Social dimension of bio energy production policy in Africa: A systems thinking perspective

M Kaggwa

Tshwane University of Technology
Email: Kaggwam@tut.ac.za

Abstract

The paper makes a case that bio energy production is a single techno-economic social system. Using a systems thinking approach, it develops a qualitative and a quantitative systems dynamics model to capture bio energy production as system and to demonstrate complex relationships that policy makers have to contend with in coming up with effective bio energy policies in African. From the models' analysis, the paper come to the conclusion that social acceptance will be an important determinant of sustenance bio fuel production in Africa. Moreover, any policy intervention geared towards increasing bio energy production that does not take into account social acceptance and does not articulate bio energy production as a single techno-economic social system is likely to be susceptible to policy resistance.

Key words: Bio-energy, Social factors, Systems thinking, Africa

INTRODUCTION

Migration from fossil to renewable energy use is an important element of the global move towards the green economy. Renewable energies, in general, reduce carbon emissions and with proper planning can provide energy for development in a sustainable way (Stambouli, 2010; Bre-Hammond et al, 1998). Specific to Africa, improved production and increased use of bio energy have been identified as a critical factors for the continent's achievement of sustainable clean energy use. Although bio energy use on the continent is not new, its production means have remained rudimentary despite advances in applicable technologies. Africa is still stuck with the outdated technology of biochemical conversion that concentrates on extraction of bio energy from animal manure and plant feedstock (Amigun et al, 2011). At international level, however, the use bio energy has been on increase. Many developed countries widely use bio energy to heat homes, generate electricity, fuel vehicles and even to provide process heat for industrial facilities. The continent is yet to catch up with this extensive use of bio energy. Herein lies a big potential for the continent's progress to a growing green economy.

Bio resource supply, however, competes for land with food production. Moreover, advancements in bio energy production can lead to unemployment of low-skilled rural people that earn a living through rudimentary production of bio energy products. It may also distort social structures and cohesion of communities. Despite its potential to increase availability of clean energy for use in economic activities in Africa, benefits from improved bio energy production may accrue to only the middle and affluent sections of society while affecting detrimentally the majority poor. As such, formulation of bio energy policy for the continent is a balancing act.

Policy pertaining to bio energy production in Africa has tended to focus on the techno-economic aspects and to a lesser extent on social dimensions of the undertaking. Commercial viability of relevant technologies and market demand growth for bio energy products have dominated Africa's policy discourse on bio energy production. Even in cases were the relationship between the techno-economic and social aspects is acknowledged, a one way causal relationship from the techno-economic to the social dimension is assumed. The one way causal relationship approach relegates the importance social aspects in determining sustainability of bio energy production intervention. It increases the likelihood of bio energy policy resistance - a situation where policy pertaining to bio energy production leads to delayed, diluted or defeat of the intended purpose (Sterman, 2000). One of the ways to mitigate against policy resistance is holistic policy articulation and analysis using systems thinking and related system dynamics methodology respectively.

Against this background, this paper assesses socio-economic implications bio energy production policy in Africa from a systems thinking perspective. It was hypothesised that without this holistic approach to bio energy policy analysis, in particular without including a social dimension, in the policy articulation, there was a high likelihood for such policies being not to be effective.

1. METHODOLOGY

The paper makes a case that bio energy production is a single techno-economic social system. Using a systems thinking approach, it articulates techno-economic and social factors involved in bio energy production. It proceeds to develop a quantitative system dynamics model to capture bio energy production as a system and to demonstrate complex relationships that policy makers have to contend with in coming up with effective bio energy policies in African countries.

From the qualitative model, key feedback loops were identified, captured in form of stocks and flows and finally quantified for the model to become a quantitative model able to simulate effect of policy intervention in bio energy production.

System thinking and system dynamics methodology are based on the concept of systems. A system can be defined as a ‘complex whole of related parts’ (Coyle, 1996). It is the summation of different parts or entities related to each other, that constitute the observed whole. Talking about a system implies, implicitly, that one is cognisant that observed phenomenon is an outcome of underlying complex interrelationships. This recognition is very important in policy analysis. Systems thinking provide a structured way of analysing complex interrelationships that are problematic or simply of interest to mankind. At the heart of systems thinking is the recognition that factors behind the problematic situations are interdependent, that causal effect between these factors is often two-way, and that the impact of action is neither instantaneous nor linear (Sterman, 2000).

Systems thinking provides means to capture complex relationships and feedback effects within a set of interrelated activities and processes. It facilities having insight into potential outcomes of policy intervention in complex systems.

Policy pertaining bio-fuel production, as one of the major potential renewable energy source for Africa, may seem simple but its ramifications are diverse and complex. It has both techno-economic and techno-social implications. It interfaces with environment via carbon emission reduction, the extent of which may be determined by available and applicable technology. The state of the environment will have a bearing on peoples’ welfare which in turn will influence future policy on bio fuel production. Systems thinking provide a useful means of having some insight into potential outcomes of policies pertaining to bio-fuel production on the Africa continent.

The development of qualitative and quantitative models was based on focus group interviews of experts on the subject. These included 5 Academics from Universities and 3 Researchers on the subject from independent research organisation. The process also benefited from extensive review of literature and data on bio energy production on the African continent in general.

2. THE QUALITATIVE MODEL

To bring to the fore complexities pertaining bio fuel production and to assess techno-socio-economic imperatives of applicable policy, a high level causal loop diagram that captures major aspects of bio fuel production was developed (Figure 1).

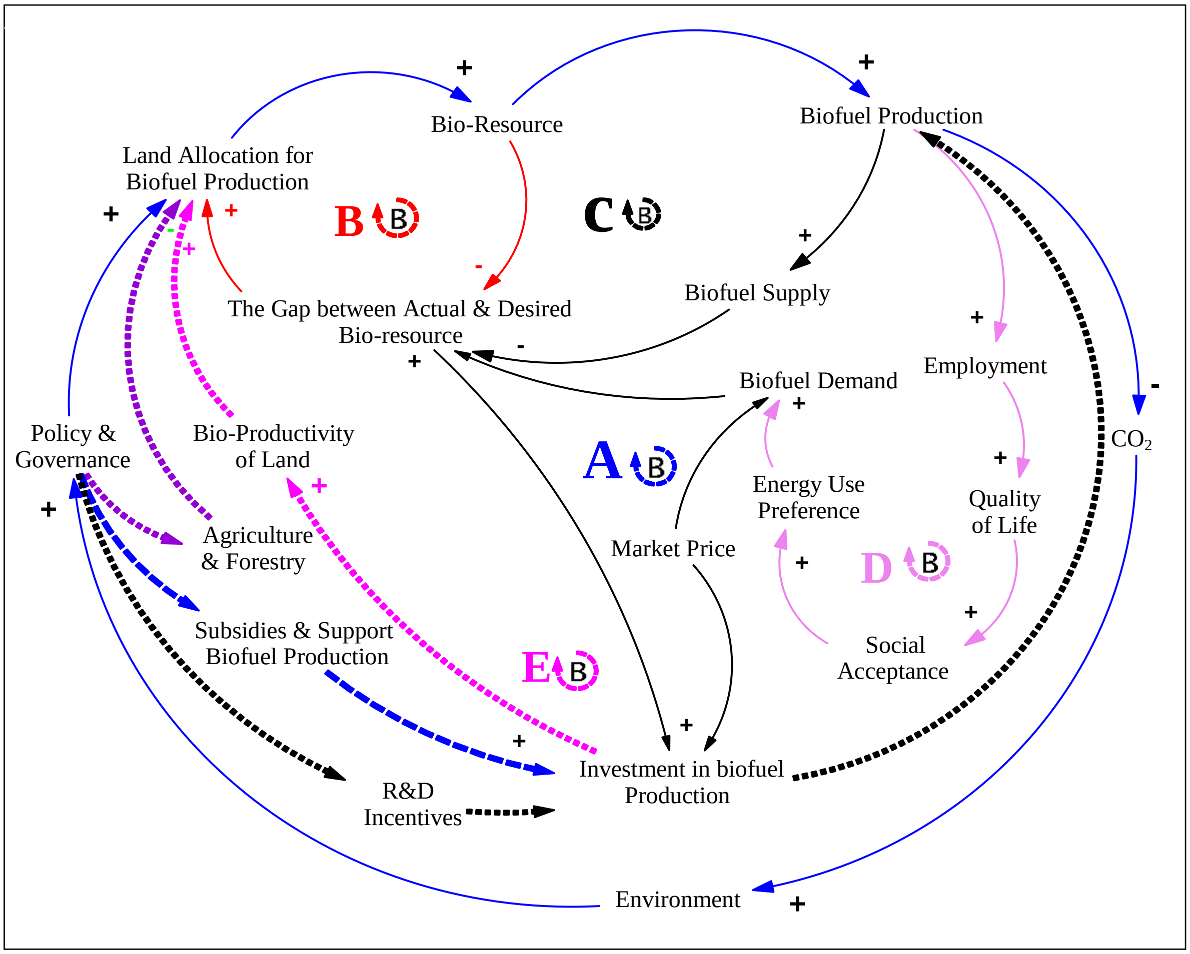

Figure 1: Techno-Socio-Economic Causal Loop Diagram for Bio fuel Production

Key closed feedback relationship in the techno-socio-economic model for bio fuel production identified included the following:

Effect of government policy on land allocation to bio fuels production in reaction to environmental concerns. It was recognised that good governance and policy regime within countries will be the major driver of bio fuel production and use in Africa. Hence, the starting point of the analysis was governance and policy. Assuming that there is no land constraint, more land allocation to bio production will ultimately lead to increase in bio fuel production. Increased bio fuel production reduces carbon emissions improving environmental conditions. The condition of the environment in turn influences future policy on land allocation to bio fuel production. This process constituted the first closed causal loop of the bio fuel production dynamics captured by the outer layer arrows.

The second closed loop relates to land allocation to bio fuel production which increases bio resource. Bio resource, in this case, refers to the stock of all bio inputs used in the bio fuel production. Increase in bio resource reduces the gap between actual and desired bio resource stock, which gap influences the allocation of land to bio fuel production. This process constituted another a closed but counter balance loop [B].

The third major feedback loop of bio fuel productions starts with land allocation to bio fuel production which increases bio resource. The availability of more bio resource will lead to higher bio fuel production. Increased bio fuel production creates jobs, holding other factors constant. Jobs improve the quality of life of those employed and will have positive externalities to communities where the employed people reside. Improved quality of life within communities will lead to social acceptance of bio fuel production and bio fuel products. Bio fuel demand will increase. This increase will widen the gap between actual and desired bio resource which in turn will influence future land allocation to bio fuel production. This feedback causal process is captured by loop [C]. Loop [C] is specifically important because it links production, which is a technical aspect, to employment which is a socio-economic aspect, and society preference which is more of social aspect. It encapsulates the techno-socio-economic dimension of bio fuel production.

Another closed causal relationship starts with land allocation, to bio fuel production, to increase in bio resource, and to increase in bio fuel production. Bio fuel production will increase the supply of bio fuels which will narrow the gap between actual and desired bio resource. The narrowed gap between actual and desired bio resource will lead to less land being allocated to bio fuel production, holding other factors constant. This captured by the closed causal loop [D].

The last closed causal loop identified in the bio fuel production relates to investment decision. Land allocation to bio fuel production influences bio resource stock. Bio resource stock has an effect on the gap between actual and desired bio resource. This gap feeds into investment decisions in bio fuel production, in conjunction with other factors. Investment in bio fuel production has a positive effect on land productivity. Land productivity influences land allocation to bio fuel production, closing the loop. This investment feedback process is captured by the loop [E].

It is acknowledged that when it comes to renewable energy resources, investment plays a dual role. On one hand it can increase the production efficiency via improved technology on the other it increases the supply resource in put through increasing bio resource productivity of land.

The above articulation brings to the fore the many factors - technical, social and economic, that have to be considered in tandem when devising a bio energy production policy and more importantly it makes explicit the complex relationship between them.

3. THE QUANTITATIVE MODEL

The migration from qualitative to quantitative required focussing on key relationships that the researcher felt were fundamental in understanding dynamics of bio fuel production in Africa. In this regards, the focus was on the relationship between social acceptance and the other conventional techno-economic factors of bio fuel production.

Figure 2 presents the relevant stocks and flows as articulated in the quantitative model.

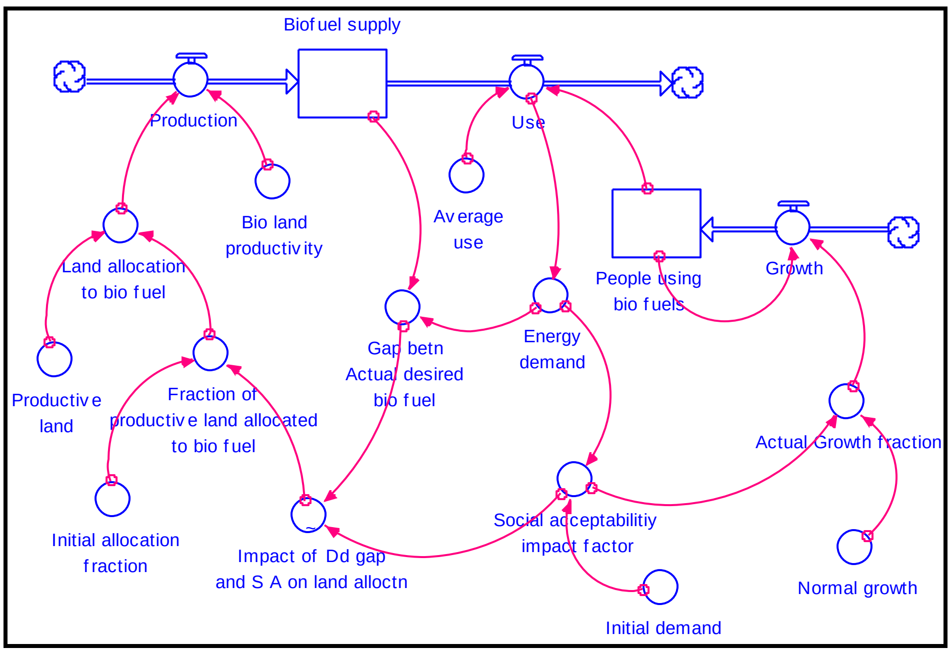

Figure 2: Stock and flow diagram for bio energy supply with social dimension

The model was developed around two stocks – bio fuel supply and number of people using bio fuels. The production of bio fuels was modelled to depend on land allocation to biomass production and general bio productivity of land. Bio fuels use was modelled to depend on average bio energy use and number of people using bio fuels. The rate of increase of the number of people using bio fuels was specified to depend on social acceptability factor and normal growth fraction of people migrating to biofuel use. Energy use was used as proxy for energy demand in short to medium term. The gap between actual and desired bio fuel energy use was captured as the difference between biofuel supply and biofuel demand. This gap together with social acceptability factor had impact on decision to allocate land for biomass production via the fraction of productive land allocated to biomass production. These relationships constituted a closed casual loop of bio fuel production.

After specifying values of exogenous variables - productive land, fraction of land allocated to biomass production, initial bio energy demand, normal growth of people migrating to bio fuel, plus specifying initial values of biofuel supply and people using biomass fuel (based on estimates from literature), the model was used to simulate likely trends of bio fuel production and supply in Africa.

Model simulation results indicated that starting with low initial demand for bio fuels was more likely create a sustainable and increasing biofuel production system than starting with high level of initial demand.

Biofuel production and supply trends with initial demand set at 100 million (trend 1), at 150 million (trend 2), at 200 million (trend 3), at 250 million (trend 4) and 300 million people (trend 5) are presented in Figure 3 below.

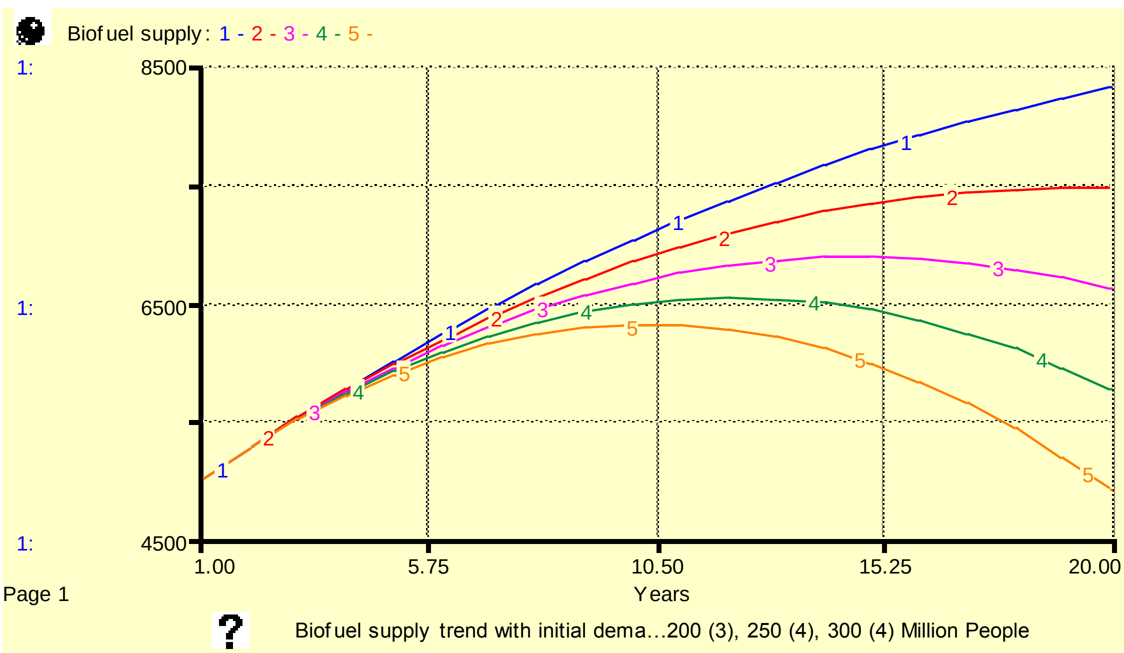

Figure 3: Biofuel Production and Supply with Varying Levels of Initial Demand

The supply trend of biofuels seemed counterintuitive at the glance but could be understood in context of effect of social acceptance on sustaining higher levels of energy production particularly in rural Africa.

Starting with low levels of initial demand for biofuels meant that future increase in demand would be determined by more people accepting the new energy form. As such, increase in biofuel demand and subsequent increase in supply, under the circumstances, was more attributable to social acceptance and change of attitude towards the energy used rather techno-economic factors.

On the other hand, starting with higher levels of initial demand for biofuel (significantly exceeding what was being produced), meant that subsequent increase in actual demand would not emanate from ‘new converts’ to bio fuel use but rather people that already desire to use bio energy source. Bio fuel production and subsequent supply will increase with time in response to existing (potential) demand. At some point, the production system will be able to meet the ‘excess demand’. Beyond this point, and without mechanism to influence social acceptance of biofuel use in society, demand will stabilise and actually begin to decline. The declining aspect could be attributed, in part, to trade off of land allocation to biomass production and to food production which is likely to become more pronounced as more and bio fuels are planned for production. This trade-off is more likely lead to social rejection rather than acceptance of bio fuels as people weigh the benefits of food against clean energy.

4. INSIGHTS AND CONCLUSION

A key observation from the qualitative analysis is that social acceptability will be an important determinant of successful take off of bio fuel production in Africa. This acceptability is a function of number of factors including, employment and poverty alleviation, community education, and social cohesion. These factors are both consequences and determinants of a bio energy production undertaking.

At a quantitative level, sustenance of biofuel production in Africa will depend, to a reasonable extent, on the increasing number or people that will come to accept bio energy use, against competing social economic needs and that will ultimately lead into increasing and sustainable demand for bio fuels. The rate of social acceptance rather than the existing demand that will be the main factor to sustain bio energy production in Africa.

Ultimately a holistic articulation of policy pertaining bio fuel production using systems thinking elevates the importance of social aspects in sustaining bio energy production in Africa as part of the wider aspiration of the continent to have a green economy. In so doing it provides useful means of reducing policy resistance in the sector.

Conclusions of this paper have to be considered with some caution though. The paper reports on the first stage of the study. The next stage of this project will involve going to the field to collect primary data. Field data will be analysed to ascertain whether it confirms conclusions of this study. Depending on the new findings the bio energy production model presented and conclusions there from will be modified or improved upon or generally validated.

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