

# Assessing the biofuel options for Southern Africa

GP VON MALTITZ, A BRENT

CSIR Natural Resources and the Environment  
PO Box 395, Pretoria, 0001  
Email: [gvmalt@csir.co.za](mailto:gvmalt@csir.co.za)

## Abstract

Biofuels have been promoted as an environmentally-sustainable solution to the global energy crisis, and a way to counterbalance global increases in CO<sub>2</sub>. The reality is more complex; under some circumstances biofuels can be a major environmental and socio-economic threat. The question then is: under what circumstances can biofuels be socially and environmentally beneficial? Southern Africa, and especially the southern African countries other than South Africa, have characteristics that make them potentially suited to biofuel production, including the availability of land and labour. The different sustainability aspects pertaining to a biofuels industry in the region is investigated. The paper recommends that interplay of research, policy and controls is needed to ensure that a viable biofuels industry can be established in the southern African countries, with net positive socio-economic and environmental impacts.

## 1. General introduction to biofuels

Biofuels are proposed as partial replacements to petroleum-based liquid fuels, but unlike petroleum fuels, are derived primarily from vegetation products, i.e. biomass through a six-stage value chain consisting of:

- Feedstock production - the cultivation of biomass for feedstock.
- Feedstock processing - the harvesting, storing, transporting and initial preparation of the feedstock for conversion to fuels.
- Bioenergy conversion - the process of converting the feedstock bioenergy into biofuels, either by mechanical, chemical or biological means.
- Biofuels transformation - the transformation of the primary biofuels into the final liquid fuel products.
- Fuel distribution - the distribution of the produced fuels to the market.
- Fuel market - the end user of the fuels.

Currently there are two main types of biofuels: bioethanol, which can be blended with petrol or used in modified petrol engines; and biodiesel,

which can be used as a direct diesel replacement or as a blend with petroleum diesel.

Bioethanol is derived from sugar through fermentation and distillation in a process functionally identical to the production of alcohol for the liqueur market (Bridgwater, 2006). Starch-based crops such as maize or sugar molasses require an additional processing step that converts the starch to a sugar. This simple and well established process is referred to as first-generation bioethanol production and has a long history of successful operation in Brazil, Malawi and many other countries. South Africa has used bioethanol in fuel in the past (1920s to about 1960), but presently only produces bioethanol for non-fuel purposes. So called *second generation* technologies are being developed that will allow lignin and cellulose to be used as a feedstock and hence enable non-food components of vegetation to be converted into fuel (van der Laak et al., 2007).

Ethanol as a fuel is distinctly different from petrol in a number of aspects. Firstly, it is corrosive and requires modifications to the engine to prevent damage. It has only about 70% of the energy content of petroleum petrol on an equal volume basis and so about 30% more fuel is needed to travel the same distance, and performance is reduced. Bioethanol used as a blend of up to 10% with petrol requires no major modifications to car engines, though from the blending perspective there are technical considerations relating to octane values. Blending beyond 10% ethanol requires specially designed dual-fuel cars. Cars optimised to run on 100% bioethanol can also be built as is the case in Brazil where garages have two sets of fuel pumps, one for petrol and one for ethanol. Most car manufacturer warranties will cover ethanol blends to 10% (Intelligent Energy Europe, 2008).

Biodiesel is derived from fats and oils through a process termed transesterification (Bridgwater, 2006). This process requires about 20% methanol, a potassium (or sodium) based

catalyst and heat. Almost any oil or fat can be used though the properties of the resulting biodiesel will differ. The production process is technically simple and can operate at almost any scale, making it feasible for farmers to produce their own biodiesel. It is, however, only large scale plants that can guarantee consistent quality. In addition, large plants are needed if the more efficient chemical extraction of oils is used instead of simple, but less efficient, oil presses, thus raising the oil recovery from about 70% to about 98% (Jongschaap et al., 2007). Almost any oil seed can be used for biodiesel though palm oil is clearly the most productive on a per ha basis. The use of soybean results in an animal fodder in the form of a protein rich seedcake by-product, which, currently, is more valuable than the biodiesel itself; the overall production costs are therefore greatly reduced. A number of tree species including *Jatropha curcus* are being established as feedstocks, but in the case of *Jatropha* the seedcake is toxic and can only be used as a less valuable fertiliser or combusted as a fuel (Jongschaap et al., 2007).

The properties of biodiesel are very similar to petroleum diesel though it only has about 91% to 94% of the energy on a per volume basis. It has a higher flash point making its handling safer, but tends to solidify at low temperatures. Biodiesel is a solvent for rubber compounds and any rubber based seals will be destroyed – a potential, but cheap to remedy, problem of older engines. Biodiesel has excellent lubrication properties and no sulphur, which are both seen as benefits. Biodiesel should work as a 100% replacement in older engines. In modern high-tech turbo-diesel engines, most manufacturers will not give warranties beyond a 5% blend, though some tractor manufactures are giving warranties up to 100% biodiesel (Intelligent Energy Europe, 2008).

## 2. Why biofuels

There are a large number of reasons as to why countries would wish to engage in biofuels. From a global climate change perspective biofuels initially appeared to be a carbon neutral source of liquid fuels. This climate change adaptation aspect of biofuels was given as the basis for development of a European biofuels industry. Unfortunately the climate change benefits of biofuels are not clear-cut and biofuels may, in many instances, have negative climate impacts (Searchinger et al., 2008). This aspect of biofuels is addressed in later sections of this paper. Despite the potential negative impacts of

biofuels, the European Union and a few other countries have instituted mandatory biofuel targets to ensure that a proportion of all liquid transportation fuels are biofuels. Climate change adaptation is, however, only one of a number of reasons as to why countries are engaging in biofuel, research.

Biofuels, in contrast to fossil fuel, create a large number of job opportunities and these are mostly in rural areas relating to the production of feedstock. Subsequently, the United States, the European Union and Canada have instituted huge subsidies, in the order of €11 billion (US\$17.6 billion in 2006) in public money, to support energy crops (Herald Tribune, 2008). Agriculture in Europe is estimated as being subsidised by as much as 60%. Biofuels also provide a market for agricultural excesses, allowing farmers to produce more without risk of depressing prices. Though this may not be stated as the primary objective for biofuels, it is clearly a key reason for maintaining biofuel programmes in these countries. In developing countries this rural development aspect is potentially of even greater importance.

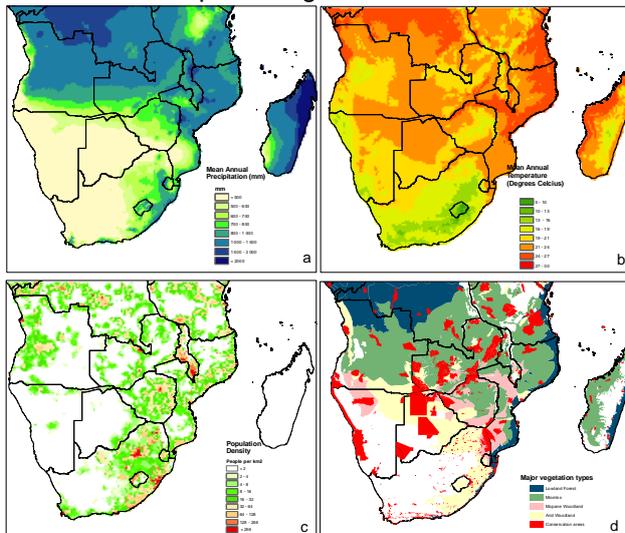
Biofuels are also seen as a mechanism to achieve greater national fuel security and hence less reliance on fossil fuel producing countries. Fossil fuels are clearly a finite resource; this appears to be an important driver for America's rapid expansion into biofuels (Meng and Bentley, 2008). Some suggest there are still extensive oil reserves and that it may be climate change impacts rather than depleted reserves that eventually force us to abandon fossil fuel (Brecha, 2008).

Promoting biofuels in countries with limited fossil fuel resources has clear macro-economic advantages. Not only does biofuel reduce foreign exchange being expended on fuel imports, but in addition a large number of national job opportunities are created. These developmental aspects of biofuel are well illustrated in Brazil. An important component of the Brazilian model is that the state put in place many subsidies and incentives to ensure the development of a biofuel industry including forcing motor manufactures to produce ethanol compliant cars (Grad, 2006).

## 3. Why biofuels for southern Africa?

Globally southern Africa has been identified as an area with extensive biofuel potential (Smeets et al., 2007). Not only do areas of southern Africa have a climate suited to high levels of biomass

production, but there is also the perception that much of this land is available for biofuel production. It is especially the Miombos (the deciduous dry forests covering vast areas of southern Africa) that are likely to be targeted for biofuels due to their favourable climate, and low population density (see Figure 1). Fertilisers are seen as a potential solution to the Miombos' inherently low soil fertility. The biofuel industry consequently sees huge potential for biofuel production in southern Africa, and a number of companies have, or are investigating, investing in the region. Many of these companies see the potential market for biofuels in Europe as the main reason for producing biofuels.



**Figure 1. A combination of good rainfall (a), subtropical temperatures (b) and low population density (c) suggest that southern Africa may have high biofuel potential. It is largely the Miombo vegetation (d) where all these parameters come together**

Namibia and Botswana are largely arid and though both these countries are contemplating biofuel industries, the potential is relatively low. South Africa has some suitable areas, but a high population density and already high intensity of land-use means that there is relatively limited land available. The areas of the ex-homelands in South Africa are suggested for biofuel expansion due to the perception that the land is under-utilised. Commercial farmers also maintain that they currently under-produce on their land due to a lack of a market for food crops. Mozambique, Angola, Zambia, Tanzania, Madagascar, the Congo and parts of Zimbabwe appear to have large potential. Angola has large fossil fuel reserves, which may mean that local biofuel production cannot compete financially with the low fuel prices. Malawi, although having large

potential from an agronomy perspective, already has a high rural population and intensive land use, meaning that limited land would be available for biofuel. Overall, Mozambique has been identified as the most promising country in tropical Africa for biomass production (Batidzirai et al., 2006).

Climate adaptation would appear to be a low priority or even irrelevant as a factor of relevance to southern African governments when considering biofuel programmes (Batidzirai et al., 2006, Haywood et al., 2008). From a government perspective three factors seem to be the key drivers for biofuel introduction to the southern

Africa region:

- Biofuels as a mechanism towards fuel security. This seems to be a key concern to National Departments of Energy in southern Africa.
- As a mechanism for national development. This is a concern of most government departments. Reduced foreign exchange expenditure and the development of local jobs are viewed as a very positive potential consequence from biofuels. A short-term reduction in tax collection from imported fuels is, however, seen as a constraint. Departments of Trade and Industry as well as National Treasuries place a lot of weight on this criterion.
- Development of the rural farming economy is a key reason for interest in biofuels from the National Departments of Agriculture and other departments dealing with rural development. However, in some cases agriculture is expressing reservations due to perceived competition with their food producing mandate.

Commercial farmers, especially in South Africa, are very keen on the establishment of a biofuels industry as they see it as a mechanism to boost agricultural production. The South African maize farmers for instance argue that they can produce 14 million tonnes of maize, but that the South African local demand is only 9 million tones. They argue that at present if they overproduce, prices drop and since their profit margins are so small, they face bankruptcy. South Africa has the technical potential to produce maize, but an open global market means that it is often not financially viable. They believe that a bioethanol industry will help stabilise the local market (Spadavecchia, 2008).

#### 4. Biofuels, climate change and other environmental implications

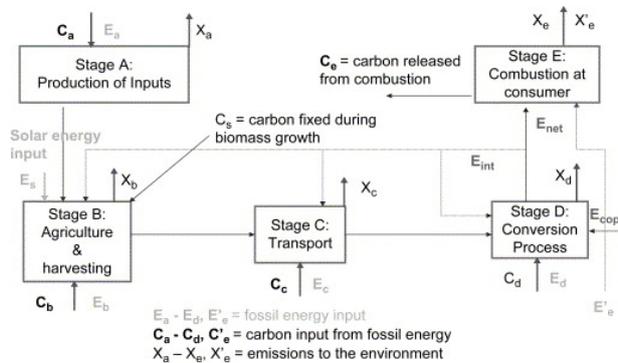
The initial euphoria that biofuels represent a carbon neutral and environmentally sustainable source of energy has been followed by numerous scientific studies showing that in many circumstances biofuels are not as sustainable as originally assumed (The Royal Society, 2007).

##### *The lifecycle approach to assessing biofuels*

Life cycle assessment (LCA), which forms part of the ISO 14000 family of standards, is a well-known and often-used approach for environmental management. LCA recognises that a comprehensive environmental assessment of an industrial system needs to consider both upstream and downstream inputs and outputs involved in the delivery of a unit of functionality (von Blottnitz and Curran, 2007). The approach involves a cradle-to-grave assessment, where the product is followed from its primal production stage involving its raw materials, through to its end use. Figure 2 illustrates a generic biofuel life cycle system, with the main sub-processes and important flows, to describe the environmental performance of such a system. A full lifecycle approach needs to be followed to fully quantify any of the indicators of environmental impacts as discussed below.

##### *Energy balance of biofuels*

The energy balance of biofuels is an assessment of the energy obtained from biofuels versus the energy required to produce the biofuels (which mostly comes from non-renewable sources). Von Blottnitz and Curran (2007) review various LCA studies that have been conducted on the energy balance of biofuels and conclude that there is typically a net positive balance, but this is crop and management dependant. Table 1 illustrates the dependence of the net energy balance on the chosen crop. Maize as a feedstock behaves exceptionally poorly from an energy perspective. Sugar on the other hand has a very positive energy balance, and this is in part due to the fact that sugar plantations can be energy self-sufficient (or even electricity exporters) due to the thermal processing of bagasse (Mbohwa, 2003). With biodiesel it is typically tree-based crops that perform better than annual crops from an energy balance perspective. The energy required to produce fertiliser is the main energy source involved in biofuel production, so conservation agriculture (organic agriculture) practices would lower this cost, but may also lower production. Depending on allocation assumptions, crop rotation and agricultural co-production could also reduce the fertiliser requirement. Furthermore, technological choices for residue handling and fuel combustion have been shown to be key issues with improving the overall energy efficiency of biofuel systems (von Blottnitz and Curran, 2007).



**Figure 2. Material flow and environmental interventions across the life cycle stages in a biofuel system (from von Blottnitz and Curran, 2007)**

**Table 1. Approximate fuel yields from competing biofuel crops in southern Africa, including data on their energy efficiency and carbon footprint**

	Sugar	Sugar Molasses	Sweet sorghum	Maize	Cassava	Jatropha <sup>2</sup>	Palm oil	Soybean	Canola	Sunflower
Litres fuel/t	60-80	240	40	366-470	160	350	230	227	400	400
T/ha <sup>1</sup>	13-105	4.5	60	1-5	3 - 8 to 80	2 - 8	13- 20	2.67	1.47	1 – 2.5
Biofuel yield L/ha	845-6825	1080	4200	366 – 3760	480 - 1280	700 - 2800	3000	446	588	400-1000
L/ha used in calculations <sup>3</sup>	4550	702	4200	1645	1280	700	3000	446	588	700
Petrol equivalent /ha	3190	490	2940	1150	896					
Diesel equivalent /ha						658 - 2632	2820	420	550	660
Energy efficiency	~8		~1	1 – 1.5		~4 to 6	~9	~3	1.9-2.9	~3
Ha X 1000 needed to supply a 100 million l/year production plant	14	92	23	60	78	35 - 142	33	224	170	105

<sup>1</sup>These are based on Southern Africa data where possible using FAO (2005) data.–

<sup>2</sup> Note: there is no reliable data on Jatropha production rate for the sub-region, and even global values are often not from production scale experience.

<sup>3</sup> We have used values that we consider representative of commercial production and have tended to the conservative. In most instances mean South African national values are used

### *Greenhouse gas emission from biofuels*

Biofuels are not carbon or greenhouse gas neutral. Emissions are highly dependant on agricultural practices, and particularly the use of fertilisers, that may lead to high releases of carbon from the soils and the emissions of nitrous oxide (N<sub>2</sub>O), which is a very important GHG with a global warming potential of 320 times that of CO<sub>2</sub> (Zah *et al.* 2007). Computing total emissions is complex due to the difficulty of bounding the system in terms of computing the carbon balance of biofuel systems, compared to conventional fuel systems. For example, by-products from biofuel production get used for animal feed production. How much of the methane from ruminants can be attributed to the change in fodder, and to what extent does the availability of bi-products from biofuels change the size of the cattle industry?

It is the impacts of biofuel growing on land use change where potentially the greatest carbon impacts occur. Where forest is cleared to grow biofuels there is both the loss of the standing biomass and loss of soil carbon. Where peatland is drained the resulting carbon emissions may take up to 900 years to be reclaimed through the biofuel produced (Fargione *et al.*, 2008). Where biofuels, and especially tree-based biofuels, are planted on abandoned agricultural land, there may be almost immediate carbon benefits. Palm oil, though potentially very effective from a biofuel production perspective, has been viewed negatively because of the clearing of indigenous forests and peatlands. If palm oil is grown on previously degraded lands there is a positive carbon balance from soon after planting. Results will also change depending on the time period over which the analysis is conducted (Reijnders and Huijbregts, 2007).

### *Total radiation forcing*

In addition to carbon and other greenhouse gasses, biofuel production may also influence global warming through factors such as change in albedo (the reflectance of the earths surface), evapo-transpiration and surface roughness. Though very limited research is available using this total radiation forcing approach, it is likely that the true benefits of biofuels to global climate change may be less than predicted when using less inclusive measures such as CO<sub>2</sub> emissions.

### *Land-use impacts from biofuels*

Biofuels by their very nature will require vast areas of land. Basically there are four types of land that can be converted to biofuel, and each conversion will have a range of impacts. In all

cases there will be some level of biodiversity impacts, carbon impact and social impact:

- Converting existing cropland to the production of biofuel feedstocks. If the previous crop was a food crop this will likely impact on food security. If the previous crop was an industrial crop such as tobacco then there are economic considerations of the conversion.
- Conversion of abandoned agricultural land to the production of biofuel feedstocks. This would be one of the main targeted land types for biofuels in South Africa and would have lesser impacts on biodiversity than if virgin land is converted to biofuel production. If the land is truly out of food production, then this should not have negative impacts on total food production.
- Conversion of natural vegetation to the production of biofuel feedstocks. This would have major biodiversity impacts and very likely negative carbon consequences, especially if forests are being converted. The destruction of peatlands has exceptionally high impacts on carbon emissions.
- Conversion of degraded land to the production of biofuel feedstocks. Where the natural vegetation has been badly degraded then the conversion to biofuels may have less negative consequences or may even assist in the restoration of ecosystem services from the land. Biofuels, and especially tree-based biofuels might be a good restoration option, though this needs to be considered against other land use and restoration options, both in terms of socio-economic benefits and in terms of the amount of carbon that will be sequestered.
- Conversion of wasteland to the production of biofuel feedstocks. The term wasteland has been used often in the biofuel literature, especially when relating to crops such as *Jatropha*. Wasteland, however, is normally one of the other land categories above. Though used widely as a land-use class in India, the term wasteland is not commonly used in the southern African context. All land tends to be playing some economic function including biodiversity conservation, animal grazing, the provision of non-timber forest products, etc.

Determining the extent of land that is potentially available for biofuels is a non-trivial task. It is relatively easy to determine the spatial extent of areas with suitable growth conditions for different biofuel crops, but estimates of the extent to which this land is currently utilised is problematic, especially where small-scale subsistence farmers

are concerned. The literature for Mozambique, for instance, suggests that between 10 and 38 million hectares may potentially be available for crop (including biofuel) production. The data on the current level of agricultural utilisation of this land is estimated at about 6%. It is not clear how much of this land is old fields versus virgin untransformed land. It is also not clear as to what extent community members currently utilise this land for other economic activities. Therefore, despite a seemingly large area of land available for biofuel production, the actual availability of this land is not clear.

In South Africa it is assumed that the areas of the homelands are available for biofuel, but many studies show that currently this land is extensively used for a variety of products. In addition this land

has complex tenure arrangements with nested levels of resource use rights. Despite the fact that this land is under-producing from a commercial agricultural perspective, this does not automatically translate into this land being available for biofuels. Due to the complex nature of land and resource tenure, it is very feasible that the individual with the legal right to allocate the land to biofuel production and who gains from the biofuel production may be a different person to the person who loses existing benefits from the use of the land.

South Africa is the only southern African country which currently has a clear biofuels strategy and it specifies a modest biofuel target of 2% of liquid fuels. To achieve this would require a significant percentage of available agricultural land. Zambia and Mozambique by contrast would only require a very small percentage of the national area to be converted to biofuels to achieve full fuel security (see Table 2).

**Table 2. Rough estimates on the extent of land needed to meet 5% (2% for South Africa) biofuel targets and total fuel needs based on 2005 petrol and diesel consumption patterns**

	Botswana	Namibia	Tanzania	South Africa	Mozambique	Malawi	Zambia
Diesel use per country per year (IEA 2005) Values in Million litres per year	281	445	667	7 987	381	140	327
Petrol use per country per year (IEA 2005) Values in Million litres per year	301	325	202	10 289	107	90	210
% of total land area needed to meet total transport fuel needs	0.9	0.9	1.2	14.6	0.8	2.3	0.8
% of arable land needed to fully meet total transport fuel needs				120	4	4	4
% of available arable land needed to meet total transport fuel needs				589	5	48	6
land area needed to meet biofuel targets in ha	26 078	38 917	53 855	307 375	30 631	13 464	56 286
Estimates of job created to meet biofuel targets <sup>3</sup>	12 251	18 608	26 399	142 919	15 036	6 261	27 046
Estimates of job created to meet total national fuel usage <sup>3</sup>	245 028	372 160	527 980	n/a	300 712	115 802	270 458

<sup>1</sup>Comparable data for Malawi was not found. Malawi data based on CIA data with same % split as in Zambia

<sup>2</sup> all calculations based on the production values from the Biofuel yield in l/ha used in table one, using sugar cane and Jatropha as feedstock. These values are therefore not linked to specific country level growth conditions and assume suitable land is available

<sup>3</sup> It is very difficult to estimate total job creation as there are many unknowns, especially relating to Jatropha growing. We base these figure on 0.5 job per ha for biodiesel and 0.33 job per ha for sugarcane as used in Econergy 2008. Most of the jobs would be low paying labourer jobs

<sup>4</sup> These estimates are substantially higher than in the 25 000 mentioned in the South African biofuels strategy and we attribute this difference to the fact that south Africa uses mechanised farming and that annual crops rather than Jatropha is being proposed i.e. more capital, fertiliser and fossil fuel but less labour intensive

Table 2 shows that it is very conceivable for many southern African countries (but clearly not South Africa) to gain full fuel security from first generation biofuels. Full conversion to 100% biofuels would have technical challenges in aspects such as engine design and motor warranties. It is more likely that biofuel in excess of a low-level blend will be exported, at least in the short term, until biofuel compliant cars are more common. A largely unknown issue is to what extent governments will allow the biofuel industry to develop. In countries such as Mozambique or Zambia, meeting local fuel needs will have relatively minimal land-use impacts. However, if a large export industry develops, this would have major land transformation impacts and secondary biodiversity impacts. There is a clear need for countries to make strategic decisions on how large a biofuels industry they are prepared to allow.

#### *Other environmental impacts*

In addition to the environmental impacts covered above a number of other impacts are possible including hydrological impacts, water and air pollution, nitrification, acidification, erosion, toxicity from pesticides, disposal of byproducts etc. (Weis et al., 2007, Zah et al., 2007). Where irrigation is required LCA studies have shown that in excess of 1 tonne of water would be required for every litre of biofuel produced (Brent et al., 2008).

### **5. Biofuels and development**

At the national level biofuels would appear to have a strong potential for national and local-level development, with a high proportion of the development taking place in rural areas. Imported petroleum products create very few job opportunities at the level of the refinery. Biofuels, by contrast, have the potential for a large number of rural job opportunities in the agricultural and processing stages, with a small displacement of jobs in the current refining sector. Distribution and garage forecourt jobs should be relatively unchanged between biofuels and fossil fuels. The background study for the biofuels strategy suggests that approximately 55 000 jobs could be created in South Africa to meet a 4.5 % blending target (NBTT, 2006). A similar study in Mozambique estimates that over one million jobs could be created if Mozambique were to commit 3.379 million hectares to biofuels production and that this would generate revenue of US\$ 3.5 billion (Econergy, 2008). A critique of both these studies is that they provide no data on the quality

of the jobs provided, and concern is expressed that these jobs may largely be manual and poorly paid.

Despite these huge potential benefits, the biofuels industry typically states that it requires state support and subsidies to be established (Tait, 2005). Proponents for a biofuels industry point out that the cost to the state of creating biofuel jobs is typically far less than the cost of creating jobs in other sectors (NBTT, 2006). It is pointed out that the biofuels industry, which is so successful in Brazil currently, required extensive subsidies to get it established. The same can be said for coal-to-fuel industry in South Africa. There are a number of compelling reasons why state intervention is needed to establish a biofuels industry. Investors need security of markets and without the state supporting a blend of fuels it is possible that the petroleum industry will not make the change. In the case of the ethanol industry in Brazil, the state forced car manufacturers to produce ethanol compliant vehicles.

With *Jatropha* as a feedstock the level of uncertainty of the economic model increases. Though *Jatropha* is currently banned in South Africa due to concerns over invasiveness, it is the crop of choice in most biodiesel projects in other SADC countries. Current *Jatropha* yield data are sketchy, as are the costs associated with management and harvesting. In addition there is not an established local biodiesel industry or market for biodiesel. This has led to macro level economic models based on *Jatropha* to rely on unproven assumptions. The job potential from *Jatropha*-based biodiesel could potentially be twice that of sugar-based ethanol per hectare planted, but it is unclear if the profit margins are sufficient to support this level of labour intensity. Oil seed crops are better understood. However, oilseeds growing would require far higher (non-labour) input costs and are likely to have higher levels of mechanisation. This would reduce their impact on rural job creation. A strong benefit of some oilseeds such as those derived from legumes (Fabiacea) is the fact that the by-products have high value as animal fodder (Econergy, 2008). However, in the southern African states in general, a local market to absorb all this high-protein animal fodder does not currently exist. By contrast, South Africa currently imports animal feed.

A key issue relating to the developmental aspects of biofuel is the farming model used to produce the feedstock. The South African biofuels industrial strategy pushes for small growers to be

the main producers. From an investors' perspective it is extremely difficult to establish a new industry that requires a large and reliable supply of a new agricultural feedstock based on smallholder production. Some level of large-scale production is probably a pre-requisite to get an industry established. The economics of small-grower production is also poorly researched. In the South African sugar industry there has been an almost 45% decline in small-grower producers over the past five years (South African Cane Growers Association pers com 2007). In Zambia small growers are being coerced into planting *Jatropha* with no clear data on either the input costs or expected returns (Haywood *et al.*, 2008).

Large-scale biofuels projects are almost sure to result in some level of displacement of people currently making use of the land where the projects are established. These individuals would often only have weak or no security of tenure to the land. Ensuring that these already marginalised groups are not further marginalised is a key concern. In most southern African states much of the available land for biofuels is in areas with customary tenure, i.e. communal or tribal tenure. It is well established that individuals in these areas do not have strong personal tenure rights to the resources that they use from the communal areas. It is very feasible that chiefs or government departments would reallocate this land to biofuels production, despite the fact that some members of the community are being disadvantaged. Putting in place the correct checks and balances to ensure that people are not disadvantaged through biofuels introduction is a major challenge to the region.

## **6. Biofuels and food security**

Globally there is clear evidence that biofuel production has had impacts on global food prices (e.g. Gallagher, 2008). The rapid expansion of the American maize-based biofuels industry in particular has been singled out as having impacts on global maize prices. However, other aspects also play a role, such as rises in input costs, rises in the price of crude oil, drought in a number of regions including Australia, and a growing market for food and especially animal protein in India and China. A large number of studies have attempted to quantify the impacts of biofuels on food prices and results range from as little as 5% contribution to up to 75% contribution to recent rises in food prices (Chakraborty, 2008). This range of values is partly explained by the length and period over which the analysis was

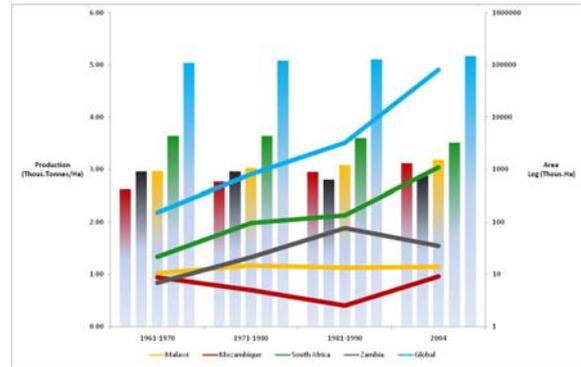
conducted, but emphasises the complexity of the problem.

Southern Africa appears to be an outlier in potential impacts of biofuel on food price. There are a number of strong theoretical arguments to suggest that a biofuels industry in southern Africa could be established with minimum negative or even positive impacts on local food security. Southern Africa has extensive tracts of land that could theoretically be converted to crop production or where crop production could be enhanced by improved agronomic practices. At a macro scale Mozambique only has about 10% of its agricultural land under crop agriculture (although there is huge disagreement on the actual percentage under agriculture due to poor data availability and conflicting data sets). At a micro scale many small-scale farmers in Zambia are currently only cropping 2 to 3 ha of their 10 ha land allotments. Establishing biofuel crops as large farms or as a component of small-scale farming enterprises is therefore possible in these situations without having to sacrifice land that is currently under crop agriculture. A word of caution is, however, raised that the labour to manage both fuel and food might be limited, especially at the level of small-scale farmers (Haywood *et al.*, 2008). In addition the land is serving other economic and environmental functions such as the provision of grazing, provision of non-timber forest products and protection of biodiversity.

Southern Africa also has the potential to greatly intensify its agricultural production. As can be seen from Figure 3, green revolution increases in maize yield have taken place in South Africa, which has low inherent maize production potential, but has not happened in most other southern African states that have a far higher production potential. This problem is particularly true for the small grower farmers. Large-scale commercial farmers in Zambia and Mozambique have demonstrated that yields above the global average are very feasible, but this requires expensive inputs. In southern Africa the problem is not the technical ability to produce high yields, but rather a poverty problem that people cannot afford to purchase the produce from commercial agriculture. In some of the southern African countries 70 to 80% of the population exists as rural subsistence farmers (Haywood *et al.*, 2008). These individuals currently have limited or no cash income, and use-low input farming to produce low yields. In Malawi a state funded fertiliser subsidy programme has had dramatic positive impacts on farmer yields, but these

yields are still far below the international norm. Globally depressed maize prices from surplus that is produced in the USA by farmers receiving large subsidies also mitigates against unsubsidised African farmers producing a surplus, since they receive poor prices on the global market. The American biofuels industry pushing up global maize prices may be a long-term advantage to African agriculture by allowing farmers to sell at market prices that are more realistic. Clearly, a free market in agricultural trade is being distorted by European and American agricultural subsidies. Though these subsidies help suppress global food prices, this is often at the cost of small agricultural producers in the third world.

Not only could southern Africa be totally food self-sufficient from an agricultural perspective, but it could be a net food exporter, even if there was a large biofuels industry. Zimbabwe was previously known as the bread basket of Africa, and it is political and infrastructural factors that now make it a net food importer. If 6 million hectares of Mozambique were farmed to produce a global average of 5 tonnes of maize (or other appropriate starch) per hectare this would give 30 million tonnes of maize or 2.5 tonnes per capita of Mozambique's 2005 population, clearly a huge surplus. If it is assumed Mozambique has 10 million hectares of available cropland this would still comfortably allow for the establishment of a 3 million hectares biofuels industry. Even in South Africa with its lesser production potential, maize farmers believe they could produce on average 14 million tonnes of maize, which far exceeds the country's 9 million tonnes requirement. They site poor market forces and the slim financial margins on maize as the reasons for not producing more.



**Figure 3. Trends in maize yield and areas planted in select southern African countries compared to global averages. Lines represent average yield per ha (left axis) and bars represent area planted (right axis). Based on von Maltitz and Setzkorn (submitted) using FAO statistics.**

## 7. Economic aspects of biofuel production

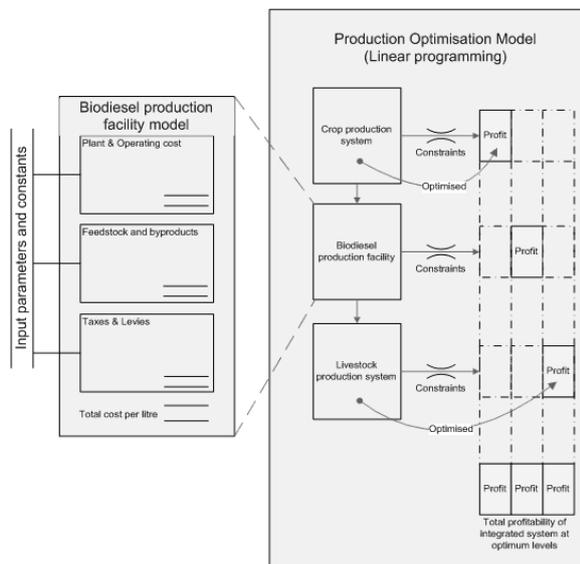
Many economic feasibility studies have been conducted for the production of biofuels that range from community-based to large-scale industrial facilities. A review of these studies, specifically for biodiesel production, has generalised the applicable cost factors into the following (Bender, 1999):

- Feedstock cost;
- Real annual capital cost (15 year book life);
- Operating costs;
- Chemical costs; and
- By-product credits.

The major limitation of these types of models, and especially for small-scale production, is that they represent standalone facilities of which the impact on an integrated production system are not considered. Pienaar (2006) has overcome this limitation through the introduction of an optimal whole-farm planning model to obtain the impact on total production system profitability. The resultant model, the on-farm Biodiesel Production System Optimisation Model (BPSOM) (see Figure 4), is capable of evaluating the feasibility of integrating an on-farm biodiesel production facility into a mixed crop-livestock production system. The model is a mathematical representation of the production system being evaluated and consists of the following components (Pienaar, 2006):

- An on-farm biodiesel production facility model for evaluating the economic feasibility of biodiesel production;
- A mathematical, linear programming model for production system optimisation; and

- An empirical model that defines the set of variables that will be modelled and the relevant constraints.



**Figure 4. Schematic representation of BPSOM**

The biodiesel production facility model consists of three sections: the plant (capital and operational), feedstock and taxation costs. The model calculates the optimised production profit generated by the integrated crop, biodiesel and livestock production processes. A proxy measure, profit per hectare cultivated land, is introduced as a generalised measure that is used to compare profit generated before and after the introduction of the biodiesel production facility in the integrated production system. The costs are factored to present a final cost per litre biodiesel produced.

Pienaar and Brent (2008) subsequently applied the model to a case study in South Africa. The farm produces a variety of crops, of which one is canola, with cattle and sheep. The model indicates that the total cost per litre biodiesel produced from a biodiesel facility with an annual capacity of 300 000 litres (1500 litres per day) is R 4.61, or approximately 66 US cents as at the end of 2006. This was R 0.79 less than the price of petroleum diesel using sunflower seed as feedstock at 2006 market prices. Previous calculations (van Rooyen, 2006) indicated that the cost per litre of biodiesel would be R 1.46 less than the petroleum diesel price. The price difference is likely due to the annualised capital cost of the facility that was included in the calculations of this study (Pienaar, 2006). The

final cost per litre biodiesel does not include fuel levies due to the tax exemption that applies to biodiesel producers in South Africa with a capacity of less than 25 000 litres per month (Coetzee, 2006).

## 8. Building sustainability into biofuel production

How does one develop a sustainable biofuels industry? Clearly biofuels have the potential to impact on many social and environment issues including climate change, water resources, biodiversity, household level livelihoods and the national economy. From the investigation the interplay of four processes is seen as being necessary to ensure that a sustainable biofuels industry is established in southern Africa.

### *A market-pull towards sustainable practices*

An extensive global process is underway to set in place sustainability standards for biofuels (GBEP, 2007). In essence this is likely to be a certification type process where international buyers will not purchase biofuel unless it can be shown that the supplies are audited as complying to defined standards (Heinimö et al., 2007). A number of national standards processes have been initiated (GBEP, 2007), and a key player in this process is the roundtable process on sustainable biofuels which will hopefully achieve a set of internationally accepted standards. There is clear evidence that the development of standards is having a direct impact on biofuels industry players. Field visits and interviews with large corporate biofuel producers indicate that they are very conscious of the potential impacts of socially or environmental bad practice on their long-term market access (Haywood et al., 2008). Since biofuels represent expensive and long-term investments the companies realise that they cannot afford to jeopardise their future markets and this is clearly impacting on current practices. For instance, *Jatropha* projects visited in Mozambique are being very careful not to be seen to be engaging in practices that could be considered as deforestation (Kevin Setzkorn pers com. July 2008) In addition, social responsibility programmes are being put in place to bring benefits such as schools and clinics to adjacent communities.

### *A national strategy backed by appropriate laws and enforcement*

National legislation needs to set the bounds for biofuel development and needs to ensure that processes such as impact assessments, labour

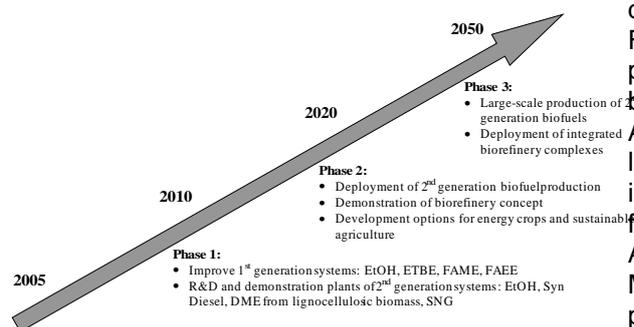
standards, etc. are adhered to (Haywood et al., 2008).

### Strategic planning for sustainability

A biofuels industry needs to be strategically planned and it is suggested that the planning should focus on ensuring sustainability. The use of the outcomes based Strategic Environmental Assessment (SEA) type framework is recommended for the planning process. The process should be participative. In this regard the CSIR is currently developing guidelines for the sustainability assessment of biofuel projects.

### Appropriate research and monitoring

Biofuels as a new industry requires extensive research. Decisions made should be evidence-based. This will require extensive research into technologies, agricultural practices, environmental impacts and social impacts. The economics of biofuels and its contribution to both grassroots and national development needs careful evaluation. Cognisance must be taken of projected technological developments (see Figure 5) and the associated potential implications for the southern African region.



**Figure 5. Anticipated future biofuels technology roadmap (adopted from BIOFRAC, 2006:27)**

## 9. Conclusions

The initial global euphoria around biofuels has resulted in a backlash with a vast number of studies suggesting that biofuels may do more harm than good. Bad practice has led to numerous case studies where negative social and environmental impacts are highlighted. The investigation summarised in this paper suggests that southern Africa has a unique possibility to engage in sustainable biofuel projects providing that projects are appropriate to their location and are carefully planned so as to achieve sustainability. An empowering national environment and social checks and balances

need to be in place to prevent inappropriate developments.

Whilst limiting the discussion to so-called first generation biofuels, it is believed that there are situations in which biofuels can be produced with net beneficial impacts. Second generation biofuels may bring further benefits and new and unique challenges, but this has not been considered in this paper.

Southern Africa is uniquely different from European countries, North America or even South America, and south-east Asia when it comes to the potential for sustained biofuels production. The drivers in the sub-region are based on development and fuel security priorities rather than reducing global warming. The region clearly has a lot of potential for biofuels, the question however remains, are biofuels the most appropriate development and land-use option in southern Africa? The current macro-economic assessments of biofuel production are encouraging, but limited in that they do not consider alternative land uses to compare to biofuel. However, whilst investors are eager to invest in biofuel, there is limited enthusiasm to invest in alternative rural land uses and as such biofuels might be a good stimulus to rural development.

From the preliminary assessment it seems that producing biofuels to meet the 5 to 10% blending targets is very feasible in southern Africa and if planned correctly would have low levels of negative environmental and social impact. Far higher production rates are very feasible in a number of but not all, southern African countries, with countries such as Mozambique, Zambia and Angola having the potential to meet all local liquid fuel needs as well as supporting an export market of fuels and food produce. The fact that there is both available land and the ability to intensify food production would seem to indicate that there would be limited competition between food and fuel, providing that fuel production did not displace current food production. An additional concern is that fuel production must provide jobs of sufficient quality to ensure that workers are able to achieve food security through their remuneration from biofuel endeavours.

The biodiversity impacts of such levels of production have not been investigated in detail. Large-scale biofuel production will undoubtedly have environmental consequences. The nature of these consequences will be site specific and dependent on the feedstock used and management practices applied. Where old fields or degraded habitats are planted to biofuels there is likely to be a net positive global climate change

benefit with relatively limited biodiversity impacts. If land is converted from indigenous vegetation to biofuel plantations, there will be biodiversity loss and it will take a long time to reclaim the carbon loss from land clearing. Through careful planning and management, many of the negative biodiversity impacts can be mitigated and in some instances it may be possible to achieve positive impacts.

The potential negative impacts of biofuels need to be compared against the no-biofuels option, an option that in itself will have environmental and social consequences. Increasing poverty and unsustainable land-use practices such as deforestation for charcoal production, subsistence farming or unsustainable levels of natural resource exploitation all have consequences. A big, but unanswered question is, is it possible to build biofuels projects in such a way as to positively impact on other drivers of biodiversity and environmental destruction? In this regard we are cautiously optimistic but acknowledge that this will only occur through careful planning.

To achieve sustainable biofuels production will require detailed, site-specific economic, financial, social and environmental assessment. The process of developing sustainability criteria for use in a certification process is already having a strong "market" pull on the attitudes and practices of companies. There is still, however, a lack of an appropriate process and set of tools to assist developers to merge both bottom-up issues with local, regional, national and global strategic issues. In this regard we advocate the outcomes-based strategic environmental assessment process, and the CSIR in conjunction with the EU is developing tools to support this.

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