Understanding the implication of investing in biodiesel production in South Africa: a system dynamics approach

J.K. Musango [a*], B. Amigun [b], A.C. Brent [c]

[a*] Correspondence author, Resource Based Sustainable Development, Natural Resources and the Environment, Council for Scientific and Industrial Research (CSIR), Stellenbosch, South Africa, jmusango@csir.co.za

[b] Sustainable Energy Futures, Natural Resources and the Environment, Council for Scientific and Industrial Research (CSIR), Stellenbosch, South Africa, bamigun@csir.co.za

[c] Centre for Renewable and Sustainable Energy Studies, School of Public Leadership, Stellenbosch University, South Africa, acb@sun.ac.za

Abstract

This paper presents a Bioenergy Systems Sustainability Assessment and Management (BIOSSAM) model. The BIOSSAM model was developed as a means to provide insights into the implications of expanding bioenergy programmes in South Africa, which is deemed critical for sustainable energy development in the region. The BIOSSAM model was applied to the case of biodiesel production in the Eastern Cape Province of South Africa. At present, biodiesel production in the Eastern Cape is envisaged to promote socio-economic development through, for example, job-creation, which, in turn, would lead to the further economic growth of the Province. The development of biodiesel production value chains is influenced by a number of factors such as producer/supplier profitability; this is determined by several factors such as: land availability to supply raw materials, feedstock prices, and government regulations/incentives, amongst others. To explore the extent of achieving the socio-economic goals from biodiesel production value chains, the BIOSSAM model provides a framework for understanding the causal-loop/feedback structure and dynamics of this emerging industry.

Keywords: *Biofuels, biodiesel, System dynamics, South Africa*

1. Introduction

Converting animal and vegetable fats and oils to liquid fuel has gained increasing interest over the past five years (Figure 1). This is mainly driven by environmental, social, and economic factors and helped along by government mandates and incentives. Most developed countries are moving from voluntary legislation to obligatory legislation imposing market share of biofuel in the transport sector. For instance, Europe is required to produce between eighteen and twenty-two million tons of biodiesel (founded on a 10% blending ratio) and presently has an annual production capacity of only six million tons (Kruger, 2009). To meet this share, EU countries would have to import feedstock (and/or biofuel) from elsewhere such as Africa. This is due to the lack of sufficient arable land for energy crops in the EU and the well established regulations safeguarding forests and governing land use. African countries are also at the various stages of initiating the commercial production of biofuel to capture the benefits of this value chain.

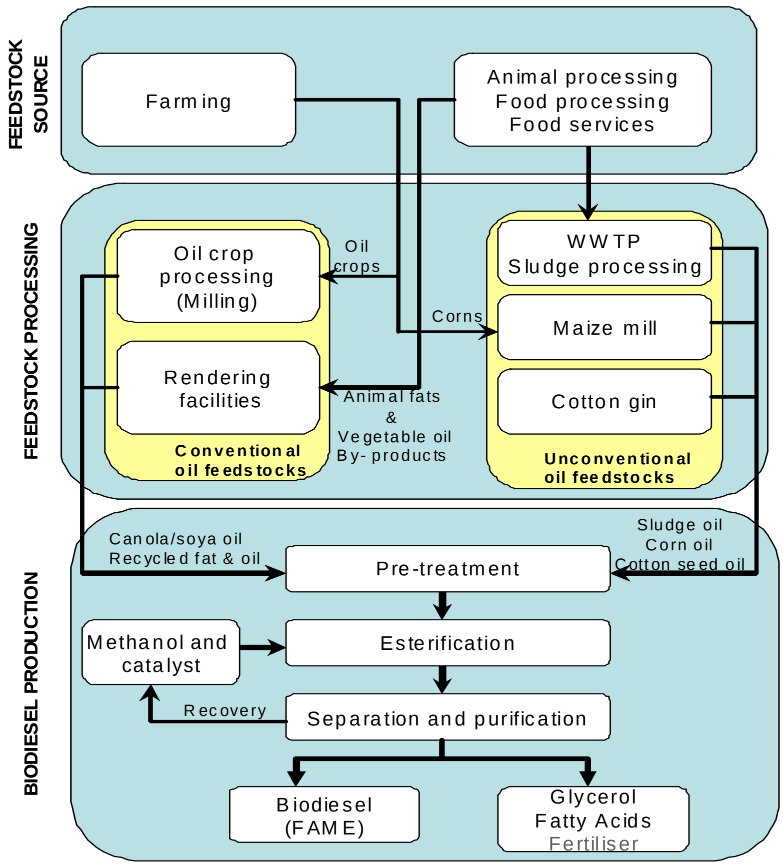

Figure 1: Biodiesel Production Process Cycle (adapted from Bantz and Deaton, 2006**)**

Biofuel is one specific issue that has been taken forward by South African Department of Minerals and Energy (DME) (now Department of Energy). At the beginning of January 2007, DME announced that the South African cabinet had approved an ambitious biofuels industrial strategy. This set bold targets, including the aim for 4.5% of road transport fuels in South Africa to be replaced with biofuel by 2013 (Department of Minerals and Energy, 2007). Significant and comprehensive efforts to establish agricultural producers and production plants were required in order to attain such a target. This target was, however, revised and downsized to 2% (400 million litres per annum). The South African biofuel industrial strategy is predominantly driven by the need to address poverty, rural development and Black Economic Empowerment (BEE). The focus of the strategy is thus in the former homeland areas, that were previously neglected by the apartheid system, and that do not have market access for their produce. The proposed crops for biodiesel are sunflower, soybeans and canola, while the bioethanol crops that are proposed are sugarcane and sugar beet (Esterhuizen, 2009).

In 2008, the attention of the DME turned to the development of an implementation plan, which included the development of the licensing criteria for biofuel and the pricing model as well as a subsidy schedules. One license has been issued to date. This slow progress has to be seen against the backdrop of a lack of locally grown feedstock approved for biofuel support. The financial support is specific to feedstock grown on new or previously "*underutilised*" land. The incentives will be agreed with each licensed producer on the basis of ensuring a fair return on assets, in terms of both the land and the associated biofuel production plant.

Biofuels were also identified as amongst the key drivers of the government program, the Accelerated Shared Growth and Industrial Strategy for South Africa (ASGISA). As a result, the development of a biodiesel industry is recognised as having multiple objectives, one of which is economic development of the second (informal) economy of the country. Job creation and employment opportunities in rural areas and feedstock supply could be enhanced by employing a cooperative farming approach. The success of this industry requires agricultural production in excess of food demand and at a competitive cost. It also depends on the provision of a guaranteed market for farmers and competitive pricing. It is for this reason that the strategy targeted local production of feedstock. For emerging farmers to get to the competitive stage financial support would be required to prepare the underdeveloped areas for commercial farming. The use of imported feedstock would not support this job creation objective. The need to achieve real agricultural growth and job creation is the reason the Biofuel Strategy provides financial support based on litres produced from crops grown on new or previously "*underutilised*" land.

A system dynamics model of the biofuel industry thus has the potential to improve understanding of system behaviour and provide useful inputs to the policy evaluation process and investment decisions. This can serve as a vehicle for evaluating alternative future developments and their implications and policy actions. System dynamics has a long history as a modelling paradigm with its origin in the work of Forester (1961). This methodology is grounded in the theory of non-linear dynamics and control theory. In contrast to simply forecasting future events, system dynamic models attempt to identify the underlying structure in order to show how to steer, control, or otherwise influence the future evolution of the system and its implication on other sector of the economy. A detailed description of the system dynamics modelling can be found elsewhere (Coyle, 1996; Sterman, 2000).

Recently, several studies have used system dynamics to analyse renewable energy related issues. Tesch et al. (2003) developed a system dynamics model of global agricultural and biomass development. Flynn and Ford (2005) modelled and simulated carbon cycling and electricity generation from energy crops. Bantz and Deaton (2006) used system dynamics to envision possible growth scenarios for the United States biodiesel industry over a course of a decade. Scheffran et al. (2007) developed a spatial-dynamics model of energy crop introduction in the state of Illinois. Pruyt and De Sitter (2008) developed a highly-aggregated system dynamics model of the worldwide food/bioenergy to investigate interactional effects between agricultural food production and bio-energy production worldwide. In the South African context, Musango et al. (2009) developed an energy model as an initial step of building a Threshold 21 (T21) model for South Africa. Their study, however, did not focus on the development of biofuel value chains.

Although bioenergy system dynamics models have already been developed for several regions and for bioenergy related aspects, this does not seem to be the case for all regions and all aspects (Pruyt and De Sitter, 2008). The use of system dynamics in studies related to bioenergy technology policies at local, national and regional levels is therefore imperative. The purpose of this study is thus to develop a system dynamics tool for policy decision and development support for bioenergy supply interventions in the Eastern Cape Province of South Africa, and specifically biodiesel production value chains in the Province.

2. History and state of Biodiesel development in South Africa

There have been many initiatives to improve the market penetration of biofuel in general, and biodiesel in particular, in South Africa. The development of the Biofuel Industrial Strategy for South Africa can be credited for being an inclusive and consultative policy process. It involved collaboration between government departments and state owned enterprises, as well as extensive public consultation. From the onset, in December 2005, the Cabinet endorsed the establishment of a Biofuel Task Team that involved twelve government departments and state entities namely the Industrial Development Corporation and the Central Energy Fund (Department of Minerals and Energy, 2009).

The Biofuel Task Team (BTT) was mandated to consider the feasibility of developing a modest biofuel industry for South Africa taking into account the country’s agricultural potential and food security issues. The Cabinet also authorised the BTT to immediately engage with interested stakeholders in the first economy to establish the possibility of a modest biofuel industry through minor regulatory changes and improvements. Out of this process, a draft Biofuel Strategy was developed and, in December 2006, it was approved by Cabinet with an instruction that it should undergo public consultation (Department of Minerals and Energy, 2009).

The final strategy has a short term incubation phase that will be reviewed in five years. The 2% target means that the cost of support will not be excessive, even if oil prices average very low over the fifteen years for which these plants will qualify for financial support, in the case of low oil prices. Of course, the associated costs of reduced crude oil import costs and pump prices make this support affordable. In the case of high oil prices, the biofuel plants will reduce foreign exchange outflows and pay taxes on profits.

Another initiative is the India-Brazil-South Africa (IBSA) Forum which is biased towards developing an ethanol industry. The Forum is tasked with strengthening cooperation between IBSA countries through knowledge sharing and systematic technology transfer. However, the pitfall has been that priorities and interests differ between countries, and these tend to influence perceptions about biofuels, and raises a number of questions about effective technology transfer. While biofuel may be a long-term energy solution for South Africa, and a way forward against climate change, gains from cooperation will depend on the country's capacity to elucidate its own strategy, define priorities and develop institutions and policies equipped to manage the development of a viable biofuels industry. Fears pertaining to food security, social development and land reform tend to cross-cut the debate on energy and climate change at present (White and Costa, 2009).

Nevertheless, the South African government support for biofuels is gaining momentum and plans are being proposed and developed to promote the planting, harvesting and processing of crops such as maize, sugar cane, soy beans, cassava and oil seeds from trees and sorghum into bioethanol and biodiesel feedstock for use in the liquid fuels industry. To this end the government, in 2005, established a joint implementation committee (JIC) for the biodiesel industry. The JIC comprises a range of interested parties such as the South African Petroleum Industry Association, farmers, oil companies and labour unions. A biodiesel standard has been completed with the assistance of the South African Bureau of Standards, and the JIC is currently developing a pricing model for the local biodiesel industry (Visagie and Prasad, 2006).

The selection of an appropriate crop or mix of crops for the production of feedstock oil is a critical factor in developing a sustainable production system. This is due to the fact that the choice of feedstock affects the capital investment decisions (technical design of the biodiesel plant). Second, feedstock input constitutes an average of 70 to 80% of the production cost (Amigun et al., 2008). Key considerations are yield per unit area, climate, soil type, availability of water, fertiliser and other resources, and whether the oil-bearing part is used as human or animal feed (Wilson et al., 2005).

The development of the biodiesel industry in Africa and specifically in South Africa is still in its infancy. The biodiesel scene worldwide can be described as a three-phase development (Figure 2).

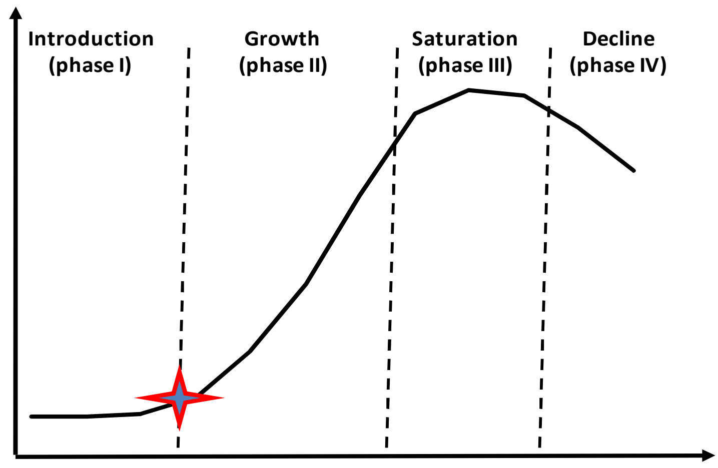

Figure 2: The three-stage model of biofuels development (Amigun and Musango, 2010)

The development of a biodiesel industry in South Africa is in transition between the introduction phase (Phase I) and the growth phase (phase II). The introduction phase is characterised by research efforts, pilot projects, establishing a framework (policy/strategy formulation) and financially-supported technical trials. This phase (phase I) consists of the very first ideas and thoughts of biodiesel being used as a fuel until the actual adaptation of the ideas on the part of decision-makers who are then motivated to put these ideas into practice. The end of Phase I is the political decision to invest money and other resources into biodiesel production (entering phase II). Phase III is marked by a biodiesel economy based primarily on commercially feasible production, distribution and use of biodiesel. The decline phase (Phase IV) is characterized by efforts to phase out the existing technology and replacing it with more efficient (second and third generation) biodiesel production technologies.

Information regarding the total production of biodiesel in South Africa is not clear. The industry is, however, characterised with small to medium scale producers (Amigun et al., 2008). Currently, South Africa has more than two hundred entrepreneurs that produce biodiesel on small scale, mostly from waste vegetable oils. Major concerns for these entrepreneurs are feedstock (virgin oils to biodiesel is expensive), uptake (no mandatory blending) and meeting the specifications that are required by petrochemical industries.

3. Methodology

3.1 Conceptual approach

The Bioenergy Systems Sustainability Assessment and Management (BIOSSAM) model illustrates the major interactions considered in biodiesel production between society, economy and environment systems. The BIOSSAM model includes three major components (Figure 3): (i) the society component, which includes population and employment, and is relevant for the social system; (ii) the economic component, which invests capital and labour for biodiesel production; and (iii) the environmental components, which determine the key resources use and supply, and biodiesel related wastes to the environmental system.

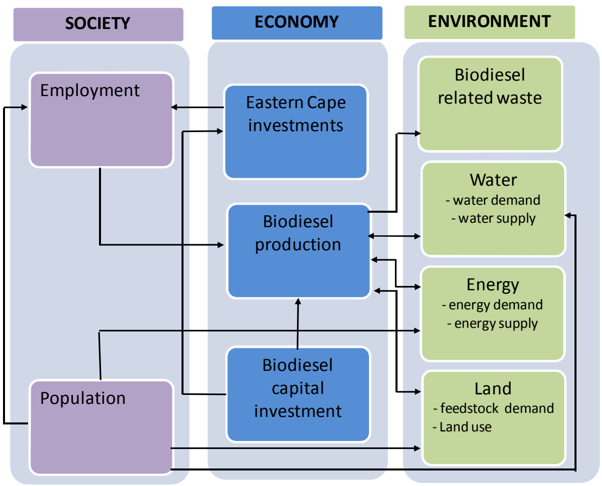

Figure 3: BIOSSAM conceptual model: society-economy-environment interactions in biodiesel investment

A simplified causal loop diagram (CLD) indicating the most relevant interconnections underlying the biodiesel production development in the Eastern Cape Province are shown in Figure 4. According to the CLD, there are four reinforcing feedback loops and one balancing loop. In loop R1, an increase in biodiesel production influences higher feedstock demand, which, in turn, necessitates additional land requirements. Higher land use implies more feedstock supply that results in higher biodiesel production. In loop R2, higher biodiesel production also demands higher energy use. The higher the energy demand, the more the energy supply that is required. High energy supply, in turn, influences more biodiesel production. Loop R3 has a similar feedback as R1 and R2 but it is for water demand and supply dynamics influenced by the biodiesel production. Loops R1 and R2 can thus be regarded as resource requirements feedback loops in biodiesel production. Loops B1 and R4 consider the profitability of the biodiesel production. In the case of B1, the higher the biodiesel production, the more the biodiesel production cost is incurred, which negatively influences the biodiesel profitability. Lower biodiesel profitability decreases the biodiesel capital, which, in turn, decreases the biodiesel production. On the other hand, R4 shows that increasing biodiesel production positively influences the biodiesel profitability. Higher profitability acts as an incentive for more biodiesel investment, which in turn leads to more biodiesel capital, therefore increasing biodiesel production.

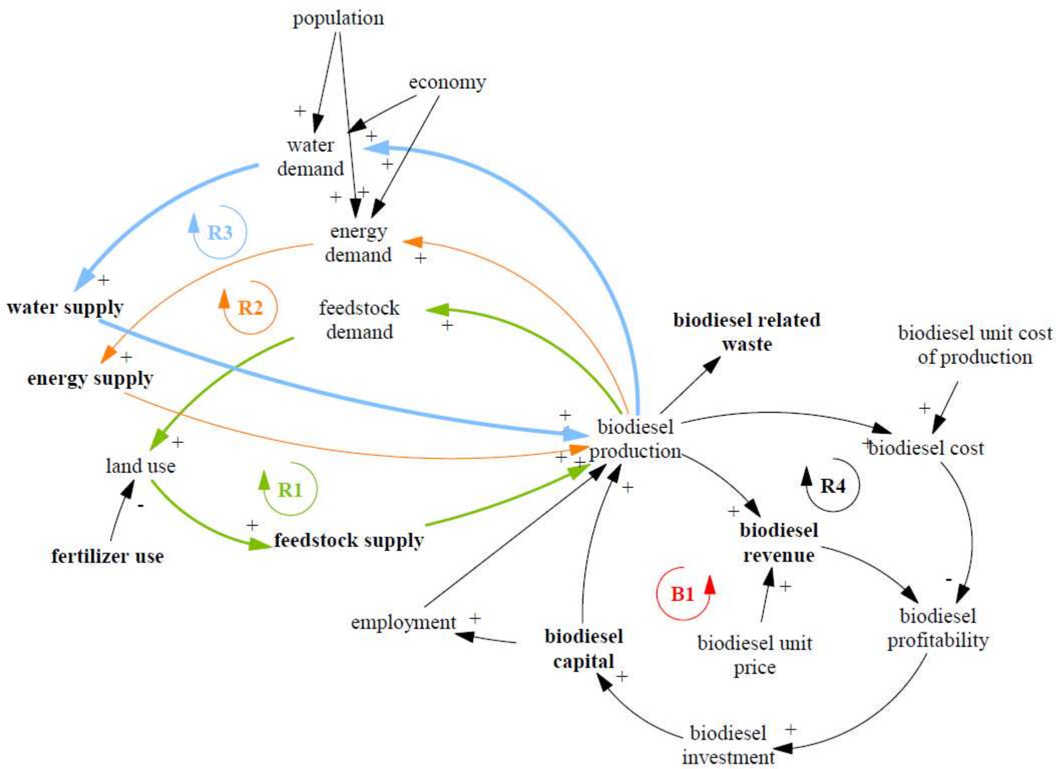

Figure 4: BIOSSAM causal loop diagram

3.2 Case study: site

The BIOSSAM model was applied to simulate biodiesel plant investment in the Eastern Cape Province of South Africa (Figure 5). The former homelands of South Africa is part of the Province, where the Xhosa people still lead a traditional way of living, and where poverty remains at its most severe; South Africa has a GDP per head of \$2500 while the GDP per head in the Eastern Cape Province is \$432. The former homelands of the Eastern Cape Province consist of fertile land for agricultural purposes. The main agricultural activity is livestock farming, but the crops farmed in the region include maize; vegetables such as tomatoes, onions and potatoes; and fruit such as pineapples. Soybean was farmed in the 1960’s and currently very limited production, at subsistence level, is taking place. Canola is predominantly produced in the Western Cape Province and this production could (potentially) be expanded to the Eastern Cape (Esterhuizen, 2009).

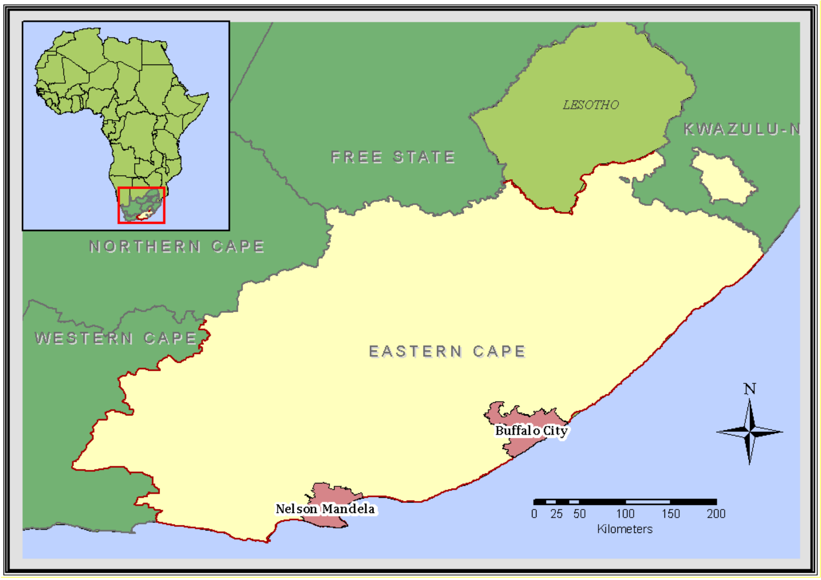

Figure 5: Map of the study area, Eastern Cape Province, South Africa

The Eastern Cape Province is playing host to a number of biofuel projects. One of these projects is a planned biodiesel refinery, in excess of 100 million US$, with canola as feedstock, which is to be produced in the former homeland areas (PhytoEnergy Development & Construction AG, 2008). The company is aiming to avoid the usual criticism of biofuel, as canola is a winter crop that would be cultivated in rotation with maize or wheat (as food crops in summer). The group also advocates the technology as the rotation of the crops is expected to enhance the food crop yields by up to 25% (Eastern Cape Department of Agriculture, 2007). This project is to leverage the Mass Food Production Programme of the Eastern Cape Province, which is already in place, and thereby bring benefits to communities, such as the creation of approximately 350 jobs in the biodiesel plant, Black Economic Empowerment (BEE), empowerment of local farmers, skills development, and possible improvement of food security.

The development of the biodiesel industry is part of a new agrarian transformation plan for the Province and one priority projects under the Accelerated and Shared Growth Initiative for South Africa (Asgi-SA); a government strategy to boost economic growth and reduce unemployment in the country. The agrarian transformation model is illustrated in Figure 6. The proposed biodiesel plant on the coast is envisaged to stimulate a huge market for agricultural products, including canola, soybeans and sunflower, which were not in the Province (Khumalo, 2007).

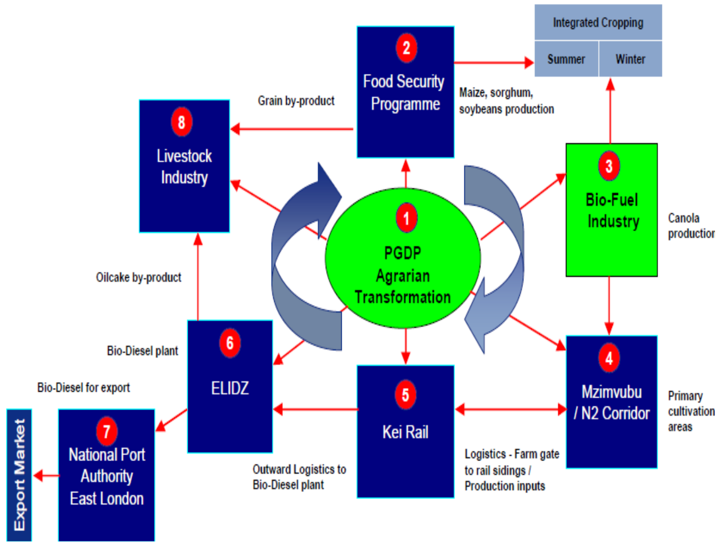

Figure 6: Agrarian transformation model proposed for the first plant location-East London Industrial Zone (PhytoEnergy Group, 2008)

While the project may help rather than hinder food crops in South Africa, the fuel itself is destined for the European market, where "cold proof" fuel, which can be used in winter in Europe, is required. The planned biofuel refineries will in all likelihood be located at the two Industrial Development Zones (IDZs) in the Eastern Cape Province, namely Coega in Nelson Mandela Municipality and East London in Buffalo City Municipality (see Figure 5). IDZs are purpose-built industrial estates geared for duty-free production for exports, and they play a hugely important part in South Africa’s macro-economic policy. They provide transport, logistics and business services tailored for export-oriented industries. The infrastructure development is first class as they are next to airports and seaports, and have direct road and rail links (Eastern Cape Development Corporation, 2010).The Eastern Cape Province – where most of the so-called “*under-utilised*” and communal land of South Africa is situated – is presently a hot-spot for agro-fuels development. In the order of 100 000 hectares of land in the former homeland areas have been identified that could (potentially) supply the centralised plants with feedstock.

3.3 Data description

Data for the BIOSSAM model was obtained from various sources. Data on population, employment, Eastern Cape investments (economy), land use and water demand and supply was obtained from: (i) Statistics South Africa[1]; and (ii) 2005 development report by UNDP

[1] www.statssa.gov.za

(United Nations Development Program), DBSA (development Bank Southern Africa) and HRSC (Human Resources Scientific Council). Data on biofuel capital investment and biodiesel production was obtained from various websites such as Engineering News[2]; bioenergy site[3]; Department of Minerals and Energy documents; Personal communication with the Industrial Development Zone in East London, South Africa.

3.4 Model construction

The BIOSSAM model was constructed using the Vensim 5.9 software package. Table 1 and Table 2 specify the key model parameters and the initial conditions of the state variables.

Table 1: BIOSSAM model key parameters

Parameter	Symbol	Value	Unit
Simulation setup	*ts*		Yr
Simulation period	*SimP*	45	Yr

Table 2: BIOSSAM model initial values

State variable	Symbol	Initial value	Unit
Population	*P*	7039000	person
Settlement land	*S*	1013796	Ha
Forest plantations	*FP*	844830	Ha
Fallow land	*F*	675864	Ha
Food crop land	*FC*	3379320	Ha
Conservation land	*C*	168966	Ha
Livestock land	*L*	10813824	Ha
Biofuel crop land	*BC*	0	Ha
Biodiesel construction capacity	*BCC*	0	Litre
Functional biodiesel capacity	*FBC*	0	Litre

The time horizon for the model is 25 years, from 2005 to 2030. The implementation of BIOSSAM model was done by dividing the society-economy-environment interactions into four main sub-systems namely: population, land, economy, biodiesel production, emissions, operating result in biodiesel plant, employment in biodiesel plant and water. The details of the contents and structures of four key sub-systems are described below

3.4.1 Population

The population helps to determine important social and economic indicators. The population in BIOSSAM model is defined as the Eastern Cape Province population, which is categorized according to sex and age groups. The key stock variable is the population (*P*) and three rate variables namely: births (r_b), deaths (r_d) and net migration (r_m). Population stock dynamics is therefore given as:

[2] www.engineeringnews.co.za
[3] http://www.thebioenergysite.com/articles/359/south-africa-biofuels-annual-report

$$\frac{dP}{dt} = r_b - r_d + r_m$$

Births and death rates are both influenced by the economic conditions which in turn influence the level of the population stock.

3.4.2 Land

This sub-model includes different types of land uses in the Eastern Cape Province. As observed in Figure 7, there are seven competing land use stocks, namely: settlement land (*S*), forest plantations (F_P), fallow land (*F*), food crop land (C_f), conservation land (C), livestock land (*L*) and biofuel crop land (C_b). Population dynamics influences settlement, food crop and livestock land requirements. The South African government plans to establish biodiesel crop land from fallow land. This makes fallow land one of the key stocks in this study because it can also be converted to other forms of land, depending on the land requirements. The dynamics of fallow land is thus given as:

$$\frac{dF}{dt} = r_{LF} - r_{FL} - r_{FC} - r_{FS} - r_{FF_P} - r_{FC_f} + r_{C_f F} - r_{FC b}$$

where: r_{LF} is the rate of conversion from livestock land to fallow land; r_{FL} is the rate of conversion from fallow land to forest land; r_{FC} is the rate of conversion from fallow land to conservation land; r_{FS} is the rate of conversion from fallow land to settlement land; r_{FF_P} is the rate of conversion from fallow land to forest plantations; r_{FC_f} is the rate of conversion from fallow land to food crop land; $r_{C_f F}$ is the rate of conversion from food crop land to fallow land; $r_{FC b}$ is the rate of conversion from fallow land to biofuel crop land.

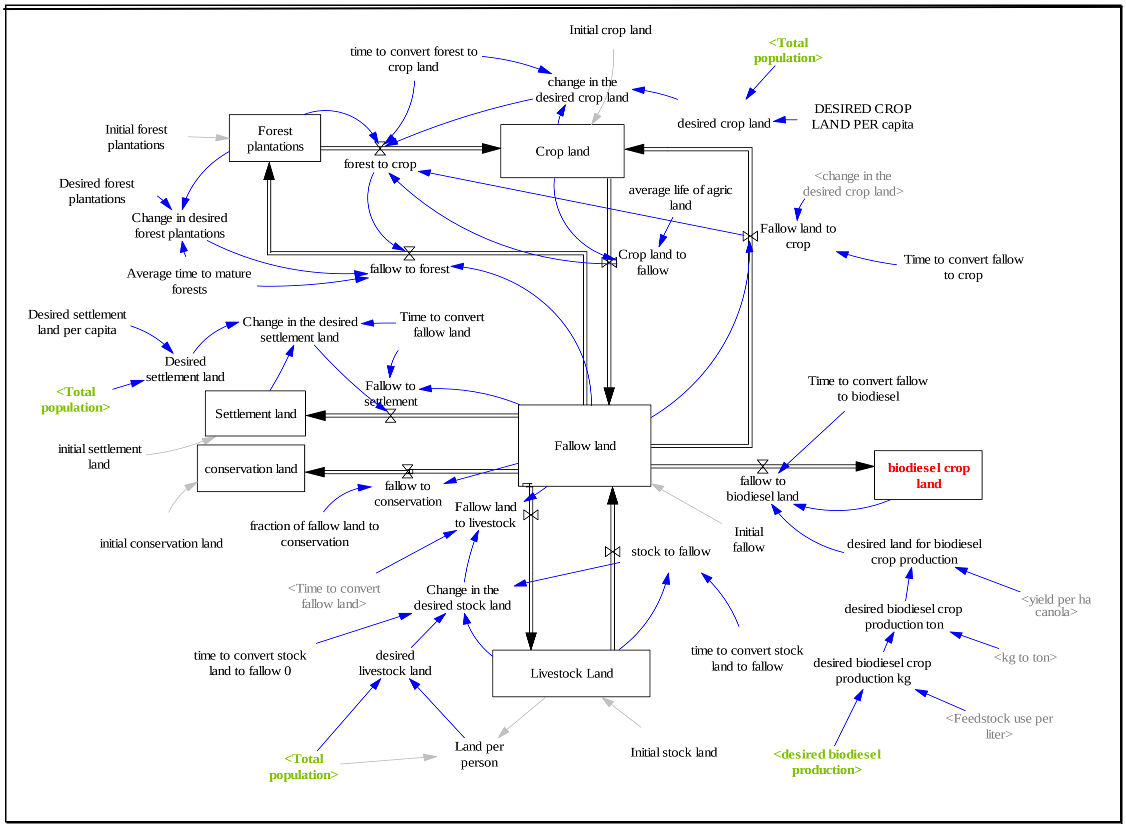

Figure 7: Land sub-model

3.4.3. Economy

One of the main factors of promoting biofuel investments in the Eastern Cape Province is to improve its economy. This is due to the fact that, Eastern Cape Province contribution to the GDP is among the least in South Africa. An explicit representation of the Eastern Cape economy therefore becomes indispensible.

Eastern Cape Province Capital (K) is the key stock in this sub-model. Future biodiesel investments influence the gross capital formation (r_{gkf}), which in turn influences the capital stock. The capital stock however is decreased by the rate of depreciation (r_{dn}) as shown in the following capital stock dynamics:

$$\frac{dK}{dt} = r_{gkf} - r_{dn}$$

3.4.4 Biodiesel production

Biodiesel production sub-model (Figure 8) is mainly related to a specific biodiesel plant construction which is proposed to be built and operational by 2012. Biodiesel capacity construction (*BCC*) is represented as:

$$\frac{dBCC}{dt} = r_{bpc} - r_{nbc}$$

$$r_{bpc} = FBI$$

$$r_{nbc} = \frac{BCC}{t_{bc}}$$

Where: r_{bpc} is the biodiesel plant construction start; r_{nbc} is the new biodiesel capacity; t_{bc} is biodiesel plant construction time; and FBI is the functional biodiesel capacity.

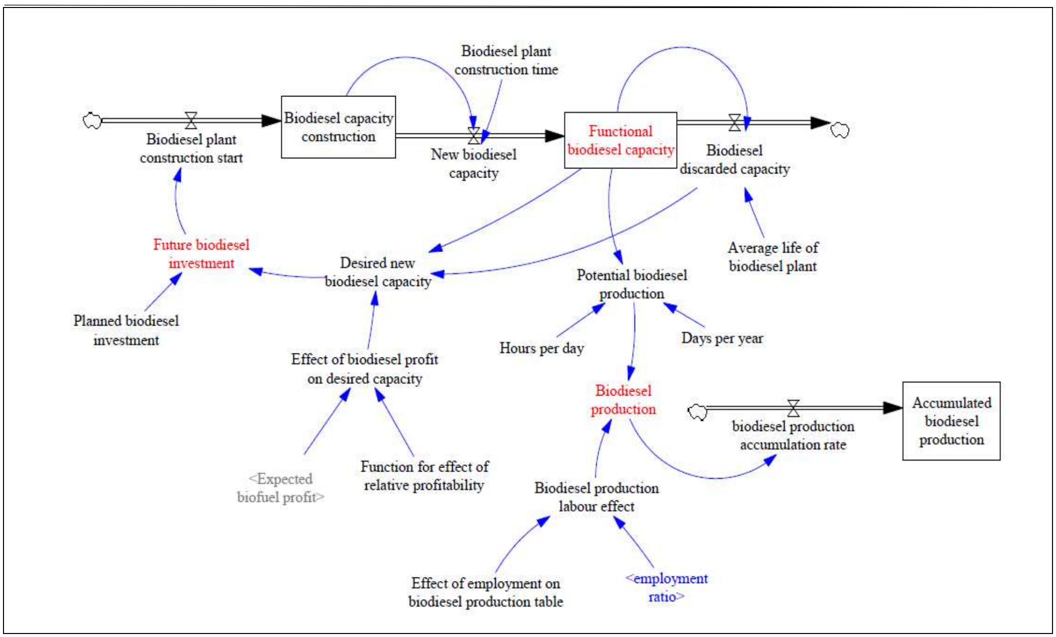

Figure 8: biodiesel production sub-model

On the other hand, the functional biodiesel capacity (FBI) is increased by the new biodiesel capacity (r_{nbc}) and decreased by the biodiesel discarded capacity (r_{bdc}). This is mathematically represented as:

$$\frac{dFBC}{dt} = r_{nbc} - r_{bdc}$$

Functional biodiesel capacity is an important stock determining the biodiesel production. On the other hand, biodiesel production has an influence on the biodiesel profitability, employment, energy and water requirements for biodiesel plant, and emissions.

3.5 Model testing and assessment

Model assessment can be done with prescribed sets of tests, but in most cases, model testing is an iterative process of building, testing, using, sharing, explaining, then and updating based on the feedback received from users. Given the fact that no commercial biodiesel production exists in South Africa, and the industry is still in its early stages of development, there are no historical data available. Thus, this study relies much on an understanding the underlying industry structure and decision-making process.

4. Results

The results presented here is a preliminary baseline simulation which is compared with two other scenarios defined to test the changes of some key variables in the biodiesel production development. Table 3 provides the list of the preliminary scenarios for the BIOSSAM model. The learning scenario reflects a situation whereby there is learning in the feedstock conversion processes due to experienced gained over time from accumulated biodiesel production. On the other hand, the suport scenario tests the biodiesel production support of R 0.53 that is stated in the South African Biofuel Strategy (Department of Minerals and Energy, 2007).

Table 3: Scenario analysed in BIOSSAM model

Parameter	**Units**	**Baseline**	**Learning Scenario**	**Support scenario**
Learning curve switch	Dimensionless	0	1	Baseline
Biodiesel support	Rand/litre	0	Baseline	0.53

4.1 Baseline scenario

Figure 9 present the baseline simulation results for biodiesel production, biodiesel productivity, biodiesel crop land and employment in biodiesel plant. In the baseline scenario, the BIOSSAM model projects an increase in biodiesel production from 2012; it increases over the simulation period reaching a high of 280.01 million litres in 2030. The biodiesel production does not reach the desired production of 400 million litres due to the low profitability. The baseline results shows a sharp decline in profitability in 2012 which result from the capital investment and this is followed by an increase in profitability at an increasing rate as the biodiesel production increases. However, with the baseline results, the profitability is still negative throughout the simulation period. Biodiesel crop land follows a similar behaviour as the biodiesel production reaching 317503 ha in 2030. Employment in the biodiesel plant, which is dependent on the functional capacity, is projected to increase over the simulation period reaching 213 persons in 2010.

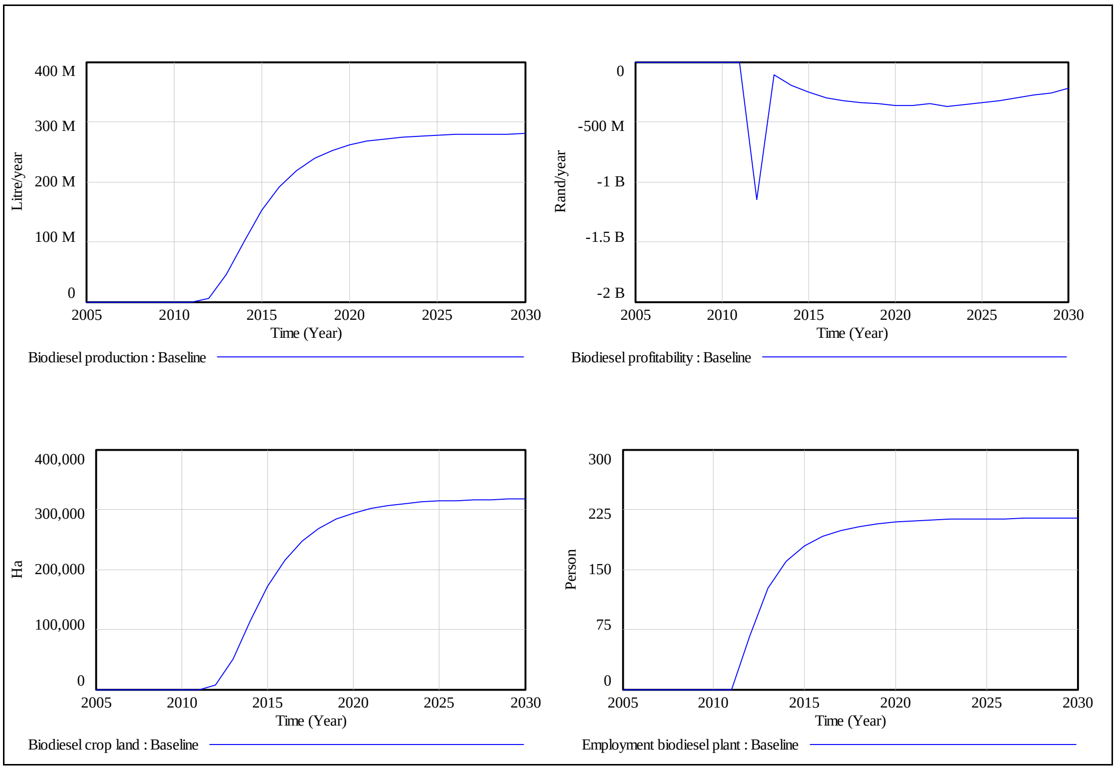

Figure 9: BIOSSAM model baseline simulation result

4.2 Learning scenario

In this scenario, it is expected that there is a reduction in feedstock demand, which in turn increases profitability and reduces the land requirement for biodiesel crops. This is clearly revealed in the simulated results presented in Figure 10. Feedstock cost is the largest component of biodiesel production cost. With this scenario, positive profitability is experienced from 2024 till the end of simulation period. Land for biodiesel crops is projected to increase from 2012 and reaches 290483 ha in 2021. Thereafter, due to learning and decrease in the feedstock requirements, the land required to biodiesel crops also declines reaching 264580 ha. At the same time, there is a slight increase in the biodiesel production that is projected with the learning scenario.

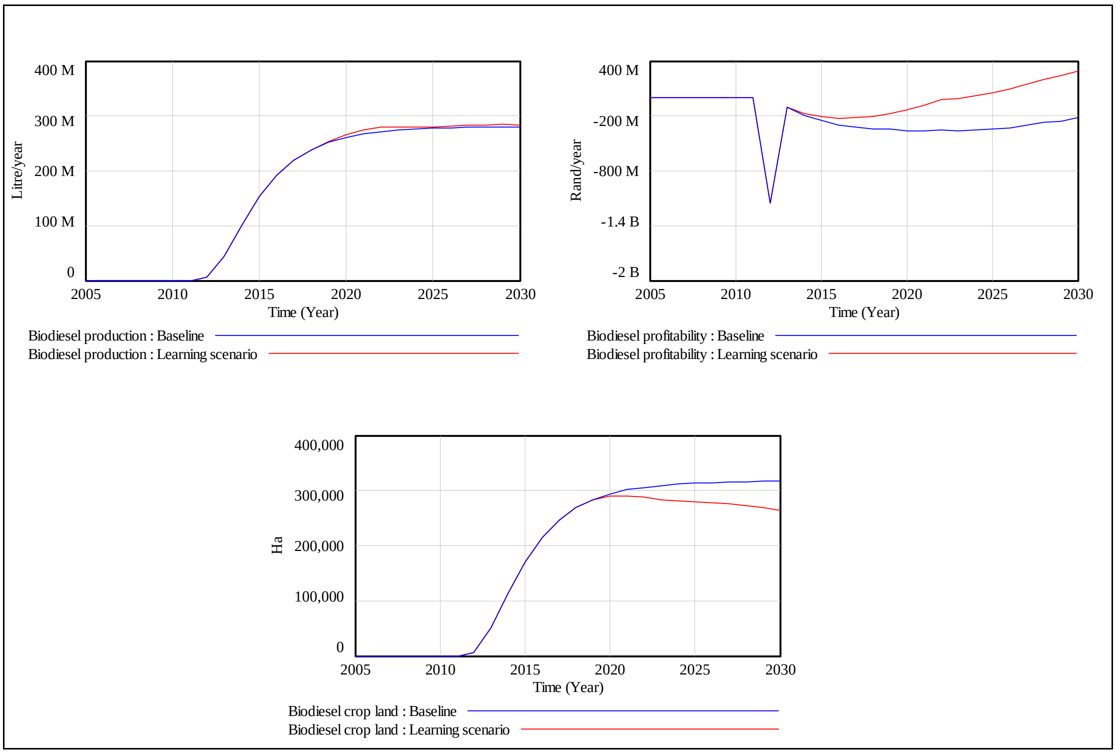

Figure 10: BIOSSAM model learning scenario simulation result

4.2 Support scenario

The simulated result for this scenario is presented in Figure 11. While provision of the support does improve the biodiesel profitability relative to baseline, the profitability is however still negative over the simulation period. This scenario does not stimulate further investments which would lead to increase in biodiesel production. Thus, the biodiesel production is similar to the baseline result. The same case applied to the biodiesel crop land, which is similar to baseline result since it is dependent on the biodiesel production

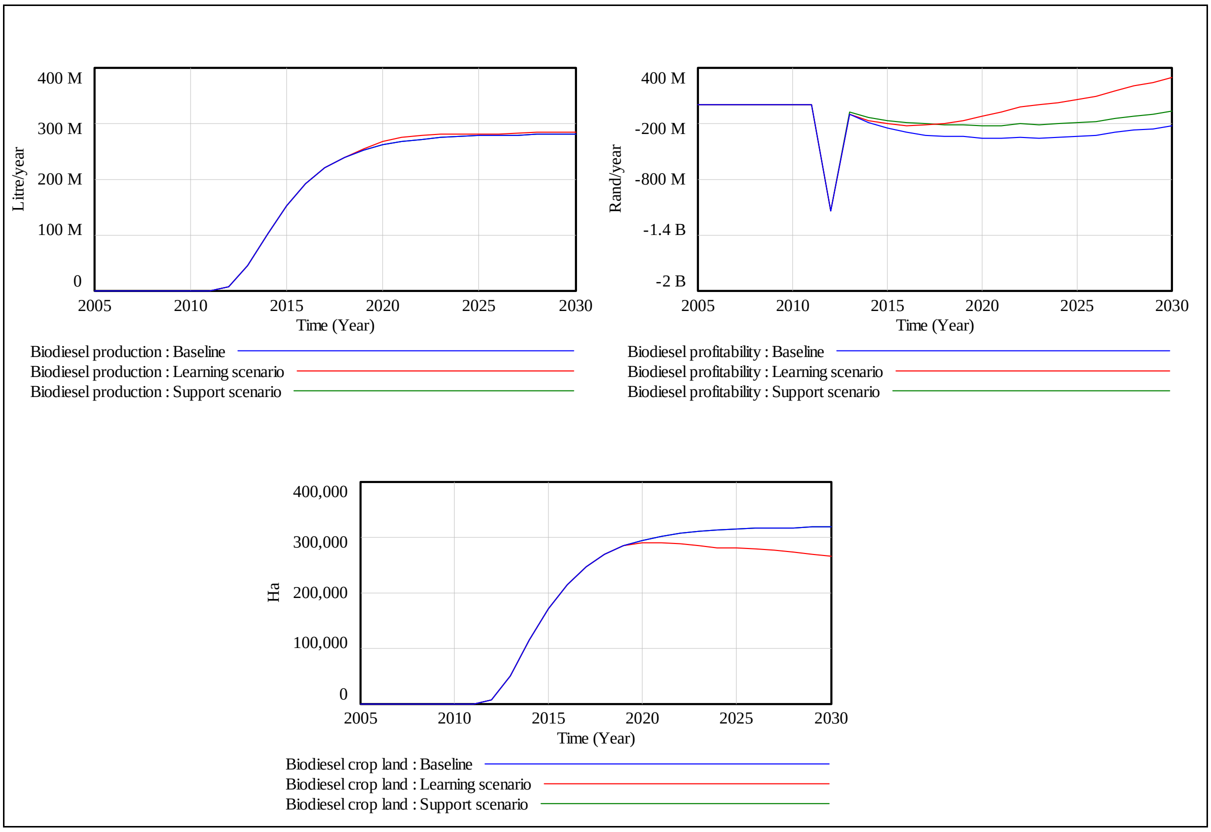

Figure 11: BIOSSAM model support scenario simulation result

5. Conclusions

In order to understand the implications of the biodiesel production development in the Eastern Cape Province of South Africa, it is necessary to take a holistic view in analysing the key society-economy-environment interactions. Exploring various scenarios using modelling and simulation can be helpful in providing this understanding. In this paper, the BIOSSAM model formulation of system dynamics is described to simulate the baseline behaviour of biodiesel development in the Eastern Cape Province. However, due to the uncertainty involved the baseline scenarios should be viewed as benchmarks on the way biodiesel industry may develop. The modelling process in this study is still in progress. Future improvements on the model would involve engaging with the key stakeholders for development of relevant scenarios for South Africa biodiesel industry, running these scenarios and model validation In addition, a more specific technology assessment model regarded as bioenergy technology sustainability assessment model (*BIOTSA*) is being developed.

Acknowledgments

The authors would like to acknowledge Dr. Andrea Bassi of Millennium Institute for reviewing the BIOSSAM model.

References

Amigun, B., Musango, J. K., 2010. An analysis of potential feedstock and location for biodiesel production in Southern Africa. Manuscript submitted to the Energy Policy Journal Manuscript number: JEPO-D-10-00767R1

Amigun, B., Müller-Langer F., Weber, M., von Blottnitz, H., 2008. Predicting the costs of biodiesel production in Africa: Learning from Germany. Energy for Sustainable Development 12, 31-47.

Bantz, S.G., Deaton, M.L., 2006. Understanding U.S biodiesel growth using system dynamics modeling. Proceedings of the Systems and Information Engineering Design. http://www.sys.virginia.edu/sieds06/papers/FMorningSession8.2.pdf [accessed 13 July 2009], pp. 156-161.

Coyle, R.G., 1996. System dynamics modeling. Chapman and Hall, London.

Department of Minerals and Energy, 2007. Biofuels industrial strategy of the Republic of South Africa. http://www.info.gov.za/view/DownloadFileAction?id=77830 [accessed 15 August 2009].

Department of Minerals and Energy, 2009. Biofuels industry development in South Africa. http://www.dme.gov.za/pdfs/energy/renewable/Biofuels%20Position%20Paper_February%202009%20FINAL.doc [accessed 17 February 2010].

Eastern Cape Department of Agriculture, 2007. Business plan for an integrated dry-land cropping and processing plan for rural development in the Eastern Cape. Unpublished.

Eastern Cape Development Corporation, 2010. Industrial Zones. http://www.ecdc.co.za/eastern_cape_districts [Accessed January 2010].

Esterhuizen, D., 2009. South Africa Biofuels Annual Report. http://gain.fas.usda.gov/Recent%20GAIN%20Publications/General%20Report_Pretoria_South%20Africa%20-%20Republic%20of_5-28-2009.pdf. [Accessed 20 January 2010].

Flynn, H., Ford, D., 2005. A system dynamics study of carbon cycling and electricity generation from energy crops, Proceedings of the 23rd International Conference of the System Dynamics Society, Boston, MA.

Forrester, J.W., 1961. Industrial dynamics. Productivity Press, Cambridge, MA.

Friedrich, M.S., 2004. A worldwide review of the commercial production of biodiesel – a technological, economic and ecological investigation based on case studies, Master's Thesis, Institute fur Technologie und Nachhaltiges produktmanagement, Vienna, Austria.

Khumalo, L., 2007. Biofuels to power Eastern Cape. South Africa. http://www.southafrica.info/business/trends/newbusiness/biofuels-080307.htm. [accessed 12 November 2009].

Kruger, J., 2009. Biodiesel project brings new opportunity to Eastern Cape, South Africa farming community. http://www.pmforum.org/blogs/news/2009/01/BiodieselProjectBringsNewOpportunityToEastern.html [accessed 19 February 2010].

Musango, J.K., Brent, A.C., Bassi, A., 2009. South African energy model: a system dynamics approach International Conference of the System Dynamics Society, Albuquerque, New Mexico, USA.

http://www.systemdynamics.org/conferences/2009/proceed/index.html.
PhytoEnergy Development & Construction AG, 2008. Development of a bio-diesel industry in South Africa. 3rd German African Energy Forum, April 23-24, 2008.
Pruyt, E., De Sitter, G., 2008. "Food or energy? Is that the question?" Proceedings of the 26th International Conference of System Dynamics, Athens, Greece.
Scheffran, J.T., Bendor, T., Wang, Y., Hannon, B., 2007. A spatial-dynamic model of bioenergy crop introduction in Illinois, Proceedings of the 25th International Conference of the System Dynamics Society, Boston, MA.
Sterman, J.D., 2000. Business dynamics: systems thinking and modelling for a complex world. . McGraw-Hill/Irwin, New York.
Tesch, T., Descamps, P., Weiler, R., 2003. The COSMOPAD modelling framework: conceptual system dynamics model of plenary agricultural and biomass development, Proceedings of the Digital Earth Conference.
Visagie, E., Prasad, G., 2006. Renewable energy technologies for poverty alleviation. http://www.erc.uct.ac.za/Research/publications/06Visagie-Prasad%20RET.pdf [accessed 10 February 2010].
White, L., Costa, T.C., 2009. Biofuel technology transfer in IBSA: lessons for South Africa and Brazil. SAIIA Policy Briefing, No 7. http://www.saiia.org.za/images/stories/pubs/briefings/saia_spb_07_white_costa_20091130.pdf [accessed 3 February 2010].
Wilson, S.C., Matthews, M., Austin, G., von Blottnitz, H., 2005. Review of the status of biodiesel related activities in South Africa. Report for the City of Cape Town, South Africa.