DNTF) is responsible for issues related to the conservation of biodiversity as well as land zoning exercising. The Ministries of Industry and Commerce; Finance; Science and Technology are responsible for internal and external market regulations and taxes; pricing, taxes and subsidies; and technological research respectively (Lerner et al, 2010: 43). [Mozambique country study]

Biofuels development intersects with other policies. For land, Mozambique is considered to have laws that safeguard the rights of its population over land and natural resources, while promoting investments and sustainable use of resources. Investors can obtain 50 year leases on land, subject to consultation with local communities. It also requires approval of a land use plan that includes assessment of possible environmental, social and economic impacts. Provisional leases for two years may be issued while these documents are being reviewed. There is at least one case where the lease was revoked after two years, so these regulations may be applied.

Investment laws award fiscal benefits to investors with tax reductions and exemptions. These would apply to biofuels investors. It is not clear if there will be additional tax incentives to stimulate biofuels, although this is apparently under discussion.

Tanzania

'The lack of integrated policy on biofuels has caused confusion and concern amongst all stakeholders affected by biofuel production in Tanzania.' Indeed, 'A moratorium [on biofuel development] was introduced in 2008.' [Tanzania country study]

Starting with consultations in 2008, a National Biofuel Taskforce formulated *Guidelines for Sustainable Liquid Biofuels Development in Tanzania*, published in January 2011. The Guidelines establish a *Biofuels One Stop Centre,* within the Tanzania Investment Centre (TIC), responsible for the *'coordination, approval and monitoring of biofuel investments'.* A Technical Advisory Group (BTAG), to consist of *'experts in Energy, Agriculture, Natural Resources (Forestry, Wildlife), Land, Land Use Planning, Food Security, Labour, Investment, Water, Industry and Environment'* is expected to support the Centre.

The Guidelines set out procedures for application and registration for biofuel investments. Applications are made through the Centre. In addition to plans, investors need to submit an Environmental and Social Impact Assessment (ESIA).

The Guidelines also address concerns over food security, land conflicts, environmental change, and social impacts. Provisions thus include that up to 5% of any land developed should be used to grow food crops '*by applying the state of the art agricultural techniques',* that biofuels developments should contribute to local economies giving priority in jobs to local communities, and that protected areas and those of high biodiversity are not affected. Land to a maximum area of 20,000 ha is to be leased to investors for 25 years, with a 5 years probationary period.

The regulations require that investors consult with national, regional, district, village authorities and the public. The former are expected to '*contribute at least 2% of revenues in improving social services, economy and environment in the project area; and … ensure locals' shareholding in the business (in cash or land-asset or both), including the out-growers.'*

Contract farming is encouraged, with outgrowers formed into associations with contracts.

Processing of biofuels tis to be carried out within Tanzania.

No specific fiscal incentives exist for biofuels, although investors registered with the TIC would be exempt from taxes on imported machinery. Agricultural policy exempts agricultural machinery imported for agricultural projects including biofuel. There are proposals for taxes and subsidies to encourage production and use of biofuels.

The Petroleum Act of 2008 is the current guiding legislation for the blending of biofuels in Tanzania, although the government plans to add other pieces of legislation over the next 2 years. The minister for Energy is responsible for regulating blending of biofuels with petroleum products.

3.2 Commentary

Four points stand out from this review of biofuels policies in the four countries, as follows.

1. Governments have only in the last few years developed policies that respond to most of the public issues that arise with biofuels development. It remains to be seen how effectively they operate for the most part. This would apply were the policies under the control of any one ministry: but for biofuels, policy crosses at least four administrative remits — those of agriculture, energy, land tenure and environmental matters. The potential for policy incoherence is high: perhaps no more so in the degree to which the different agencies find effective ways to apply policy.
2. The intentions expressed are laudable, but there is a tension between, on the one hand, the regulations designed to prevent undesirable developments that stress prior approval and imply control and monitoring, and the aim to encourage investors as a way to create jobs and growth. In some cases, the policy seems to focus on large-scale investors and correspondingly to say less about smaller-scale initiatives. There may be a presumption that it is the large-scale investors who are to be favoured, on account of their capital and know-how. This relates to the next point.
3. Most of the policy is about regulating investment and private initiative. There is much less than might be expected on the role of the state in setting out a framework for the development of biofuels. Arguably, having a consistent, clear and credible framework — that sets out the degree to which biofuels might be used for transport and other energy uses, and measures such as

taxes, subsidies and trade rules that will be used to encourage this — is a prime concern for investors. To some extent it seems that governments expect private enterprise to take the risks of developing a new industry. The danger here is that investors will only take such risks if they can see high returns, and hence will look for ways to maximise their returns, regardless of the interests of others.

4. Civil society in all four countries is taking considerable interest in the development of biofuels, partly in the form of acting as a watchdog against possible abuses by large-scale investors. The issues that biofuels raise, however, are contentious; and made all the more so by the complexity of the systems in which biofuel developments take place that results in uncertainty. For example, does allowing feedstock production reduce or enhance food security? Clearly allocating land to biofuels potentially competes with food production, but it may create jobs and incomes that allow the food insecure to buy food; it may give farmers cash returns that can be used to buy fertiliser and otherwise intensify their food crops. Public debates on biofuel are thus always likely to be divisive: finding ways to create a broad public consensus on these matters is a challenge.

One practical measure to help ensure that biofuels developments do exacerbate poverty, hunger or harm the environment is applying standards and certifying biofuels. This is the subject of the next chapter.

4 Biofuels Certification: Good for Development?

4.1 Standards being developed in OECD countries

Mandates for blending biofuels into vehicle fuels are typically accompanied by supporting mechanisms such as subsidies and tax exemptions, tariffs to limit import competition into domestic fuel markets[5] and increasingly, standards as to how biofuels have been produced. A formidable architecture is developing on biofuels standards; certification systems to ensure their sustainable production are evolving rapidly, particularly in the major biofuels markets of the EU and US.

A fuller account of the standards being developed in the EU and US appears in Appendix C. For current pruposes this can be summarised as follows in this section.

In the European Union, the biofuel strategy (2006) and roadmap (2007) did not initially define any sustainability criteria, but since then there has been a lively debate on what should be included. Two developments affect the ability of other countries to export to the EU. One is that the 2009 Fuel Quality Directive (EC, 2009b introduces a revised biodiesel standard which fixes the iodine level required for vegetable oil used in the production of biodiesel, which in turn determines the type of feedstock that can be used. Only rapeseed oil — which is produced domestically— complies easily with this standard; soy and palm oil, less so (Oosterveer and Mol, 2010).

Two, there are environmental and social sustainability criteria to be met. The 2009 Renewable Energy Directive (EC 2009a) which entered into force in 2010 means that for biofuels to be counted towards the 10% renewable energy target, and therefore eligible for related tax incentives, they must offer at least a 35% carbon emission savings compared to fossil fuels, a figure that rises to 50% for 2017 and 60% for2018. Biofuels may not come from land with high carbon stocks: primary forest and woods, nature protection areas, highly biodiverse grassland; wetland; continuously forested areas; areas with 10–30 % canopy cover; and peatland. In addition, there are social criteria to meet as well, such as respecting labour rights and conditions, maintaining food security, and avoiding abuse of land rights. Individual member states may have their own requirements as well.

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[5] See Josling et al. (2010).

Joining voluntary schemes is one way to certify that biofuels meet these criteria: the Roundtable on Sustainable Biofuels (RSB) has applied for recognition, as have other private voluntary providers, as well as national standards established by Argentina and Brazil.

The United States' Energy Independence and Security Act (EISA) passed in 2007 set the first mandatory GHG reduction thresholds for different fuel categories, defined as first-generation or conventional ethanol production with a 20% reduction in GHG compared to gasoline, biodiesel and advanced biofuels, 50% less, and cellulosic biofuels, 60% less. In 2010 the Renewable Fuel Standard imposes GHG reduction standards based on lifecycle analysis.

Important exemptions apply however to ethanol plants in production or under construction in December 2007; as well as to feedstock harvested from agricultural lands cleared or cultivated at any time prior to December 2007, and that are actively managed or fallow, and non-forested.

The mandatory sustainability criteria developed by the US refer only to environmental matters: they and do not attempt to address other social and economic concerns.

Similar to the EU, individual states in the US also have their own regulations which could create technical barriers to trade, or reduce potential scale benefits if additional costs are involved with meeting different standards in each state. For example, Oregon excludes food crops from biofuel production; the state of California does not mandate the use of an individual fuel like the RFS but instead requires a 10% reduction in GHG per unit of energy for gasoline and diesel fuel by 2020.[6] In relation to technical requirements for biofuels, Echols (2009) notes that US standards, unlike those set in the EU, do not appear to impose any particular challenges for exporters. But the sustainability standards developed related to land-use changes and GHG emissions reductions thresholds may pose particular challenges for some exporters.

4.2 How are biofuels certification schemes evolving in ESA countries?

Biofuels certification schemes are evolving rapidly in the major markets of the EU and US, there remain areas of legal uncertainty, as well as concerns about how far these schemes may serve as formidable non-tariff barriers to potential exports of biofuels produced in ESA countries, given their technical standards and sustainability criteria.

We sought to investigate how biofuels standards and certification schemes are evolving in the selected ESA countries, the objective being to understand the implications of the associated compliance costs of schemes, enforcement mechanisms, and associated upgrading opportunities for biofuel producers in the ESA countries. There are different levels of standards development apparent in the four countries, tailored to specific markets. But as becomes apparent, because these schemes are only just developing there is a lack of evidence related to their potential costs of compliance; links to regulatory structures and enforcement mechanisms are generally quite limited.

Ethiopia

The Ministry of Mines and Energy in Ethiopia created a biofuels development and utilization strategy in 2007. Although Ethiopia has been an industrial producer of bioethanol for some time, the production of feedstock for biofuel purpose is a recent phenomena and the processing of biodiesel is at an early stage. Voluntary standards to ensure the sustainable production of biofuels are not reported as being practised; there is little evidence that industry is interested in such standards. There are no mandatory sustainability standards for the production of feedstock for biofuels.

However, because Ethiopia has introduced targets for the substitution of imported fossil fuel by domestically produced biofuels, it has developed quality and technical standards for these types of fuels and for the domestic market. The Ethiopian Quality and Standards Authority has developed

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[6] See Devereaux and Lee (2009) who also make reference to Charles (2009).

gasoline-ethanol blended fuel specification standards for the domestic market and blending requirements, in addition to others including castor seed, a potential export product (see Table 4.1).

Although there is a lack of certification systems to ensure that biofuels are produced in Ethiopia in a sustainable way, however defined, there already exist regulations on the need for Environmental Impact Assessments (EIAs) before projects are implemented, or before policies, strategies and laws are approved.

Despite the formulation of policies, strategies and proclamation, their practical implementation is considered weak. For example, none of the companies currently operating in the biofuel sectors undertook an EIA prior to project implementation. There are concerns that the lack of a coherent legal framework and guidelines, low level of public awareness of environmental concerns, and limited expertise have compromised the EIA process so far in Ethiopia. Clearly, given the ambitious targets set for the substitution of biofuels for fossil imports, these weaknesses may have the potential to become problematic in the future.

Table 4.1: Standards and specifications for castor seed in Ethiopia

Standard	Specification
Land	• Prepared timely and in such a way that a clean level seedbed is obtained • Seed fields shall be prevented from contamination and build up of soil borne disease from the same kind of crops grown in the previous season unless the seed crops grown in the previous season was a certified one of varietals purity
Field inspection	• A minimum of two shall be made for all classes of seed production at flowering and maturity
Packaging	• Sound and strong materials that maintains the original quality of seeds
Labelling	• Names of the producers, certifying agency and the variety and classes of seed • Germination in percentage • Purity in percentage • Year of production • Net Weight in KG • Batch or identification number • Moisture content
Marking	• Shall bear the quality mark upon approval

Source: Quality and Standards Authority of Ethiopia, 2001

Kenya

The Energy Act 2006 which became operational in July 2007 mandates the government to pursue and facilitate the production of biofuels. It provides rather more limited information on how this is to be achieved in practice. For example, it is unclear whether it is permissible to produce, sell or use biofuels in the absence of clear standards from the Kenya Bureau of Standards (KEBS), although the Act states that the KEBS will determine fuel quality and blending standards for biofuels.

Though the production and processing of biodiesel is yet to take place in Kenya, the government and stakeholders anticipate it in the future. In this regard, the KEBS, together with the Ministry of Energy and other stakeholders in the energy sector has drafted biodiesel and bioethanol quality and technical standards, which although still in draft, give the minimum requirements that biodiesel should meet in chemical composition, physical properties and safety as shown in Table 4.4 and 4.5 below. There are currently no certification schemes in operation in Kenya to address sustainability concerns.

Table 4.4: Physical and chemical composition of biodiesel

Property	Requirement	Test method
Sulphated ash content	0.02	ISO 3987
Alkaline content		
Free glycerol content % mass fraction, max	0.02	EN 14105, 14106
Copper stripe corrosion (3 h at 50 ^{0}C) rating, max	Class 1	ISO 2160
Methanol and ethanol content	0.2	EN 14110
Acidic number mg KOH/g, max	0.5	EN 14104
Total glycerol content % mass fraction	0.25	EN 14105
Phosphorous content mg/kg, max	10	EM14107
Carbon residue on 10 % distillation residue)	0.3	ISO 10370
Ester content (% mass fraction, min)	96.5	EN14103
Distillation temperature		
Flash point 0C, min	120	ISO 3104
Total contamination mg/kg, max	24	EN 12662
Sulphur content mg/kg, max	10	ISO 20846, ISO 0884
Cold climate operability	6	EN 116
Cetane number, min	51	ISO 5165
Oxidation stability at 110 ^{0}C, h, min	6	EN14112
Mono, di, tri, acylglycerides	0.8, 0.2, 0.2 respectively	EN 14105
Density at 20^{0}C,kg/m^{3}	860-900	ISO 3675,ISO 12185
Kinetic viscosity at 40^{0}C ,kg/m^{3}	3.5-5.0	ISO 3104
Water content and sediment %mass fraction	0.05	ISO 12937
iodine number g of iodine/100g of FAME	140	EN 14111
Linoleic acid content	12	EN 14103
Polyunsaturated methyl ester	1	

Source: KEBS, 2010

Table 4.5: Physical and Chemical Composition of Bioethanol

Property	Requirement
Colour	Colourless
Appearance	Clear
Density at 15 ^{0} C ,max	0.7961
Sulphate content	
Total Sulphur content by mass, max	0.2
copper content 3 h at 50 ^{0} C	Class 1
iron content	
sodium content	
Electrolyte conductivity	
Ethanol content % by vol at 15 ^{0} C, min	99.5
Acidity as acetic acid % by mass, max	0,006
Phosphorous content	
Ph	
Gum/ residue evaporation	0.005
Chloride content	
Water content % by volume, max	0.5

Source: KEBS, 1990

As in Ethiopia, EIA are expected for any project before it may be approved.

Mozambique

Mozambique does not currently have any national certification schemes and standards in place applicable to biofuels and their feedstock, although the Mozambican National Biofuels strategy launched in 2009 identifies nine biofuels products for development.[7] However, the country is reportedly finalising its sustainability criteria which borrow heavily from internationally recognised schemes and standards including the RSB standard, a process been undertaken with widespread consultation between the government and private sector to allay the danger that simply adopting international criteria could burden domestic producers with high compliance costs.

Because the EU and SADC are expected to be Mozambique's main international markets for biofuel exports, the standards to be selected for the country's sector will most likely be harmonised with those. Although consultations are still ongoing, the government of Mozambique is likely to adopt sustainability criteria that fall under six main principles: legalities; social responsibility; energy security; economic benefits and economic and financial feasibility; food security; agriculture productivity; and environmental protection.[8] The current draft sustainability standard is summarised in Table 6 below.

Table 4.6: Mozambique's Draft Sustainability Criteria

Framework/ Criteria	Criteria
Legalities	
Legal Framework	Biofuels shall comply with Mozambican national legislation
Water Rights	Biofuels shall respect formal and customary laws and rights relevant to use of, and access to land, water, and other natural resources
Land Rights	
Social	
Stakeholder Participation	Community consultation shall be carried out through a free, prior, informed and well-documented process that respects the rights and needs of local communities
Human and Labour Rights, and social well-being	Biofuel production, processing and use shall contribute to rural, socio-economic development of local stakeholders by generating employment and income generation
	Biofuel production, processing and use shall facilitate the responsible involvement smallholder producers
	Biofuel production, processing and use shall not violate human rights and respect for social and cultural practices
	Biofuel production, processing and use shall promote decent working conditions and well-being of workers
Food security and other biomass applications	Biofuel production, processing and use shall contribute to local and national food security, and shall be avoided in land with high food production potential
Energy Security	
	Biofuel production, processing and use shall contribute to the diversification of the energy matrix on the national level
	Biofuel production, processing and use shall contribute to energy security of local communities
	Biofuel production, processing and use shall contribute to energy transition in local communities
Economic Security & viability	

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[7] Bioethanol: Sugar cane, sorghum, cassava, maize; Biodiesel: Jatropha curcas, Coconut, Sunflower, Soya and Peanut.

[8] Each of which coincides with the major private voluntary biofuels sustainability standards, as discussed in detail in the Mozambique country report.

Macroeconomic		Biofuel production, processing and use shall be competitive and economically sustainable to create substantial benefits at the macro level
		Biofuel production, processing and use shall Ccontribute towards local prosperity
Agriculture productivity		
		Biofuel production, processing and use shall increase agriculture productivity, by continuous monitoring of production and processing efficiency and promote the use of by-products, residues and waste
Environmental		
GHG emissions		Biofuel production, processing and use shall contribute to the continuous reduction of GHG-emissions as compared to fossil fuels
Biodiversity		Biofuel production, processing and use shall avoid negative impacts on biodiversity, ecosystem functions and services, land with high conservation value, unless evidence is provided demonstrating that production does not interfere with nature protection purposes
Soil	Soil carbon stocks	Biofuel production, processing and use shall minimize negative impacts on soils quality
	Soil quality	Biofuel production, processing and use shall avoid negative impacts on air quality
Water		Biofuel production, processing and use shall avoid negative impacts on water availability and quality
Air		

Although well intentioned, at the current time it is unclear how adherence to sustainability criteria in Mozambique will actually be enforced. Although the national biofuels strategy document is relatively comprehensive and identifies the core motivations for the promotion of biofuels, links to the regulatory environment are limited and not clear at present. Despite this, the standards once developed, will apply to the planned national biofuels purchase program to be established by the government of Mozambique, as part of its strategy of reducing fossil fuel imports and substituting with domestically produced biofuels, whilst avoiding food/fuel trade-offs.

Tanzania

The official government Guidelines for Sustainable Liquid Biofuels Development in Tanzania were released in January 2011. These include an application and registration process for biofuel investments. So far areas of contention with them have mainly focused on the level of community consultation, land rights and the ways in which environmental and social impact assessments (ESIAs) are carried out.

The guidelines specify fairly generic procedures that investments in biofuels production should adhere to. For example, all applications for Biofuel Investments will be submitted to the Biofuel One Stop Centre, created within the Tanzania Investment Centre (TIC), and be subject to Environmental and Social Impact Assessment, rules that apply to all investments including biofuels.

More specific guidelines are provided to ensure food security and sustainability, as well as community engagement, which are fairly demanding (see Table 4.7). However, although guidelines have been created the links to the regulatory environment, monitoring and enforcement are not currently clear (see Table 4.7). No sustainability standards for biofuels have been implemented in Tanzania at a national level. The closest criteria that could be seen as a national standard for biofuels was drawn up by stakeholders in a workshop held by the World Wide Fund for Nature in 2008, but these have not yet been taken forward at a national level.

Table 4.7: Examples of Guidelines for Biofuels Development in Tanzania

Objective	Guidelines
Ensuring biofuels development do not result in negative impacts on food security, food and land prices, land conflicts, ecosystem change, environmental degradation, negative social impacts, decreased water availability and diminished water quality.	"30) Any biofuel development must ensure that; a. There is abidance to land use plan in order to avoid threatening potential land for food crop production/ farming/ livestock and other human needs. Areas of high biodiversity and of cultural value, protected forests game reserves, Ramsar sites and National Parks are not permitted for biofuel investments. b. Biofuel production activities contribute positively to the local economy. c. Biofuel production activities contribute positively to social well-being of employees and the local population d. Priority on employment is given to the community in the locality. 31) The production/ farming by small-scale farmers should be approved and monitored by local authorities to ensure that the proposed areas meet sustainability conditions. 32) To ensure that biofuels production has a positive impact on food production, all investors/ developers shall set up to 5% (exact figure to be issued by the One Stop Centre) of land for biofuels production to grow relevant food crops by applying the state of the art agricultural techniques. 33) All biofuel investments shall be monitored by and evaluated by the One Stop Centre to ensure that all development phases meet the sustainability criteria."
Ensuring community engagement with biofuels development.	"42) As part of public participation, investor(s)/ developer(s) shall:- a. Consult and involve the public during the feasibility study or project planning phase. Involvement shall include;- i. Regional authorities; ii. District authorities; iii. The local (village) authorities; iv. National Authorities (e.g. Ministries); and v. The Public (i.e. ordinary people). b. Provide a brief description in the feasibility study report on how the local community will be fully engaged in project(s); c. Contribute at least 2% of revenues in improving social services, economy and environment in the project area; and d. Ensure locals' shareholding in the business (in cash or land-asset or both), including the out-growers. 43. There shall be an MoU between developer(s)/ investor(s) and the relevant village authorities defining terms to develop village land that falls in the area within the identified biofuels project. 44. Carbon revenue stream emanating from biofuel farming should benefit the stakeholders through consultation with the Designated National Authority (DNA). **45.** Mainstream HIV/AIDS control and gender sensitivity in biofuel projects and programme(s)."

Source: Adapted from Tanzania country study

4.3 Summary on certification

Table 4.8 presents a framework for different types of standards, distinguishing between general principles to which all types of production and investments should adhere to, compared to specific standards to ensure the sustainable production of biofuels.

In the case of the US and EU regulations on environmental management have long been in place and are increasingly becoming built into bilateral trade agreements (known as WTO+ type agreements).

Biofuels projects are also expected to undertake environmental impact assessments in the four ESA country case studies reviewed. Although the regulatory frameworks within each of these countries are generally quite weak, they nevertheless exist.

Table 4.8: Types of Biofuels Standards and Regulatory Framework

	General	Domestic market	Domestic/export market		
	Environmental management	Technical/ quality Standards	Sustainable production of biofuels		
			Environmental	Social	Economic
EU	✓	✓	✓	✓	✓
US	✓	✓	✓		
Ethiopia	✓	✓			
Kenya	✓	✓			
Mozambique	✓	✓	✓	✓	✓
Tanzania	✓				

Targets for the substitution of biofuels for fossil fuels have been set in Ethiopia, Kenya and Mozambique, and quality standards for biofuels used in the domestic market have been developed. This is also the case in the EU and US. However, although quality standards are in place in Ethiopia, Kenya and Mozambique, only in the case of the last have efforts been made to link the development of national regulations to best international practice on sustainable biofuels production. Although Tanzania has developed guidelines on biofuels development, which includes social and economic criteria, this procedure remains verification undertaken prior to biofuels production, rather than an ongoing monitoring.

There remain concerns over the potential tensions that an increase in biofuels production might bring. How stated policy on biofuels production will be put into practice remains unclear; similarly, how any potential food-fuels trade-offs, where they might exist, might be overcome. Links to sustainability criteria and standards related to best international practice remain limited.

The development of standards to ensure the sustainable production of biofuels could help avoid the dangers of biofuels, as it has done in other regions, and indeed play a developmental role: as, for example, through procurement initiatives linked to regulatory systems, domestic biofuels targets and rural development strategies.[9] The development of such initiatives may, however, be premature within some ESA countries given the current level of policy formulation for biofuels. That the US and EU are pushing ahead with their criteria gives cause for alarm, particularly given the potential for the sustainable biofuels criteria developed for these markets to exclude more GHG efficient producers including those within the ESA region.

The biofuels sustainability schemes being developed by the US and EU distinguish between products based on where they have been produced: whether the biofuel has been produced using feedstock grown on land with a high carbon stock. Even though the EU has since moved towards the mutual recognition of private voluntary standards, as well as national schemes, including those of Argentina and Brazil, these schemes typically introduce additional social and environmental criteria over and above already stringent mandatory market access requirements. This could result in the potential

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[9] The 'Social Fuel Stamp' policy was part of a drive in Brazil to encourage and reward biodiesel production by smallholders. The fuel stamp is granted to processors who purchase from family agriculture, sign contracts with family producers and provide family farmers with training. The benefits of the Social Fuel Stamp include: tax exemption from federal taxes according to the amount purchased, low rate loans and overseas trade facilities (see Romeiro et al. 2007).

exclusion of those exporters least able to meet stringent standards based on production processes, because of technical, as well as financial, barriers, in addition to geographical location — being from region classified as having a high carbon stock.[10]

5 Trade and markets: opportunities for exporting biofuels or their feedstock

The assumption made at the start of this project was that the countries of Eastern and Southern Africa (ESA) had the potential to export biofuels (or, more probably, feedstock) to the EU. This was based upon their combination of physical and political characteristics: some of the countries of the region possess the natural resources to produce the most cost-effective biofuel feedstock and all are among the relatively small group of countries with these resources that can export to the EU without facing punitive tariff barriers.

In the event, the clear message from the four case studies is that trade possibilities are focused mainly on import substitution. Since all of the countries have large relative energy trade deficits the foreign exchange implications of the two options (exporting and import substitution) are similar, but what is interesting is the reason why our initial assumptions have been shown to be unrealistic. It illustrates key features of the current production possibility curve in the countries studied (which may well apply to a greater or lesser extent in other African states) and the inter-relationship between relevant product markets both domestically and internationally.

Why did it need case study evidence to demonstrate these characteristics? Partly it is because published data on both trade and production are often too aggregated to provide a clear guide to relative prices. Crops may be aggregated or simply overlooked, as is frequently the case with the novel feedstock being considered for biofuels such as sweet sorghum, jatropha and croton. Or, if they are shown separately, no distinction is made between biofuel and non-biofuel uses. Trade categories in particular often obscure rather than illuminate.

Table 5.1 provides details of how biofuels are treated in the trade classification system. A data supplement (in Excel) provides key figures referred to in this report for each of the four case study countries. But, in the main, these simply establish the broad context for the detailed, crop and area specific information provided by the case studies.

Table 5.1: Trade codes for biofuel constituents

Product	HS6 [a]	HS6 description
Biodiesel		
	382490	chemical products and preparations of the chemical or allied industries, incl. those consisting of mixtures of natural products, n.e.s.
Ethanol		
Undenatured	220710	undenatured ethyl alcohol, of actual alcoholic strength of >= 80%
Denatured	220720	denatured ethyl alcohol and other spirits of any strength
Bioethanol constituents		
Barley	100300	Barley
Maize	100590	maize (excl. seed)
Sugar cane	121292	sugar cane, fresh or dried, whether or not ground
Cane molasses	170310	cane molasses resulting from the extraction or refining of sugar
Wheat	ex 100190	wheat and meslin (excl. durum wheat)

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[10] The GATT period necessity test requires a member to show that there is a need to use trade impacting measures and if demonstrated, that the least trade restrictive measure had been used. These requirements constitute a difficult hurdle particularly if the disputed measure is weighed against purely hypothetical alternatives rather than those that are actually practical for environmental regulators.

Product	HS6[a]	HS6 description
Biodiesel constituents		
Soya beans	120100	soya beans, whether or not broken
Soybean oil	150710	crude soya-bean oil, whether or not degummed
	150790	soya-bean oil and its fractions, whether or not refined (excl. chemically modified and crude)
Rapeseed (aka Canola)	ex 120510	low erucic acid rape or colza seeds "yielding a fixed oil which has an erucic acid content of < 2% and yielding a solid component of glucosinolates of < 30 micromoles/g"
	ex 120590	high erucic rape or colza seeds 'yielding a fixed oil which has an erucic acid content of >= 2% and yielding a solid component of glucosinolates of >= 30 micromoles/g', whether or not broken
Rapeseed oil (aka Canola oil)	ex 151411	low erucic acid rape or colza oil "fixed oil which has an erucic acid content of < 2%", crude
	ex 151419	low erucic acid rape or colza oil "fixed oil which has an erucic acid content of < 2%" and its fractions, whether or not refined, but not chemically modified (excl. crude)
	ex 151491	high erucic acid rape or colza oil "fixed oil which has an erucic acid content of >= 2%" and mustard oil, crude
	ex 151499	high erucic acid rape or colza oil "fixed oil which has an erucic acid content of >= 2%", and mustard oil, and fractions thereof, whether or not refined, but not chemically modified (excl. crude)
Sunflower	120600	sunflower seeds, whether or not broken
Sunflower oil	ex 151211	crude sunflower-seed or safflower oil
	ex 151219	sunflower-seed or safflower oil and their fractions, whether or not refined, but not chemically modified (excl. crude)
Jatropha seed	ex 120999?	seeds, fruits and spores, for sowing (excl. leguminous vegetables and sweetcorn, coffee, tea, maté and spices, cereals, oil seeds and oleaginous fruits, beets, forage plants, vegetable seeds, and seeds of herbaceous plants cultivated mainly for flowers or used primarily in perfumery, medicaments or for insecticidal, fungicidal or similar purposes)
Jatropha oil	ex 151590?	fixed vegetable fats and oils and their fractions, whether or not refined, but not chemically modified (excl. soya-bean, groundnut, olive, palm, sunflower-seed, safflower, cotton-seed, coconut, palm kernel, babassu, rape, colza and mustard, linseed, maize, castor, tung and sesame oil)
Palm fruit	120710	palm nuts and kernels, whether or not broken
Palm kernel oil	ex 151321	crude palm kernel and babassu oil
	ex 151329	palm kernel and babassu oil and their fractions, whether or not refined, but not chemically modified (excl. crude)
Palm oil	151110	crude palm oil
	151190	palm oil and its fractions, whether or not refined (excl. chemically modified and crude)
Castor bean	120730	castor oil seeds, whether or not broken
Castor oil	151530	castor oil and fractions thereof, whether or not refined, but not chemically modified
Cotton seed	120720	cotton seeds, whether or not broken
Cotton seed oil	151221	crude cotton-seed oil
	151229	cotton-seed oil and its fractions, whether or not refined, but not chemically modified (excl. crude)
Cassava	071410	fresh, chilled, frozen or dried roots and tubers of manioc "cassava", whether or not sliced or in the form of pellets

Product	HS6 [a]	HS6 description
Coconut	080119	fresh coconuts, whether or not shelled or peeled
Coconut oil	151311 151319	crude coconut oil coconut oil and its fractions, whether or not refined, but not chemically modified (excl. crude)
Sorghum	100700	grain sorghum

Note:

(a) Not all codes shown are still valid (e.g. sugar cane is no longer has its own discrete code). However, up-to-date trade data are available (in the UN COMTRADE database) in all versions of the HS.

5.1 The trade policy context

The effect of the complex web of trade agreements to which all ESA states belong is to provide those countries able to supply bio-ethanol competitively with an incentive to sell to the EU as the primary export market; with the regional market also a potential possibility but better seen primarily as a destination for cross-border surplus disposal. This is because: the EU is a major market, prices are relatively high —as a consequence of protection for European producers — and ESA exporters are shielded from direct competition with suppliers like Brazil.

The market for biofuels is large because the EU has set targets for renewable energy production and use. It has set a legally binding target by 2020 of 20% for renewable energy sources in 'gross inland consumption', with the minimum target for biofuels at 10% of overall consumption of petrol and diesel in transport. In setting policy to achieve these targets there has been a heavy emphasis on direct and indirect support for European producers to divert into biofuel production resources that would otherwise have been used for food production (ODI 2008). This is achieved partly through a pattern of subsidies, that has evolved over time, to producers, processors or distributors; and, by standard setting, with every EU member having a different set of complex rules on denaturing, which makes compliance for imports expensive.

Crucially, it is also achieved by setting tariffs on imports from the globally most competitive states at very high levels. The EU claims not to be protectionist, pointing out that a wide range of countries have unlimited duty-free access to the European market. These include all of the countries of ESA apart from South Africa under one of three trade regimes: an Interim Economic Partnership Agreement (IEPA), an autonomous preferential regime granted by the EU since 1 January 2008 to all states that have initialled but not yet signed an IEPA, and the Everything But Arms (EBA) window of the EU's Generalised System of Preferences (GSP) for all least developed countries (LDCs).

Between them the four countries cover all of these groups which can export bioethanol to the EU duty free. Ethiopia, Mozambique and Tanzania are all EBA beneficiaries, Mozambique is also an IEPA signatory, and Kenya and Tanzania have initialled IEPAs. But whilst bioethanol (Harmonised System heading 2207) enters the EU market duty free under these preferential regimes it does not when supplied by the largest world producers such as Brazil and China. The 2010 tariff on imports from Brazil of denatured ethanol was equivalent to 15.7%.The net effect is to restrict imports of ethanol and to boost market prices in Europe above the level that would otherwise prevail. African sugar exporters also have preferential access to the USA, but due to lower tariffs this is not their preferred target market.

The same does not apply to bio-diesel feedstock. The maximum tariffs that the EU can impose on oilseeds without breaching WTO rules were set at low levels, mainly below 10%, in the 1960s and cannot now be increased. Any ESA states that attempted to export bio-diesel feedstock to the EU would face competition not only from (subsidised) European output, but also from the most competitive suppliers in the world.

One effect of this EU policy orientation to favour domestic over imported supplies when meeting its self-imposed biofuel consumption targets is to exacerbate the competition between resources used for food and energy production. An inter-agency task force charged in November 2010 by G20 leaders 'to develop options … on how to better mitigate and manage the risks associated with the price volatility of food…' has criticised *inter alia* the government support policies that have 'largely driven' the increases 2000– 2009 in global output of biodiesel (tenfold) and bio-ethanol (fourfold) at least in OECD countries. [G20 2011] It also cites the latest data for the OECD countries which indicate that 'government support still accounts for 22% of the total receipts of agricultural producers and that more than half of that support is delivered in ways that are highly distorting of trade and competition.'

5.2 What do the four ESA states produce?

In other words, were ESA (and other favoured states) to export bioethanol, but not biodiesel feedstock, to the EU they would be protected from direct competition with Brazil and other highly competitive suppliers and would benefit from the artificial stimulation to European prices that results. This is why, localised regional exports apart, the EU is presently the natural destination for any ESA biofuel exports. But the evidence is that they do not export on any scale. The precise level of European imports exclusively for biofuels is not known, as the EU's tariff codes do not distinguish between denatured ethanol for biofuel and that for other industrial uses (see Table 5.1), but there is no evidence that any of the sugar-derived imports from ESA states are for biofuel.

One reason is commercial: those ESA states with an export surplus of sugar can obtain a better price in the EU market when supplying a product for human consumption — normally raw cane sugar for further refining in the EU — than a biofuel (ODI 2008). Most ACP and least developed country producers of surplus, competitively priced sugar have industries that are geared up to supply the EU sugar market at prices that are still well above world market levels, despite recent and planned cuts (see Data Supplement). It does not make commercial sense to export low-priced ethanol feedstock rather than high priced sugar or ethanol for human consumption.

But the country case studies in this project have identified another reason: that the opportunity cost of the resources needed to produce biofuel feedstocks (given current technology and infrastructure) are greater than the returns (net of transport) from exporting. The countries studied do not only have an energy trade deficit — all of them also have a substantial cereals trade deficit and, apart from Ethiopia, a deficit in vegetable oils/oilseeds (see Data Supplement). There are alternative, trade-related uses for most of the resources used for biofuels. Moreover, prices for the alternative products from these resources are linked to a certain extent with the price for biofuel. Many soft commodity markets are linked to a greater or lesser degree so that there is some similarity in the direction and scale of price movements (albeit often with a lag).

To be economically viable, biofuels must either utilise resources that have few alternative commercial uses; or result in an output that has greater value than the other goods that could have been produced using the same resources.

Much of the initial enthusiasm for biofuels (especially biodiesel) was based on the assumption that the former condition applied: that production made use of resources that would otherwise be unused. Hence, the value of output would be largely additional to pre-existing agricultural output. The case studies suggest that this is over-optimistic: it is more often the case that the resources required for biofuels (including water) have an opportunity cost.

This change in expectations is linked to disappointing results for rainfed jatropha and other novel crops that were originally advanced as offering an opportunity to make use of unexploited resources. The gross margins are simply too low: see chapter 2. In Tanzania, Gordon-Maclean *et al* (2011) cite research showing that jatropha 'was only found to be profitable under certain conditions, never competitive with sunflower and as a result unlikely to increase employment and income in rural areas.' In Mozambique, Atanassov *et al* (2011) cite scientific evidence that jatropha needs irrigation at least in the first stages of plantation and grows best in fertile soils. They argue that

> … despite the large amount of commercial interest in Jatropha, little reliable information on yields and oil production is actually available. Little technical information is available about the crop, and as the seeds mature at different times, it is highly manually intensive needing a large amount of pruning resulting in high labour costs.

If biofuels are not additional, the task of assessing their relative attractions in each case becomes one of comparing the alternative economic and social returns from the alternatives. This needs to be done at the farm and the national levels.

At the farm level, the evidence from the case studies is that biofuels are only competitive with the alternatives under certain circumstances. In Kenya, for biodiesel feedstocks, sunflower has a slightly negative gross margin per hectare: bu even if it were positive, farmers would not sell it for this purpose, since a litre of sunflower cooking oil retails at about Ksh 200 compared to Ksh 90 for a litre of diesel. Consequently, while 'sunflower oil has been put across as one of the crops with a huge potential for biodiesel production in Kenya … due to its wide uses and high cost, the likelihood of it being used to make biodiesel is marginal.'

At the national level, a range of economic and social factors need to be taken into account. Even when narrowly defined solely in terms of foreign exchange savings, it is not always the case that using production resources to produce biofuels is advantageous. Gordon-Maclean *et al* point out that in Tanzania 'the prices of crops such as cassava and maize are linked in the medium term. If Tanzania were to start producing ethanol from cassava without increasing the supply of cassava, maize imports would increase [resulting in] …the increased price of both crops'. In 2010, Tanzania had a net trade deficit in maize of 17,812 tonnes (see Data Supplement).

When calculating gross margins in Kenya, Ndegwa *et al* only consider biofuels feedstocks production in agro-ecological zones IV to VII, which have medium to marginal agricultural use. This is to eliminate the danger of potential competition with traditional food and cash crops and the main export crops of coffee and tea. In these agro-ecological zones the main competitive uses are for production of sugar cane and cotton.

Some biofuel investment has taken insufficient account of the need to avoid direct competition with important domestic food and export crops and, in addition, has revealed the complex issues of land ownership and livelihoods that can arise. Those 'horror stories' reported in the case studies appear to reflect both institutional problems (notably corruption and inadequate monitoring) and a lack of information. The Mozambique case study cites concerns about the accuracy and reliability of the current agro-ecological zoning scheme as a basis for allocating land for new biofuel investment. The problems include:

- the mapping scale being too large to allow for more than a broad overview of land availability;
- out-dated soil suitability data with agro-climatic suitability analysis based on rainfall data from the 1980s;
- disregard in zoning of opportunities for irrigated agriculture near rivers; and,
- questionable accuracy of land availability data.

These previously under estimated problems have resulted in most of the four countries witnessing a hiatus in biofuel development. In Kenya, Ndegwa *et al.* find that farmers have been abandoning jatropha due to poor yields and lack of market for the produce. There is an absence of processing infrastructure and a policy and legal framework: farmers who harvested the seeds did not have the technical capacity to process them to oil and there was no established market.

In Tanzania there was an influx of foreign investors from 2005 looking to set up large-scale plantations of biofuel feedstock. In 2008, twenty-three biofuel projects were identified in several studies. However, controversy arose over fears about the lack of regulation. A moratorium on land acquisition for biofuels was announced and many of the proposed investments halted. Little or no ethanol or biodiesel is currently being produced in Tanzania.

It is unclear when this hiatus on investment will end: Gordon-Maclean *et al.* report that there are currently 17 projects registered for large-scale biofuel production but that the majority have no land legally committed to them, only proposed requests. But when investment does start again, its character appears likely to be rather different from that of the first wave. There seems to have been a shift from an initial focus on primarily producing biofuels for the transport sector for the markets in North America and Europe, to instead initially focusing on producing food for human consumption and then gradually, as the food demand is met, shift to biofuel production but for the local market. And not only the local transport market but also the domestic cooking fuel market.

In Mozambique, too, there was an initial flurry of interest – and a subsequent change in focus (but in the opposite direction to what was observed in Tanzania). During the national electoral campaign of 2004 the Government encouraged farmers to produce jatropha on marginal and unused lands country-wide with the goal of planting 5 ha in each of the 128 districts as a contribution to energy security, sustainable socio-economic development, agricultural stimulation and climate change mitigation. This soon attracted a number of large scale foreign and national players. By 2009, the government had received requests for 12 million hectares of state-owned land for biofuels feedstock production (although only requests for 2 million ha were considered as credible). Today the industry in Mozambique is mainly driven by such large scale investments, some ranging up to a planned 30 000 ha of biofuels plantations in the form of jatropha, coconut, sugar-cane and sorghum.

Such large scale land acquisitions, going far beyond the government's initial vision of producing biofuels feedstock on unused and marginal lands, have given rise to concerns over the potential pressures on land, water and food production. Although the government decided to freeze large-scale land requests between October 2007 and May 2008, and undertook its questionable agro-ecological zoning, the go-ahead was then given for some investments. As of December 2010, there were 48 biofuel projects, of which 23 had land in cultivation, 16 are active, 4 are in progress of beginning activities, 3 have ended activities, 4 are paralysed, and no information was obtained by the country case study on the others.

5.3 Most cost-effective trade-related uses for bio-energy

It is beyond the scope of this project to second guess the decisions made by governments over the viability of the projects that are approved, apart from passing on the case study evidence that some 'biofuel investors' could have their eyes primarily on other targets such as the value of timber felled as part of initial land clearing. At the same time, it is possible to raise the question of which areas have the potential for more rather than less cost-effective biofuel development.

The point was made in a case study that 'if an effect of the bioenergy industry would be to increase investment in agriculture, and bring new higher yielding cultivars, then this has the potential to have a net positive effect on food security and reduce fears that fuel would compete with food.' In a region where total agricultural production is well within the production possibility curve and investment markets are far from perfect it is entirely possible that funds might be available for biofuel development and not for other, higher yielding agricultural development projects.

If there is investment that is available for bio-energy but not for other agricultural uses then the question of the economic value of production *relative* to alternative uses for the land becomes less relevant than the question: if there is to be bio-energy investment where would it best be directed? The answer to this question provided by the case studies seems to be that there are four trade-related areas with the greatest apparent potential for biofuels to increase energy security without harming food security. They are investments in:

1. new production of the small number of energy crops that could reduce the foreign exchange costs of imported vehicle fuel;

2. expansion of established sugar industry to increase its contribution to energy security without damaging its contribution to foreign exchange earnings, or savings in the case of import substitution, from sugar for human consumption;
3. small scale production of (a wider range) of biofuels in remote areas where they can be a cost-effective with imported fuel; and,
4. bio-energy production (especially in remote areas) to substitute for other domestic cooking and heating materials such as charcoal and kerosene.

Cases 3 and 4 offer the greatest potential for informal cross-border trade of any surplus. Cases 1 and 2 might offer the longer term potential for more formal cross-border trade but probably only if either one country is much better endowed than its neighbour, or economies of scale do not justify more than one regional plant, or both these. In this context the word ‘regional’ is used to denote an area within which power can efficiently be reticulated that crosses national borders rather than in the usual sense of two or more states. It is possible, for example, to envisage one ‘region’ that covers parts of two states and is supplied from a facility in one of them whilst another ‘region’ covers different parts of the same two countries and is supplied by a facility that might be in the second state.

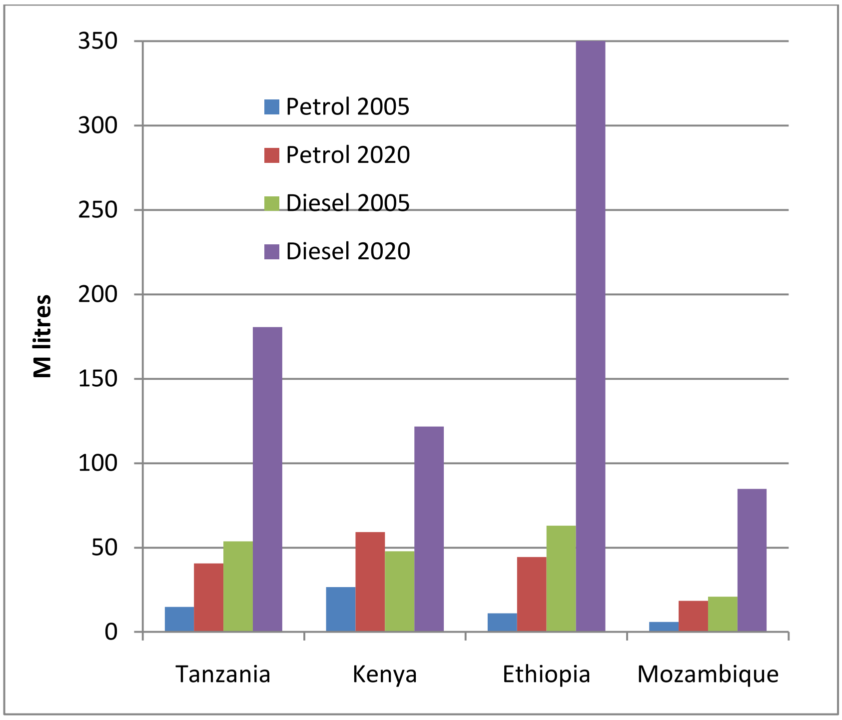
This particular example would deal with a problem that may befall other schemes that require all generation to be in one state. This is that for the consuming state the arrangement has no clear advantage over the *status quo*. Since the energy will still be imported (at a price that is likely to be related in the long run either to that of oil or of alternative outputs from the resources employed) it does not address the goals of either forex saving or increasing the return to an established industry. This partly explains why regional energy markets have not been liberalised. Kenya, for example, has since 2003 used the COMESA safeguard mechanism to protect its sugar industry from cheap imported sugar from other COMESA countries by limiting such imports; initially to an annual 200,000 tons, later increased to 220,000 tons. Although the safeguards were due to expire in March 2008 Kenya extended them until to 2012.

Investment for fuel substitution

There is considerable demand in all of the case study countries for a domestically-produced substitute for vehicle fuel, all of which is imported; the issues are primarily on the supply side. Fuel imports are not only a heavy burden on the balance of trade but costs are usually high by global standards, making it more likely that a domestic substitute would be a cost-effective substitute.

In all four countries the cost of petroleum imports is very substantial ranging in 2010 from US$501M in Mozambique to US$2,151M in Tanzania (see Data Supplement) . Aklilu 2011 states that 80% of Ethiopia’s export earnings are used to pay for petroleum imports. Gordon-Maclean *et al*. 2011 cite figures that Tanzania’s 2007 oil import bill was equal to 40% of the country’s total exports. Mozambique is similarly dependent on imports and, as it has no operating refinery, must import all supplies as finished products. In 2009 petrol consumption totalled 177 598 litres with consumption of diesel almost three times as great (accounting for 74% of the national transport fuel market in 2009). In 2009, Kenya consumed a total of 0.46 million tons or 633 million litres of petrol. Figure 5.1 shows one projection of demand for transport fuel: as can be seen, demand is expected to grow very quickly indeed through to 2020 — growth rates range from 5% a year to 12% a year.

Figure 5.1: Demand for transport fuels, 2005 and 2020, expressed as 10% blend



Source: Using data from Mitchell 2011

Note: Figure shows 10% of actual consumption to reflect the amount of biofuels that would be needed to meet a 10% blend target.

Both Ndegwa *et al.* and Gordon-Maclean *et al.* cite a November 2008 survey by GTZ which showed that petrol prices across Africa were generally double those in the USA: while crude oil prices were US$48 a barrel, the retail price was US$1.12 per litre for petrol and 1.02 per litre for diesel; prices in landlocked countries were even higher. Ndegwa *et al.* also point to forecasts that demand for transport fuels is projected to grow by more than 5.0% per year in sub-Saharan African countries during 2005–2020. Diesel consumption in Mozambique increased by 62% from 2001 to 2009 and is forecast to increase by another 55% by 2014.

All the governments in the four countries have set targets for blending domestic biofuel and imported fossil fuel. Ndegwa *et al* argue that the targets for petrol are probably feasible but question whether they can be achieved in Kenya for diesel. They cite a study done in 2008 which showed that sweet sorghum is by far the best raw material, as far as cost of raw material is concerned, for bioethanol production in Kenya: confirmed by the analysis in Chapter 2. As well as having a short crop rotation period compared to sugarcane, it is the only contending crop for which there is sufficient land suitable for its cultivation that cannot more productively be used for other crops. The current plans of the sugar companies to start ethanol production (see below) will mean there will be a huge shortage for molasses forcing a diversification into alternative raw materials with sweet sorghum the most touted option. These features more than compensate for the lower sugar content and additional processing costs of sweet sorghum compared to molasses.

To achieve the government's target of a 10% biofuel-petrol blend, 63.3M litres of imported fuel will have to be displaced by ethanol. Given the yield figures cited in the report this would require about 45,000 hectares of sweet sorghum (which would, in turn, also yield 66,000 tons of sorghum grain for consumption, more than wiping out the country's net trade deficit in sorghum in 2010 – see Data Supplement). Already, a large commercial firm has begun importing sorghum seeds from India and has been bulking seed to distribute to farmers when they start the ethanol production from sweet sorghum.

Meeting the Government's targets for biodiesel would require about 35M litres of biodiesel. Given the low yields of croton and jatropha a rough estimate is that this would require around 45,000 hectares of land (rising to 104,000 hectares to meet the eventual blend target). 'This,' the authors argue ' is a sobering reality the government will have to take into consideration before plunging into … blending because it can lead to either massive competition with other land uses to satisfy demand or collapse due to lack of feedstock.'

The physical constraints will not necessarily be so tight in the other case study countries with larger natural resource endowments. The Mozambique case study cites an estimate that the country has the potential to produce around 5.2 billion litres of ethanol and biodiesel annually, from a land area of about 1.6M ha. But even there obstacles exist. In Mozambique as in Kenya sweet sorghum is the lowest cost option (based on data from grain sorghum) followed by molasses, sugarcane and cassava. But sorghum is mainly grown in northern Mozambique and would need either to be transported or grown in the south to blend with imports in Maputo and other cities of the south. There is speculation that the south could provide suitable land for its cultivation where, as it is not traditionally used as a food crop, it may be more easily available for use in the ethanol industry (although it does have alternative uses including for animal feed). But the authors argue that 'well thought out and coordinated logistics are imperative in order to make a profit from the crop'.

Increasing value-added from existing sectors

In ESA the most obvious candidate for increasing value added in existing sectors is sugar. Ethanol production has the highest potential from sugarcane in Africa since cane growing is already taking place and the existing production technology is easily adapted to African conditions. In many countries, smallholder outgrowers are easily integrated into the system through subcontracting ensuring they receive high quality inputs, technical field support, and an assured market. The scope for the sector to contribute to energy security lies both in the use of bagasse for co-generation and in producing ethanol from molasses. Given that sugar for domestic consumption has a higher value than for biofuel, there are limits to the *share* of domestic production used for energy. But since all the case study states apart from Mozambique have a sugar trade deficit as well as a fuel deficit (see Data Supplement) there could be scope to expand sugar production further with the viability of expansion enhanced by capturing both food and energy outputs.

The sugar industry in Kenya has struggled for many years for various reasons, such as lack of accountability and transparency in the sector, poor management, excessive taxation and delayed payments to farmers to name a few. Sugar production technology in most factories is old and inefficient making sugar production to be among the highest in the continent. However, the sector has impressively recovered in the last decade due to major government reforms and increase in acreage under cane.

Ethanol production for fuel in Kenya can be traced back to 1977 with the construction of the Kenya Chemical and Food Corp (KCFC) which was aimed at producing ethanol for blending, but this did not start until 1983. In 1983, another power alcohol plant, Agro Chemical and Food Corp (ACFC) was constructed to support the national blending programme. But blending was abandoned in 1995 after the liberalization of the industry mostly due to unsustainable commercial arrangement as well as inadequate policy framework. The handling, pricing and operational logistics made the bioethanol fuel venture commercially unattractive to both the bioethanol producers and the petroleum marketers leading to its collapse.

Currently, the government is trying to revive the ethanol blending programme. Ndegwa *et al.* calculate that a total of about 90,000 hectares would be required to produce ethanol from molasses to cover the E10 blend that the government has targetted. Current production is only one-third of this targeted level: Kenya is currently producing 57,400 litres of ethanol per day equivalent to a *maximum* of 21M litres a year. This is only one-third of the national E10 blending program requirement. But planned capacity will increase this to 235,000 litres per day in the future which would yield a *maximum* per year of 86M litres. This would cover the national requirement and leave a surplus for export.

Gordon-Maclean *et al.* find that in Tanzania the price for molasses may be as little as US$0.10 per litre of ethanol, with each ton of sugar processed yielding 35 kg of molasses and a ton of molasses yielding 250 litres of ethanol. If the price of molasses is about is US$25 per ton, it contributes about US$0.10 per litre of ethanol production costs, processing costs (depends on plant scale, factory efficiencies and input costs) are 0.07 – 0.10 per litre. The ex-factory price of molasses is about US$0.17–$0.20 per litre of ethanol and is between 25 and 50% of the pretax wholesale petrol prices the imported wholesale price of gasoline in Tanzania was recorded as being US$0.35 per litre in March 2009.[11]

Growing sugar cane has the advantage that cane can be switched between milling for sugar, and distilling for ethanol as when the relative prices of petroleum products and sugar vary. Brazil has long taken advantage of this in the development of its ethanol industry based on sugar cane.

Small-scale production

One reason that fuel prices are so high in Africa is transport costs – and the more remote the region from the main port of importation, the greater are the transport costs. One very interesting finding from the case studies is that there may be scope for small-scale, local production of fuel that would be cost-effective relative to alternative resource uses precisely because of these high delivery costs for fuel supplied from the coast.

After describing the very high costs of jatropha production, Gordon-Maclean *et al.* cite Wahl:

> Is this the end to immediate cultivation of jatropha? Not at all, there is one way to avoid high opportunity costs for land and labour without the need to evade to less suitable land. It is the traditional use of jatropha as hedges and fences.

They raise the possibility that seeds could be are pressed locally which would make the costs of producing the oil competitive with vegetable oil and local fuel prices. They cite evidence that the cost of crushing seeds in a small scale facility using a mechanical press is approximately US$35 per ton of oil assuming a modest 24% of oil extraction from seed.

Fuel substitute

Bioenergy could partly displace other forms of domestic heating and cooking energy. ‘As 92% of Tanzanians use wood fuel, either charcoal or wood as their main source of energy,’ write Gordon-Maclean *et al, ‘* liquid biofuels… have a great potential to be used as a cooking fuel rather than to export it or blend it into the transport.’ Unfortunately, the most cost-effective feedstock would be ethanol which has more alternate uses than other biofuel sources.

Gordon-Macleod *et* al cite evidence that the production costs of jatropha grown in Northern Tanzania were much higher compared to fuel wood or charcoal from carbon forestry or woodlots. Jatropha oil is too expensive and too high quality energy carrier for household cooking. Its properties are better appreciated when utilized as a diesel substitute or for the production of soap, which are both highly economical.’

In areas where it can be fed directly into the transport fuel supply chain, they argue that ‘the financials favour using ethanol as a vehicle fuel’ rather than for domestic purposes. But this does raise the possibility of using bio-energy as a domestic fuel source in remoter areas, even though

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[11] This figure, however, looks remarkably low: roughly half the cost to be expected at the crude oil prices of the time.

there would be trade-offs as charcoal employs more people than ethanol and provides important employment for thousands of Tanzanians.

6 Conclusions

6.1 Summarising the main findings

The rise of oil prices since the mid-2000s may prove a blessing in disguise for eastern Africa. The costs of petroleum imports may have risen, but this provides incentives for developing biofuels to replace imported fossil fuels for transport, and to some extent, for cooking and lighting as well.

Of the four countries studied, Mozambique and Tanzania have very large areas of land currently little used that might be used to grow feedstock. Ethiopia also has land to develop, although currently parts of this are remote and access is costly. Kenya has the least unused agricultural land, but possesses large areas of semi-arid land that might be used to grow feedstock adapted to such conditions.

Economic returns to biofuel feedstock, assuming oil prices of US$90 a barrel or more, can be high for some potential feedstock, notably sugar cane and sweet sorghum — generating returns to labour of US$12 a day or more. These two crops are already cultivated widely across the region: sweet sorghum can be grown in semi-arid areas making it particularly attractive. There would thus appear to be great scope to develop ethanol plants using these feedstocks, sourced probably from outgrowers, perhaps with a nucleus estate. The resulting biofuel could then be blended into transport fuels, as well as replacing some of the kerosene currently consumed for cooking — predominantly in urban areas — and for lighting in rural areas lacking electricity.

Returns to oil crops that might be used to make biodiesel are far less attractive. Indeed, of the four oil feedstocks considered here, only croton megalocarpus seems able to generate reasonable returns — US$6 a day — to labour. Castor and sunflower have much lower returns. But then again, their oil is more valuable for industry and cooking, respectively, so that they are unlikely to be grown for biofuels. Jatropha curcas, a crop that has been highly touted as a biodiesel feedstock on account of its ability to grow in semi-arid conditions, shows marginal returns.

At first sight, then, the prospects for biodiesel are far less than for ethanol. But that needs qualification. Costs of production of croton and jatropha seed fall when these plants are grown for other purposes, as shade trees and hedges, respectively. For the rural poor, collecting oil seeds from these plants might be laborious, but may generate cash income that they could not otherwise realise. Moreover, the value of these oils will be higher when used locally, either as straight vegetable oil or processed to biodiesel, to power diesel engines and motors, than when sold for blending with diesel. The more remote the location and the higher the costs of transport to ports and major cities, the more attractive growing oilseeds for biofuel becomes.

Biofuels had been only slightly developed in the region prior to the higher oil price. Some sugar mills, although surprisingly not all, distilled the molasses by-product of sugar refining to ethanol — largely for industrial use rather than for transport fuels.

Since the cost of imported fossil fuels has risen, great interest has been shown by private enterprise and some non-governmental organisations in producing biofuels. In all four countries, but especially in Mozambique and Tanzania, investors have filed numerous applications for biofuels projects, often involving production of feedstock on large estates. To date, few of these investments are operating at scale: most are running trials on small fractions of any land they have been granted. Some have run into problems in obtaining the land they were granted, or in producing feedstock: consequently some have been abandoned. It remains to be seen whether the current low realisation of such projects is temporary, as they start up and expertise is developed; or whether there are serious obstacles to realising the plans.

NGOs have been similarly active with trial programmes, usually looking to assist small farmers to grow feedstock for local processing and use. Again, few if any of these have yet gone to significant scale.

To some extent, private initiatives have not had much support from the state. Governments have been running behind the pace of private investments in defining national strategies for biofuel development, in setting rules and regulations to guide the infant biofuel industry, and in considering what public support is needed and justified. The delay in establishing official positions on biofuels has added to the uncertainties faced by large-scale investors, small farmers and industrialists contemplating investments in feedstock and processing plants.

It is easy to see why policy development has been slow. Biofuel policy crosses at least four administrative remits: those of agriculture, energy, land tenure and environmental matters. The potential for policy incoherence is high. Moreover, there are uncertainties over the impacts of biofuels development: uncertainties that are matched by the degree of concern by civil society about the potential harm that unwise development could bring to the physical environment, to rights of poor rural people to land, to food production and security.

Governments have been trying to catch up: in the last two or three years policies have been drafted in the four countries. Generally these have laudable and attractive objectives of stimulating growth and jobs. In content, however, many policies consist of regulations designed to prevent undesirable developments that stress prior approval and imply control and monitoring. There is less than might be expected in setting out a framework for the development of biofuels. Policy also seems to focus on large-scale investors and correspondingly to say less about smaller-scale initiatives. It seems that large-scale investors are to be favoured, on account of their capital and know-how.

One particular aspect of policy that has lagged is the definitions of standards to be met if the countries were to export feedstock or biofuel to OECD countries, and the European Union in particular. Fortunately, there are signs that forums such as the Roundtable on Sustainable Biofuels may be able to develop standards and methods of certification that would meet the demanding standards that the EU is likely to demand for imports.

Civil society in all four countries is taking considerable interest in the development of biofuels, partly to act as a watchdog against possible abuses by large-scale investors. The issues that biofuels raise, however, are as contentious as they are substantial; made all the more so by the complexity of the systems within which biofuel developments take place that results in uncertainty over the impacts of different forms and degrees of development of biofuels. Public debates on biofuels are thus always likely to be divisive: finding ways to create a broad public consensus on these matters is a challenge.

For the moment it seems that developing biofuels in eastern Africa will be focused on domestic use, to replace increasingly costly fossil fuel imports. That said, the European market is growing, especially since to produce much more than is currently produced in the Union is likely to be at high cost. Most of Eastern Africa enjoys preferential access to this market, for example under the tariff-free privileges of the Everything-but-Arms initiative: competing producers of tropical biofuels such as Brazil, Malaysia and Indonesia do not have such access. Given the high tariffs that are otherwise applied to ethanol imports, there is real potential for exports of ethanol — a prospect for Mozambique and Tanzania that have considerable areas that might be developed for biofuels.

6.2 Discussion

Two interlinked points arise from these findings: one is the need for more precise information; the other is for policy-making to catch up with events on the ground — that would be facilitated with more and better information.

Information. Although much public debate on biofuels unsurprisingly focuses on prominent issues such as land rights and food security, technical understanding about agronomy, economics and markets is incomplete. The agronomy of promising feedstock such as sweet sorghum and croton megalocarpus needs testing, adaptation and dissemination: more extensive trials in different areas on farmers' fields are needed to confirm their potential. Economic and market analysis is needed that has precise data relevant for particular countries and locations within them. Most analysis to date — including that reported here — is indicative, generating estimates that may be no better than plus or minus 25% accurate: that needs improvement.

Policy: once more and accurate information is available, it should be easier for policy makers and stakeholders to discuss the options and reach agreement. The priority is to set out consistent, clear and credible strategy for biofuel development: one that indicates the degree to which biofuels might be used for transport and other energy uses, the ambitions if any for exports, and measures such as taxes, subsidies and trade rules that will be used to encourage this.

Once a framework is in place, the detail needs defining. Mitchell (2011) expands on this when considering the policies needed to development biofuels for domestic use:

> Biofuel standards would need to be defined, monitored, and enforced. Regulations would need to be developed on handling, storage, transport, and distribution. Blending facilities would be needed, and procedures, regulations, and investment incentives would need to be agreed on. Pricing, taxing, and tariff policies would be needed. Limits on blending levels of biofuels with fossil fuels must be established.

A clear framework would not only help stimulate development of biofuels; but it would also help clarify the risks that such developments run, and indicate how these could be monitored and minimised. The current situation of schemes for certification that try to address a wider range of risks, with little or no distinction between the more or less likely and the more or less serious, arguably creates unnecessary work and contributes to confused debate over the issue.

These measures would help Eastern African countries to take advantage of what this research suggests may be a major opportunity to develop new industry, to create jobs, to improve the trade balance and to reduce dependence on imported energy.

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Appendix B: Costs and returns of producing biofuel feedstock in Eastern Africa

Technical notes

The physical inputs and outputs have been largely taken from Kenya estimates. In most cases the level of input and yield is from the middle of the range.

Output has been valued by deriving the value of feedstock in terms of the international oil price. This was done as follows:

- A crude oil price of US$90 was set;
- Converted to retail pump prices that apply in OECD countries, net of tax, on the basis of observed prices from 1996 to 2008 — changes in retail prices for gasoline and diesel correlate with crude oil prices to 99% degree;
- From the pump price the costs of distribution from storage depots are subtracted —this established the value of any replacement biofuel delivered to depot;
- From these prices the costs of processing and transport of biofuel feedstock are subtracted to get an estimate of the farm-gate value of feedstock;
- But this is still expressed in US$ per litre so to get the value of feedstock per tonne, the physical conversion of feedstock to biofuel is applied.

The calculations appear below, on the following page.

The beauty of this approach is that returns to labour implicit in the physical relations can be readily derived: a feature that is attractive in farming systems when most of the labour is unpaid household labour.

Note that these valuations are *very* conservative: they assume that fossil fuels can compete with biofuel at the efficiency of transport and distribution seen in OECD countries. In reality, when fuel reaches the pump in Africa, transport and distribution have been far greater than those in OECD countries.

In addition less elegant, more straightforward calculation of the cost of production has been made.

For trees and bushes where it takes time to establish the crop, costs and returns have been discounted to present value at a rate of 10%.

Deriving the value of biofuel feedstock at the farm gate in terms of the cost of imported petroleum fuels

Biofuel:	Unit					Ethanol			
Data concerns:		Jatropha	Sunflower	Castor	Croton	Sugar cane	Molasses	Sweet Sorghum	Cassava
Pump price [see FuelP spreadsheet]	US$/litre	0.85	0.85	0.85	0.85	0.79	0.79	0.79	0.79
Transport, distribution and retail margin of fuel	US$/litre	-0.07	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Value of fuel, warehouse	US$/litre	0.78	0.73	0.73	0.73	0.68	0.68	0.68	0.68
Processing ethanol & refining	US$/litre					-0.075	-0.075	-0.075	-0.075
Transesterification, including oil refining	US$/litre	-0.14	-0.14	-0.14	-0.14				
Oil extraction	US$/litre	-0.08	-0.08	-0.08	-0.08				
Transport feedstock from farm gate to processing plant.	US$/litre	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Total, processing & transport	US$/litre	-0.25	-0.25	-0.25	-0.25	-0.11	-0.11	-0.11	-0.11
Value of biofuel, ex farm-gate	US$/litre	0.53	0.48	0.48	0.48	0.57	0.57	0.57	0.57
Conversion of feedstock, in tonnes, to biofuel, litres		293	326	521	316	75	250	40	150
Value of feedstock	**US$/tonne**	**154.35**	**156.34**	**249.71**	**151.40**	**42.79**	**142.65**	**22.82**	**85.59**
Memo:									
Oil extraction rate		0.30	0.30	0.50	0.30				
Specific gravity		0.92	0.92	0.96	0.95				

Gross margins for ethanol feedstock

Cassava

Item	Units	Quantity	Unit price, US$	Total, US$/ha
Yields	tons	10	85.59	855.89
Variable costs(A)				
Inputs				
Cuttings	no.	10000	0.01	125.00
Equipment (hoes, machete)		1	25.00	25.00
DAP fertilizer for planting	50kg bags	2	31.25	62.50
CAN fertilzer for topdressing	50kg bags	2	31.25	62.50
Sub-total				275.00
Labour (Ksh/ha)				
Land preparation	man days	20	2.50	
Planting	man days	20	2.50	
Fertilization	man days	5	2.50	
Weeding	man days	20	2.50	
Earthing up	man days	20	2.50	
Harvesting	man days	40	2.50	
Bagging and transport	man days	20	2.50	
Sub-total		145	2.50	362.50
Total variable costs (B)				637.50
Gross margin				218.39
Return to labour				4.01
Costs of production per tonne cassava				*63.75*
Cost of production per litre ethanol, distillery gate				*0.53*

Sweet sorghum

Item	Units	Quantity	Unit Price, US$	Total, US$/ha
Yields:				
Seeds	Kg	2000	0.21	425.00
Stalks	tons	35	22.82	798.83
Total income (A)				1,223.83
Variable costs				
Inputs				
Seeds	kg	10	0.25	2.50
Equipment (hoes, machete)	no.	1	25.00	25.00
DAP fertilizer for planting	50kg bags	2	31.25	62.50
CAN fertilzer for topdressing	50kg bags	2	31.25	62.50
Pesticides (Thiodan)	L	2	6.25	12.50
Pesticides (Furadine)	kg	2	15.00	30.00
Sub-total				195.00
Labour (Ksh/ha)				
Land preparation	man days	15	2.50	
Furrowing	man days	10	2.50	
Planting	man days	10	2.50	
Fertilization	man days	5	2.50	
Pest control	man days	5	2.50	
Weeding	man days	15	2.50	
Harvesting	man days	10	2.50	
Threshing, winnowing and packing	man days	10	2.50	
Sub-total		80	2.50	200.00
Total variable costs (B)				395.00
Gross margin, season				828.83
Return to labour				12.86
Cost of production, net of grain value				*403.83*
Costs of production per tonne cane				*11.54*
Cost of production per litre ethanol, distillery gate				*0.40*

Sugar cane

Plant crop	Unit	Cost, US$
Labour	days	229
Labour	US$	459
Seed	US$	310
Fertiliser	US$	224
Mechanisation	US$	823
Others	US$	279
Sub-total	US$	2,094
First ratoon		-
Labour	days	160
Labour	US$	321
Chemicals	US$	224
Machinery	US$	516
Others	US$	233
Sub-total	US$	2,735
Second ratoon		-
Labour	days	143
Labour	US$	286
Chemicals	US$	224
Machinery	US$	424
Others	US$	193
Sub-total	US$	2,414
Total costs	US$	7,243
Yields		
Plant	tonnes	128
First ratoon	tonnes	97
Second ratoon	tonnes	80
Total yield	tonnes	305
Av cost of prod	US$/t	24
Value as feedstock	US$/tonne	55
Total value	US$/ha	3,952
Gross margin	US$/ha	2,242
Return to labour	US$/day	16
Lab days	days	160

Based on physical data for Mumias rainfed outgrowers

Gross margins for food crops

Beans

Item	Units	Quantity	Unit Price, US$	Total, US$/ha
Income (A)	90kg bags	8	60.00	480.00
Variable costs				
Inputs				
Seeds	kg	25	1.25	31.25
Equipment (hoes, machete)	no.	1	25.00	25.00
DAP fertilizer for planting	50kg bags	2	31.25	62.50
CAN fertilzer for topdressing	50kg bags	2	31.25	62.50
Storage dust	50 gm bags	2	3.13	6.25
Sub-total				187.50
Labour (Ksh/ha)				
Land preparation	man days	15	2.50	
Planting	man days	10	2.50	
Fertilization	man days	5	2.50	
Weeding	man days	15	2.50	
Harvesting	man days	10	2.50	
Threshing, winnowing and packing	man days	10	2.50	
Sub-total		65	2.50	162.50
Total variable costs (B)				350.00
Gross margin				*130.00*
Returns to labour				4.5

Maize

Item	Units	Quantity	Unit Price, US$	Total, US$/ha
Yields (A)	90kg bags	17	22.50	382.50
Variable costs				
Inputs				
Seeds	kg	40	0.25	10.00
Equipment (hoes, machete)	no.	1	25.00	25.00
DAP fertilizer for planting	50kg bags	2	31.25	62.50
CAN fertilzer for topdressing	50kg bags	2	31.25	62.50
Storage dust	50 gm bags	2	3.13	6.25
Sub-total				166.25
Labour (Ksh/ha)				
Land preparation	man days	15	2.50	37.50
Planting	man days	10	2.50	25.00
Fertilization	man days	5	2.50	12.50
Weeding	man days	15	2.50	37.50
Harvesting	man days	10	2.50	25.00
Threshing, winnowing and packing	man days	10	2.50	25.00
Sub-total		65	2.50	162.50
Total variable costs (B)				328.75
Gross margin				53.75
Return to labour				3.33

Gross margins for biodiesel feedstock

Castor

Years				1	2	3	4	5	6	7	8	9	10
Yields (Kg/ha)	**kg/ha**			750	750	750	750	750	750	750	750	750	750
Income @ Ksh 20/kg (A)			**0.25**	187.28	187.28	187.28	187.28	187.28	187.28	187.28	187.28	187.28	187.28
Variable costs													
Inputs													
Seeds (10 kg @ksh 200/kg)	kg	10	2.5	25	0	0	0	0	25	0	0	0	0
Equipment (Shovels, hoes, sprayer, buckets, etc). 10% replacement cost of worn-out equipment every other year		1	61.25	61.25	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
Manure (0.5kg/tree @Ksh 1.1/kg)	kg	6500	0.014	89.38	89.38	89.38	89.38	89.38	89.38	89.38	89.38	89.38	89.38
Pest/diseases control (0.25 g/tree @ Ksh 2000/ kg)	kg	0.8125	25	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31
DAP fertilizer for planting (2, 50kg bag @ 3500	bag, 50 kg	2	43.75	87.5	0	0	0	0	87.5	0	0	0	
Sub-total				**283.44**	**115.81**	**115.81**	**115.81**	**115.81**	**228.31**	**115.81**	**115.81**	**115.81**	**115.81**
Labour (Ksh/ha)													
Land preparation (20 man days @ Ksh 200)	day	20	2.5	50	0	0	0	0	50	0	0	0	0
Planting (10 man days (year 1 and 6)@ksh.200)	day	10	2.5	25	0	0	0	0	25	0	0	0	0
Fertilization (5 mandays/year @ Ksh 200)	day	5	2.5	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Pest/diseases control (5 man days/year @ Ksh 200)	day	5	2.5	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Weeding (20 man days/year @ Ksh 200)	day	20	2.5	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Harvesting (15 man days/year @ Ksh 200)	day	15	2.5	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50
Sub-total				**187.5**	**112.5**	**112.5**	**112.5**	**112.5**	**187.5**	**112.5**	**112.5**	**112.5**	**112.5**
Total variable costs (B)				283.44	115.81	115.81	115.81	115.81	228.31	115.81	115.81	115.81	115.81
Cash flows (A-B)				**-96.16**	**71.47**	**71.47**	**71.47**	**71.47**	**-41.03**	**71.47**	**71.47**	**71.47**	**71.47**

Discount rate	**%**		**10**	0.91	0.83	0.77	0.71	0.67	0.63	0.59	0.56	0.53	0.50
Discounted cash flows				-87.42	59.56	54.98	51.05	47.65	-25.64	42.04	39.70	37.61	35.73
NPV				**255.26**									
IRR				**0%**									
NPV annual equivalent				**25.53**									
PV costs of production				**257.67**	**96.51**	**89.09**	**82.72**	**77.21**	**142.70**	**68.13**	**64.34**	**60.95**	**57.91**
Output, discounted				**681.82**	**625.00**	**576.92**	**535.71**	**500.00**	**468.75**	**441.18**	**416.67**	**394.74**	**375.00**
Average cost of production	**US$/tonne**			**198.82**									
Annual average costs production				**377.92**	**154.42**	**154.42**	**154.42**	**154.42**	**304.42**	**154.42**	**154.42**	**154.42**	**154.42**
Average cost of production, biodiesel	US$/litre			0.63									
Labour	day			75	45	45	45	45	75	45	45	45	45
Labour, discounted	**day**			68	38	35	32	30	47	26	25	24	23
PV, labour	day			346.97									
Labour costs, discounted				170.45	93.75	86.54	80.36	75.00	117.19	66.18	62.50	59.21	56.25
PV labour cost				867.42									
Return to labour				2.50									

Croton megalocarpus

Years	Unit	Q ty	Unit costs, US$	1	2	3	4	5	6	7	8	9	10
Yields (Kg/ha)	**kg/ha**			0	600	1200	2400	4000	5600	7200	8400	9200	10000
Icome @ Ksh 6/kg (A)			**0.15**	0	90.8	181.7	363.4	605.6	847.8	1,090.1	1,271.8	1,392.9	1,514.0
Inputs (KSh/Ha)													
Seedlings (500 @ksh 25/seedling)	Seedling	500	0.31	156.25	0	0	0	0	0	0	0	0	0
Equipment (Shovels, hoes, sprayer, buckets ,etc). 10% replacement cost of worn-out equipment every other year		1	61.25	61.25	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
Manure (2.5kg/tree @Ksh 1.1/kg)	kg	2500	0.014	34.38	34.38	34.38	34.38	34.38	34.38	34.38	34.38	34.38	34.38
Pest/diseases control (3 g/tree @Ksh 2000/ kg)	kg	3	25	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00
DAP fertilizer for planting (2, 50kg bag @ 3500)	bag, 50 kg	2	43.75	87.50	87.50	87.50	87.50	87.50	87.50	87.50	87.50	87.50	87.50
Sub-total				**414.38**	**203.00**	**203.00**	**203.00**	**203.00**	**203.00**	**203.00**	**203.00**	**203.00**	**203.00**
Labour (Ksh/ha)													
Land preparation (20 man days @ ksh 200)	day	20	2.5	50	0	0	0	0	0	0	0	0	0
Planting (20mandays @ksh.200)	day	20	2.5	50	0	0	0	0	0	0	0	0	0
Fertilization (5 mandays/year @ Ksh 200)	day	5	2.5	12.5	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Pest/diseases control (twice, 5man days/year @ Ksh 200)	day	10	2.5	25	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Pruning (12 man days @ Ksh. 200)	day	12	2.5	30	30.00	30.00	30.00						
Weeding (20 man days/year @ Ksh 200 first four years)	day	20	2.5	50	50.00	50.00	50.00						
Harvesting	day			0	5.00	10.00	15.00	30	40	50	60	70	80
Harvesting @ Ksh 200/ man day			2.5	0	12.5	25	37.5	75	100	125	150	175	200
Sub-total				**217.5**	**130**	**142.5**	**155**	**112.5**	**137.5**	**162.5**	**187.5**	**212.5**	**237.5**
Total variable costs (B)				631.88	333.00	345.50	358.00	315.50	340.50	365.50	390.50	415.50	440.50
Cash flows (A-B)				**-631.88**	**-242.16**	**-163.82**	**5.36**	**290.11**	**507.35**	**724.59**	**881.27**	**977.40**	**1,073.5**

													2
Discount rate	**%**		**10**	0.91	0.83	0.77	0.71	0.67	0.63	0.59	0.56	0.53	0.50
Discounted cash flows				-574.43	-201.80	-126.01	3.83	193.40	317.09	426.23	489.60	514.42	536.76
NPV				**1,579.09**									
NPV annual equivalent				**157.91**									
PV costs of production				**574.43**	**277.50**	**265.77**	**255.71**	**210.33**	**212.81**	**215.00**	**216.94**	**218.68**	**220.25**
Output, discounted				**-**	**500.00**	**923.08**	**1,714.29**	**2,666.67**	**3,500.00**	**4,235.29**	**4,666.67**	**4,842.11**	**5,000.00**
Average cost of production	**US$/tonne**			**95.10**									
Annual average costs production				**#DIV/0!**	**555.00**	**287.92**	**149.17**	**78.88**	**60.80**	**50.76**	**46.49**	**45.16**	**44.05**
Average cost of production, biodiesel	US$/litre			0.55									
Labour	day			87	52	57	62	45	55	65	75	85	95
Labour, discounted	**day**			79.09	43.33	43.85	44.29	30.00	34.38	38.24	41.67	44.74	47.50
PV, labour	day			447.07									
Labour costs, discounted				197.73	108.33	109.62	110.71	75.00	85.94	95.59	104.17	111.84	118.75
PV labour cost				1,117.67									
Return to labour				6.03									

Jatropha curcas

Years	Unit	Qty	Unit costs, US$	1	2	3	4	5	6	7	8	9	10
Yields (Kg/ha)	**kg/ha**			0	0	0	2000	2500	3000	3500	4000	4000	4000
Income @ Ksh 15/kg (A)	**US$/ kg**		**0.15**	0	-	-	302.8	378.5	454.2	529.9	605.6	605.6	605.6
Variable costs													
Inputs (KSh/Ha)													
Seeds (3 kg @ksh 775/kg)	kg	3	9.69	29.06	0	0	0	0	0	0	0	0	0
Equipment (Shovels, hoes, sprayer,buckets,etc). 10% replacement cost of wornout equipment every other year		1	31.25	31.25	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13
Manure (1.2kg/tree @Ksh 1.1/kg)	kg	1200	0.014	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50
Pest/diseses control (3 kg furadine @ Ksh 1200/ kg)	kg	3	15	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Sub-total				**121.81**	**64.63**	**64.63**	**64.63**	**64.63**	**64.63**	**64.63**	**64.63**	**64.63**	**64.63**
Labour (Ksh/ha)													
Land preparation (ox)@ ksh. 3000/ha	day	1	37.5	37.50	0	0	0	0	0	0	0	0	0
Planting (6 mandays @ksh.250)	day	6	2.5	15.00	0	0	0	0	15	0	0	0	0
Fertilization (5 mandays/year @ Ksh 250)	day	5	2.5	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Pest/diseses control (4 man days/year @ Ksh 250)	day	4	2.5	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Weeding (12 man days/year @ Ksh 250)	day	12	2.5	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Harvesting @ 30 kg/day	*day*	*30*		-	-	-	*66.67*	*83.33*	*100.00*	*116.67*	*133.33*	*133.33*	*133.33*
Harvesting @ ksh.250/man day			2.5	-	-	-	166.67	208.33	250.00	291.67	333.33	333.33	333.33
Sub-total				**105.00**	**52.50**	**52.50**	**219.17**	**260.83**	**317.50**	**344.17**	**385.83**	**385.83**	**385.83**
Total variable costs (B)				226.81	117.13	117.13	283.79	325.46	382.13	408.79	450.46	450.46	450.46
Cash flows (A-B)				**-226.81**	**-117.13**	**-117.13**	**19.01**	**53.05**	**72.08**	**121.11**	**155.15**	**155.15**	**155.15**

Discount rate	**%**		**10**	0.91	0.83	0.77	0.71	0.67	0.63	0.59	0.56	0.53	0.50
Discounted cash flows				-206.19	-97.60	-90.10	13.58	35.36	45.05	71.24	86.19	81.66	77.57
NPV				**16.77**									
IRR				**0%**									
NPV annual equivalent				**1.68**									
PV costs of production				**206.19**	**97.60**	**90.10**	**202.71**	**216.97**	**238.83**	**240.47**	**250.25**	**237.08**	**225.23**
Output, discounted				**-**	**-**	**-**	**1,428.57**	**1,666.67**	**1,875.00**	**2,058.82**	**2,222.22**	**2,105.26**	**2,000.00**
Average cost of production	**US$/tonne**			**150.15**									
Annual average costs production				**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**141.90**	**130.18**	**127.38**	**116.80**	**112.61**	**112.61**	**112.61**
Average cost of production, biodiesel	US$/ litre			0.76									
Labour	day			27	21	21	88	104	127	138	154	154	154
Labour, discounted	**day**			25	18	16	63	70	79	81	86	81	77
PV, labour	day			594.86									
Labour costs, discounted				95.45	43.75	40.38	156.55	173.89	198.44	202.45	214.35	203.07	192.92
PV labour cost				1,521.25									
Return to labour				2.56									

Appendix C: Biofuel certification in the European Union and the United States

The inclusion of sustainable development criteria within the certification schemes developed in the major biofuels markets of the EU and US is a recent phenomenon which came about most notably because of concerns in 2008 over food price rises and the role of biofuels production — Mitchell, 2008; Rosegrant, 2009 — in contributing to these increases. Because of this, efforts to integrate sustainability criteria within biofuels certification so as to address such as aspects as land-use change, and therefore better identify and prevent food/fuel trade-offs, have gathered pace since 2008. But many of the schemes developed go beyond these concerns and also include other indicators on environmental social and economic criteria. The following section critically analyses the extent to which the schemes being developed in the EU and US are actually able to meet their objectives in terms of ensuring sustainable biofuels production.

European Union

The EUs biofuel strategy (2006) and roadmap (2007) did not initially define any sustainability criteria,[12] but since then there has been a lively debate on what should be included. The EU sustainability criteria and associated verification systems were expected to be finalised by the end of 2010 in order to meet the deadlines set out in the Renewable Energy Directive (EC 2009a) which establishes ambitious targets for all member states in relation to the use of renewable energy and biofuels.[13] There are a number of contentious areas in relation to the EU's proposed sustainability criteria, which are additional concerns over and above those already raised regarding the recently amended Fuel Quality Directive (EC, 2009b). This is because the Directive introduces a revised biodiesel standard which fixes, among others, the iodine level required for vegetable oil used in the production of biodiesel, which in turn determines the type of feedstock that can be used; only rapeseed oil —which is produced domestically— complies easily with this standard; soy and palm oil, less so (Oosterveer and Mol, 2010).

The new regulations tighten quality standards fuel. They permit higher levels of ethanol blends in petrol: from 5% to 10%. In addition, they introduce a new limit for the levels of fatty acid methyl esters (FAME) in diesel. Whereas the biodiesel standards in Brazil and the U.S. are applicable to both FAME and fatty acid ethyl esters (FAEE), the current European biodiesel standard is only applicable to the former. Although these new regulations form part of the EU's single market legislation and are intended to eliminate technical barriers to trade within the EU, there are concerns that the revised biodiesel standards are slanted in favour of EU products and could therefore constitute a technical barrier to trade for other third-party suppliers. Despite this, the Commission posits the policy amendments as not only increasing the use of biofuels within the European market, but also delivering on GHG emissions savings (see Table C1).[14]

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[12] The policy objectives were stated as: 1. reducing greenhouse gas emissions; 2. boosting the decarbonisation of transport fuels; 3. diversifying fuel supply sources and developing long-term replacement fuels; and 4. offering new opportunities to diversify income and employment in rural areas. In its 2006 Strategy, the Commission recognised the economic and environmental benefits for several developing countries from the production of biofuels from suitable feedstocks: it could create additional employment, reduce energy bills and open up potential export markets, as well as offer a feasible alternative for some sugar-producing countries affected by reform of the EU sugar regime (see Stevens and Keane, 2008).

[13] The EU will reach a 20% share of energy from renewable sources by 2020; 10% share of renewable energy specifically in the transport sector. It also establishes sustainability criteria for biofuels. See http://ec.europa.eu/energy/renewables/index_en.htm for introduction and overview.

[14] For example, the IPC (2006:30) note that "the EU biodiesel standard while not premised on the use of rapeseed oil might as well be".

Table C1: Summary of Changes for Biofuels Quality

Blending requirements for bioethanol	Petrol is currently limited to a maximum ethanol content of 5% by volume due to perceived vehicle operability issues with higher proportions of ethanol. The Directive increases the permitted limit to 10% ethanol (E10). This will enable increased use of bioethanol in petrol, leading to a reduction in greenhouse gas emissions from petrol.
Blending requirements for bioethanol	A new limit of 7% by volume on the FAME content of diesel is introduced, up from 5%. This revision reflects the current position of vehicle manufacturers - blends with up to 7% biodiesel content are compatible with both the existing diesel vehicle fleet and new models. The increased use of biodiesel is posited to help reduce lifecycle greenhouse gas emissions from diesel. Member States are however permitted to allow marketing of diesel with more than 7% FAME content and this is reflected in draft regulation 6 which permits such fuels to be marketed.

Source: Adapted from Baker (2010).

The sustainability criteria introduced in the Renewable Energy Directive (EC 2009a) which entered into force in 2010, means that for biofuels to be counted towards the 10% renewable energy target, and therefore eligible for related tax incentives,[15] they must offer at least a 35% carbon emission savings compared to fossil fuels. This figure rises to 50% as of 2017 and 60% as of 2018. This Directive makes both the biofuels targets and related sustainability standards, mandatory. It introduces a mechanism for reporting reductions of life-cycle greenhouse gas emissions from fuel: biofuels producers and importers are responsible for showing that environmental and social criteria have been fulfilled; verification is left to member states.[16]

According to the Directive, 'biofuels' means liquid or gaseous fuel for transport produced from biomass; 'bioliquids' includes viscous liquids such as waste cooking oil, animal fats, palm oil, crude tall oil and tall oil pitch. Default values for greenhouse gas savings may be used, but rules are also detailed on the calculation of actual values.[17] For the calculation of emissions from 'cultivation', the method allows for the use of averages (for a particular geographical area) as an alternative to actual values (noted as particularly useful for feedstocks where no default value exists).[18] The Directive also identifies categories of land with high carbon stocks. If land fell into one of these categories in January 2008, raw material for biofuels/bioliquids should not be taken from the land. For example, raw material should not be obtained from:

- primary forest and other (primary) wooded land;
- designated nature protection areas;[19]
- highly biodiverse grassland;
- wetland; continuously forested areas;
- areas with 10–30 % canopy cover; and

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[15] Biofuels not meeting these criteria can still be imported and used, but are unlikely to be marketable given that biofuel prices are well above fossil fuel prices and therefore not competitive without incentives (See Lendle and Schaus, 2010).

[16] The rules for certification schemes and what they must do in order to be recognised by the Commission were outlined in the following documents: Communication on voluntary schemes and default values in the EU biofuels and bio-liquids sustainability scheme (EC, 2010a); Communication on the practical implementation of the EU biofuels and bio-liquids sustainability scheme (EC, 2010b); and Guidelines for the calculation of land carbon stocks (EC, 2010c).

[17] The fossil fuel comparator to be used at present for biofuels is 83,8 g CO 2 -eq/MJ (see EC, 2010b).

[18] Member States can draw up lists of such average values, which may be incorporated into voluntary certification schemes.

[19] The Commission intends to establish in 2010 the criteria and geographic ranges to determine which grassland can be considered to be highly biodiverse grassland.

- peatland.

Evidence of compliance with the land-related criteria may take different forms, such as aerial photographs, satellite images, maps, land register entries/databases and site surveys. Sustainability criteria relating to greenhouse gas savings, land with high biodiversity value and land with high carbon stock may be proved in the following ways:

- by providing the relevant national authority with data, in compliance with requirements that the Member State has laid down (a 'national system');
- by using a 'voluntary scheme' that the Commission has recognised for the purpose; or
- in accordance with the terms of a bilateral or multilateral agreement concluded by the Union with third countries and which the Commission has recognised for the purpose.

For a voluntary scheme to be recognised by the Commission it must address all of the sustainability criteria set out in the Directive, but may also cover other sustainability issues related to other social or economic concerns. Voluntary schemes had to make a submission to the commission in June 2010 in order to be recognised. The Roundtable on Sustainable Biofuels (RSB) submitted an application, as did other private voluntary providers, as well as national standards established by Argentina and Brazil.

Figure C1 summarises how sustainability criteria will be proved in the EU market in relation to imported biofuels. In sum, this regulatory approach will establish mechanisms at the Union level to help reduce the proliferation of sustainability standards. This 'meta-standard' approach relies heavily on voluntary certification schemes and is an example of regulatory 'out-sourcing' to private actors in European clean development governance (Lin, 2010). However, although some harmonisation of sustainability standards is expected, EU member states still maintain a number of their own including in relation to blending requirements.[20]

Figure C1: How will sustainable use of biofuels be proved?

A UK fuel supplier who is using ethanol from Brazil has to notify the quantities of biofuels to the UK authorities. To show that they are sustainable according to the Directive, the supplier can join a voluntary scheme.
The fuel supplier has to make sure that throughout the production chain all records are kept, by the trader he buys the biofuels from, by the ethanol plant the trader buys the ethanol from, and by the farmer who supplies the ethanol plant with sugar cane. This control is done before the company joins the scheme and at least once a year thereafter.
Auditing is done as in the financial sector: the auditor checks paper records and inspects a sample of the farmers, mills and traders. Checks include whether the land where the feedstock for the ethanol is produced has been indeed farm land before and not a tropical forest. It is not obligatory for a certification scheme to mark the end product with a label.
Source: Adapted from Memo, 10 June 2010, Commission Sets Up System for Certifying Sustainable Biofuels http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/10/247&format=HTML&aged=0&language=en&guiLanguage=en

In the UK, supply of biofuels is encouraged by the Renewable Transport Fuels Obligation (RTFO). The RTFO requires 3.25% (by volume) of transport fuels to be delivered from renewable sources by

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[20] Germany has its own biofuels sustainability ordinance. Other bilateral agreements exist between Sweden's largest bioethanol importer and Brazilian producers (see Devereaux and Lee, 2009).

2009/10.[21] Reporting under the UK RTFO is similarly based on a meta-standard approach to sustainability, which includes environmental and social principles.[22] The current list of qualifying standards that are recognized by the UK Renewable Fuels Agency (RFA) are summarised in Table C2.[23] The assurance schemes can broadly be broken down into two groups: those developed with biofuels in mind, often focusing on a particular feedstock such as the Roundtable on Sustainable Biofuels (RSB) and those designed with a broader agricultural remit, such as Linking Environment and Farming (LEAF). The latter has been specifically designed for production systems within the European Union. In comparison, the former is currently undertaking a number of pilots within sub-Saharan Africa so as to be able to adapt its standard to local circumstances, whilst ensuring adherence to the general principle of UK and EU meta-standards.

The RSB aims to be the "one-stop shop" for compliance with various regulations and seeks to be recognised by market regulators, such as the EU.[24] Its principles and criteria for sustainable biofuels, include criteria such as “biofuels shall not violate human rights or labor rights, and shall ensure decent work and the well-being of workers” and “biofuel production shall not impair food security” amongst others. That is, this standard includes not only environmental criteria, but also social and economic. In relation to recent efforts to benchmark the RSB with the new rules included in the EU Renewable Fuel Directive (2009a) the main aspects that the RSB needs to cover in Version 2.0 of its standard are related to land-use changes; more specifically, certifying that biofuels have not been produced on land with high biodiversity or high carbon stock. The RSB methodology for the calculation of lifecycle GHG emissions is still underway. Based upon the information obtained from the pilot tests undertaken in 2010 it is expected that a single GHG emission reduction threshold value will be set.[25]

Table C2: Qualifying Standards in the UK RTFO

Assured Combinable Crops Scheme (ACCS)	Part of the UK’s broader Red Tractor assurance scheme and a wholly owned subsidiary of Assured Food Standards (AFS), the ACCS standard is part of an initiative with a wider reach than simply biofuel feedstocks. It is a standard adopted by some 78,000 British farmers and growers, only a small proportion of whom are currently involved in biofuel production and supply.
The Basel Criteria for Responsible Soy Production (Basel)	Drawn up by specialist consultants ProForest for Co-op Switzerland with input from conservation NGO WWF. The Basel criteria represented the first steps towards providing an international benchmark against which social, environmental and economic impacts of soy production could be measured. While growing soy according this standard is still a theoretical possibility, it has been effectively superseded by the RTRS scheme, which has been developed by many of the same stakeholders.
Bonsucro (formerly know as the Better Sugar Cane Initiative (BSI))	A global standard being developed by a round table formed of industry, finance and NGO representatives. It aims to reduce negative environmental and social impacts of sugar cane production. Designed for the wider sugar industry – including the food and drink sector, not solely for those focusing on the production of bioethanol.
Forest Stewardship Council (FSC)	One of the first major international sustainability standards, the standard focuses on forest products such as timber used for biomass and cellulosic ethanol. FSC says it plans to expand into non-timber related areas that impact on forestry – including biofuels.
Genesis Quality Assurance (Genesis	A sister scheme to ACCS, Genesis has a number of British-based farm assurance standards covering both livestock and crops. The one of importance to the biofuels sector is its arable and

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[21] The Renewable Transport Fuel Obligation (Amendment) Order 2009, pursuant to the Energy Act 2004, “Amendment of Article 4 (the renewable transport fuel obligation)”. See Lin (2010).

[22] These include environmental principles such as ‘biomass production will not destroy or damage large above or below ground carbon stocks’ as well as social principles such as ‘biomass does not adversely affect workers rights and working relationships’. These principles are summarised here: http://www.renewablefuelsagency.gov.uk.

[23] Not all of these schemes are operational at the time of writing yet.

[24] See http://energycenter.epfl.ch/page85866.html

[25] See: http://www2.epfl.ch/webdav/site/cgse/shared/Biofuels/Version%20One/Version%201.0/09-11-17%20RSB%20PCs%20Version%201%20%28clean%29.pdf

QA)	sugar beet standard.
Linking Environment And Farming (LEAF)	A UK-based kitemark scheme promoting environmentally-responsible farming. Standards are designed to be applicable anywhere in the world.
Roundtable on Sustainable Biofuels (RSB)	The RSB is a global organisation made up of representatives from agriculture, industry, NGOs, governments and expert bodies concerned with the sustainability of biofuel production and processing. Its tight focus on biofuels combined with broad scope covering all feedstocks makes it unusual – and set to be a major player in this field as its standards develop.
Roundtable on Sustainable Palm Oil (RSPO)	Palm oil has proved to be the most controversial feedstock to date and is widely used by food producers as well as for biofuel. The RSPO is a cross-sector roundtable representing industry, NGOs, banks and investors, set up to address the "urgent and pressing global call for sustainably produced palm oil".
Round Table on Responsible Soy (RTRS)	A global organisation with representatives from producers, industry, the finance sector and civil society groups. Initially used Basel criteria but has since been developing its own standard that could be used by soy producers around the world. It was one of the first bodies to apply for EU approval for its standard in preparation for RED implementation.
Sustainable Agriculture Network/Rainforest Alliance (SAN/RA)	Emerging from Central and South American origins, this standard is now used around the world and is designed to cover a range of agricultural practices, not just the production of biofuel feedstocks. The SAN is made up of a number of environmental NGOs, principally those active in Latin America, and was set up by the Rainforest Alliance to 'link responsible farmers to conscientious consumers'.

Source: http://www.renewablefuelsagency.gov.uk/page/qualifying-standards-summary

The United States

The United States' Energy Independence and Security Act (EISA) passed in 2007 set the first mandatory GHG reduction thresholds for different fuel categories in the country. The legal requirements set out under the Renewable Fuel Standard (RFS1) specify yearly volume standards for cellulosic biofuel, biomass-based fuel and advanced biofuel, and also provide for environmental goals. For renewable fuels to count towards the US blending mandates they must reduce emissions as follows:[26]

- first-generation or conventional ethanol production must emit 20% less GHG than gasoline;
- biodiesel and advanced biofuels, 50% less; and,
- cellulosic biofuels, 60% less.

Corn ethanol plants that produced bioethanol or were under construction as of December 2007 are 'grandfathered' or exempted from this rule. The rule states that feedstock harvested from agricultural lands cleared or cultivated at any time prior to December 2007, and that are actively managed or fallow, and non-forested, will be exempt from the GHG restriction. This exemption weakens the environmental standards, given that bioethanol produced from maize is consistently identified as being one of the least GHG efficient crops (Keane and Stevens, 2008), and that diversion of maize from grain markets to bioethanol has been identified as contributing to the dramatic increase in food prices in 2008 (Mitchell, 2008). The mandatory sustainability criteria developed by the US refer only to environmental matters: they and do not attempt to address other social and economic concerns.

Other changes to the RFS made in 2010 — moving from RFS1 to RFS2 — include new volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel; definitions and criteria for both renewable fuels and the feedstocks used to produce them; and, new GHG thresholds for

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[26] The Energy Policy Act (2005) established the standard which required the use of blending of biofuels in the nations transport fuel supply; specifically it mandated the use of 7.5billion gallons of renewable fuel by 2012 (Devereaux and Lee, 2009).

different types of renewable fuels. The EISA mandates the Environmental Protection Agency (EPA) to apply lifecycle GHG performance threshold standards to ensure that each category of renewable fuel emits lower emission than the petroleum fuel it replaces. These changes result in four separate standards for different types of biofuels, which are linked to the results of lifecycle GHG analysis for specific products:[27]

- **Cellulosic Biofuel:** Includes renewable fuel produced from cellulose, hemicellulose, or lignin, e.g. cellulosic ethanol, BTL diesel, green gasoline, etc. Must meet a 60% lifecycle GHG threshold.
- **Biomass-Based Diesel:** Biodiesel, BTL diesel, 'renewable diesel' if fats and oils not co-processed with petroleum. Must meet a 50% lifecycle GHG threshold.
- **Advanced Biofuel:** Includes cellulosic biofuels and biomass-based diesel plus an additional 4 billion gallons (essentially anything but corn starch ethanol). Must meet a 50% lifecycle GHG threshold.
- **Total Renewable Fuel:** Must meet 20% lifecycle GHG threshold. Only applies to new fuel production capacity (since December 2007).

The RFS2 essentially changes how data on emissions from biofuels are calculated compared to RFS1.[28] It assesses each biofuel based on its assumed GHG emissions in the year 2022, the deadline by which renewable fuel production must be at levels mandated by the ESIA.[29] To calculate reference figures related to GHG reductions thresholds, ten countries were analysed with satellite imagery: Argentina, Brazil, China, EU, India, Indonesia, Malaysia, Nigeria, Philippines and South Africa.[30] In terms of GHG reductions, soy-based biodiesel, sugarcane and corn-based ethanol produced using advanced technologies all conform to the EPA's standards. Biodiesel made from waste grease, oils and fats also passed. Should the EPA determine in a future rulemaking that other types of fuel meet certain GHG reduction thresholds such as canola oil, grain sorghum, pulpwood, or palm oil as a feedstock, the revised regulation may be applied retrospectively.[31]

Similar to the EU, individual states in the US also have their own regulations which could create technical barriers to trade, or reduce potential scale benefits if additional costs are involved with meeting different standards in each state. For example, Oregon excludes food crops from biofuel production; the state of California does not mandate the use of an individual fuel like the RFS but instead requires a 10% reduction in GHG per unit of energy for gasoline and diesel fuel by 2020.[32] In relation to technical requirements for biofuels, Echols (2009) notes that US standards, unlike those set in the EU, do not appear to impose any particular challenges for exporters. But the sustainability standards developed related to land-use changes and GHG emissions reductions thresholds may pose particular challenges for some exporters.

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[27] See http://epa.gov/otaq/renewablefuels/420f09024.htm.

[28] Appendix D presents how life cycle GHG analyses were calculated for each type of fuel, the simulation models used and the results for each fuel type. Data on land-use changes come from MODIS satellite data (validated by NASA). The resultant emissions calculations follow IPCC guidance and use the latest available information to determine the carbon content of different types of lands at regional levels by country.

[29] The recent recalculation by the EPA of the lifecycle emissions of corn ethanol found it to be 20% less GHG emitting than gasoline, therefore it qualified as a renewable fuel. This assessment was however, based on strong assumptions which include expected increases in the yields of corn crops and improvements in bio-refining technology by 2022. See Pew Centre (2010).

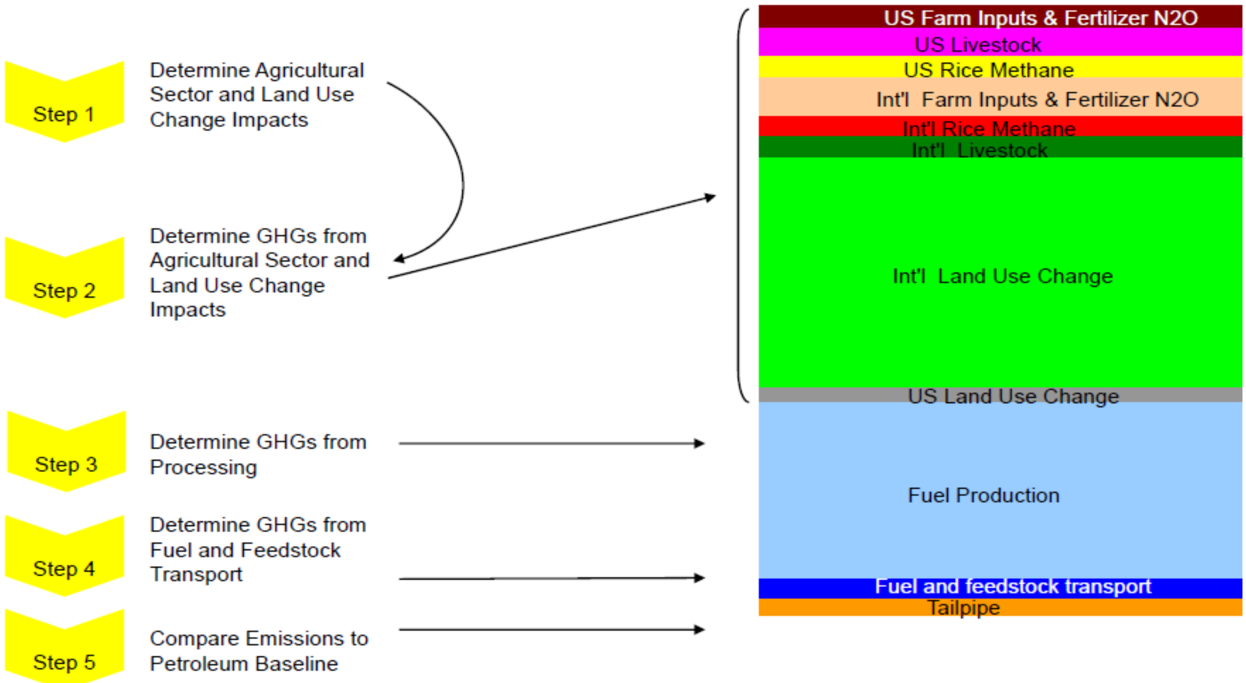
[30] Other countries were assigned a weighted average of the covered countries; over time satellite data for all remaining countries will be used to update these estimates.

[31] Major refiners, blenders and importers had submit applications for consideration under the EPAs expanded renewable fuels standard program in 2010 for consideration within the scheme. See: http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm

[32] See Devereaux and Lee (2009) who also make reference to Charles (2009).

Appendix D: Lifecycle GHG Analysis in the US

Figure D.1: Calculation of Lifecycle Analysis for Renewable Fuels in the US



Source: EPA (http://client-ross.com/lifecycle-workshop/)

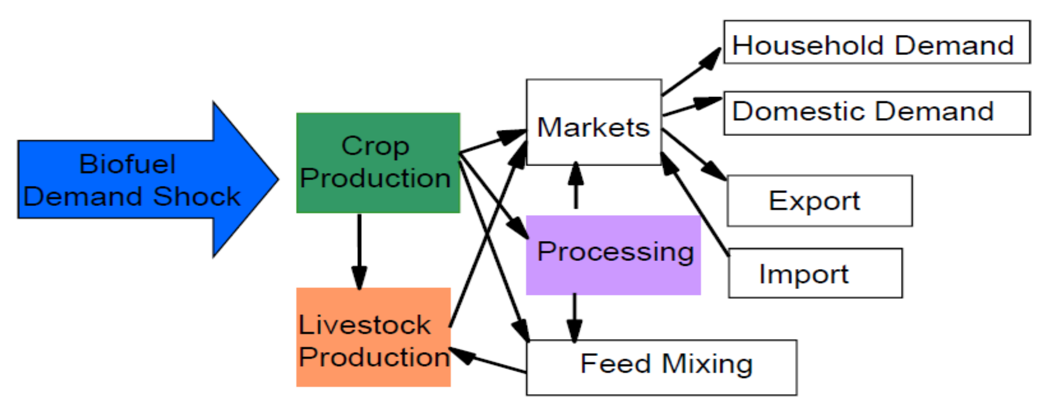
The following models are used to calculation the full life cycle as defined by the EPA:

- The Forest and Agricultural Sector Optimization Model (FASOM); and
- The Food and Agricultural Policy Research Institute (FAPRI) Model).

FASOM: Simulates the full range of U.S. agricultural sector market behavior response to a policy change (e.g., increase in biofuels). Provides detailed domestic GHG emissions estimates; accounts for changes in CO2, captures the impacts of all crop production, not just biofuel feedstock. Thus, as compared to some earlier assessments of lifecycle emissions, using FASOM allows us to determine secondary agricultural sector impacts, such as crop shifting and reduced demand due to higher price methane, and N2O from most agricultural activities and tracks carbon sequestration and carbon losses over time.

FAPRI: Simulates the full suite of responses of the agricultural sector to a policy change. Allows for a detailed Interaction between domestic and international agricultural sector markets. Quantifies international acreage changes from biofuel policies. These models capture the biological, technical, and economic relationships among key variables within a particular commodity and across commodities. The FAPRI models have been previously employed to examine the impacts of World Trade Organization proposals, changes in the European Union's Common Agricultural Policy, analyze farm bill proposals since 1984, and evaluate the impact of biofuel development in the United States. The FAPRI models have been used by the USDA Office of Chief Economist, Congress, and the World Bank to examine agricultural impacts from government policy changes, market developments, and land use shifts.

Figure D2: Simulation Model for LCA



Source: EPA (http://client-ross.com/lifecycle-workshop/)

Data on land use changes come from MODIS satellite data (validated by NASA). The resultant emissions calculations are based on Winrock data (GREET), which follows IPCC guidance and uses the latest available information to determine carbon content of different types of lands at regional levels by country. In order to calculate reference figures, 10 countries were analyzed with satellite imagery: Argentina, Brazil, China, EU, India, Indonesia, Malaysia, Nigeria, Philippines, South Africa. Other countries were assigned a weighted average of the covered countries. Over time satellite data for the remaining countries will be used.

Box D1: Calculation of International Agricultural and Land-use Change GHG Emissions

International Agricultural GHG Emissions

- Average farm energy use by crop and country estimated with FAO and IEA data.
- Upstream energy production GHGs calculated with GREET
- N2O emissions calculated with Tier 1 IPCC guidance.
- Average livestock emissions by region from IPCC guidance (includes enteric fermentation and manure management).
- Other activities including methane from rice production and residue burning determine with IPCC guidelines.

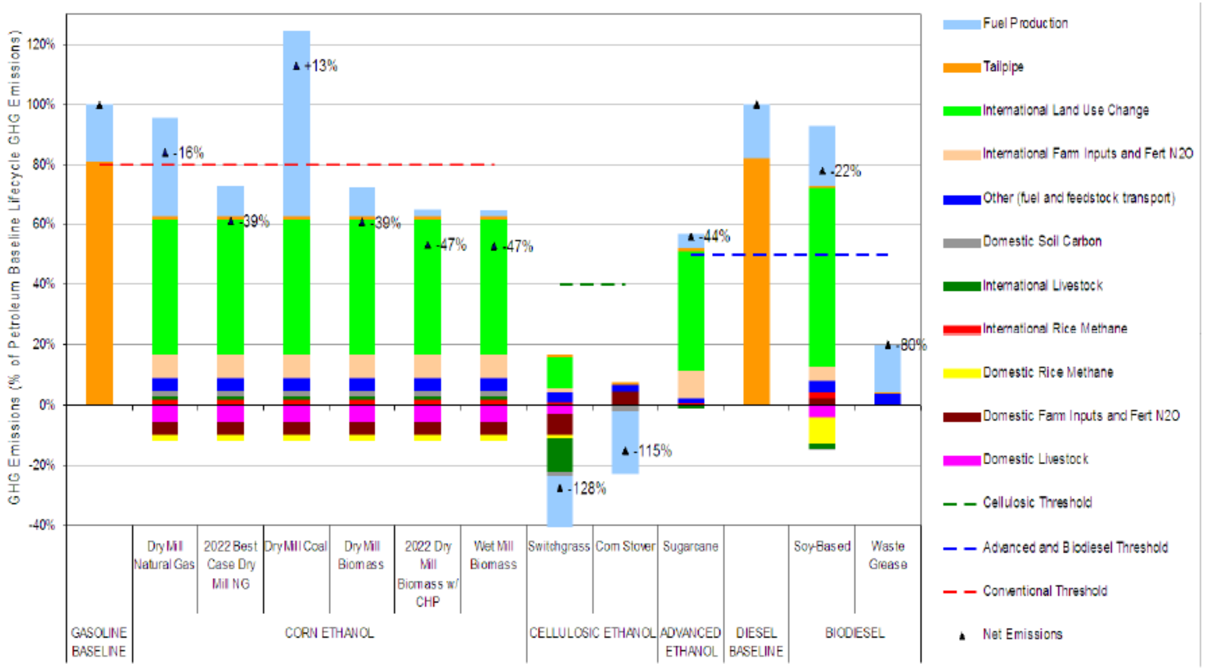
International Land-Use Change

- Land conversion emissions factors estimated by Winrock International Inc., following IPCC's 2006 Agriculture, Forest and Other Land Use (AFOLU) guidelines
- Land conversion emission factors (tCO2ha-1) = SUM of :
    - Change in aboveground and belowground biomass carbon stocks;
    - Change in soil carbon stocks
    - Lost forest sequestration (if applicable)
    - Non-CO2emissions from clearing with fire (if applicable)

Source: Adapted from EPA (http://client-ross.com/lifecycle-workshop/)

A 2% discount rate is used because it falls within the range of EPA recommended rates of 0.5 -3% for intergenerational discounting. This rate is also used in the economics literature to quantify the intergenerational impacts of climate change policies (e.g. Stern xxx).

Figure D3: Results of Lifecycle Analysis



Source: EPA (http://client-ross.com/lifecycle-workshop/)

The amount of biofuel-induced land use change in each country is determined with agricultural sector modeling. Internationally, the FAPRI model accounts for reduced exports and higher commodity prices, and projects the amount of crop expansion by country that occurs as a result of U.S. biofuel consumption. But, FAPRI does not disclose what types of land (e.g., forest or grassland) are displaced when an acre of cropland is added internationally. Satellite imagery is used to determine the types of land that are cleared when cropland is added in each country. GHG emissions per acre of land use change are determined following IPCC guidelines.[33]

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[33] For an overview see: http://client-ross.com/lifecycle-workshop/docs/1_EPA_Overview_6-9-09am.pdf