The socio-economic implication of 2nd generation biofuels in Southern Africa: A critical review

Gratitude Charis, Gwiranai Danha, Edison Muzenda
Department of Chemical, Materials and Metallurgical Engineering, College of Engineering and Technology, Botswana International University of Science and Technology, Plot 10071, Boseja Ward, Private Bag 16 Palapye, Botswana.
Corresponding Author: Gratitude Charis
gratitude.charis@studentmail.biust.ac.bw , danhag@biust.ac.bw, muzendae@biust.ac.bw

Edison Muzenda
Department of Chemical Engineering in the Faculty of Engineering and Built Environment, University of Johannesburg
PO Box 524 Auckland Park, 2006
Johannesburg, South Africa

Abstract
This article summarises some of the major findings and developments on global 2G biofuels' research in a non-chronological order. This was done in order to give a highlight on some of the potential implications these findings could have on Southern Africa's decision making processes, given its abundant lignocellulosic biomass resources and residues. Before specific feasibility studies can be made on a country-to country basis, this overview can give a glimpse into some potential opportunities and hurdles for such waste-to-biofuels systems from a socio-economic perspective. The findings indicate that biofuels demand is increasing around the globe, and it is envisaged that 2nd generation (2G) biofuels will gain a larger market share compared to 1st generation (1G) due to their vast availability, limited interference with food security and ecological benefits. Southern Africa will have to take advantage of the abundance of biomass, especially lignocellulosic residues from forestry and agriculture and create room for the transfer of some promising, demonstrated or commercialised technologies. The largest opportunity for the 2G biofuels will be from waste feedstocks like crop and forest residues, organic fraction of municipal solid waste (MSW), black liquor and other wood process wastes. Issues of limited supply and associated conversion costs will have to be considered along with the supplementary options to determine the socio-economic sustainability of such waste-to-biofuels ventures. Lessons will have to be drawn from socio-economic shortcomings of 2G biodiesel Jatropha projects to ascertain the viability of feedstock supply chains, right choice of conversion technologies and proper projection of potential socio-economic impacts.

Keywords
biomass, residues, biofuels, 2nd generation, socio-economic, supply chain

1. Introduction
The global biofuels for the transport industry were projected to grow at a compound annual growth rate (CAGR) of 44% from 2017-2021. This projected growth is driven by global oil insecurities, supportive government policies, a drive towards cleaner fuels and reducing greenhouse gas (GHG) emissions and potential to drive regional economic growth and new jobs [1]. One distinct attractive feature about bio-fuels is that they can allay the dependence on politically and socially unstable international energy transactions from crude oil. As a result, bio-fuel policies are increasingly becoming popular; for instance, the US and EU have recently adopted ambitious bio-fuel support policies, namely 60bn litres of 2G bio-fuel by 2022 and 10% renewable energy in the transport sector by 2020 respectively. As biofuels demand increases, experts argue that 2G technologies for lignocellulosic biomass will

inevitably become the primary route to bio-fuel production due to their vast availability and the fact that they do not pose a competition for food resources [2]. Meanwhile, the conventional 1G feed stocks (food crops and edible oil seeds) are limited, even if they were all to be utilized for bio-fuel production, they could only substitute 40% of fossil fuel stocks [3]. Moreover, there have been hot debates on the continued use of these feed stocks since they compromise the global food security, have high net lifecycle GHG emissions and contribute to climate change [4]. Second generation biofuels also offer far greater energy balances. The fossil fuel input for every 1million BTUs of *cellulosic* ethanol is 0.15-0.23million BTU while up to 0.78millon BTU fossil fuel input is required to produce the same amount of 1G biofuel [5]. An even more attractive alternative is to utilize biomass residues from forestry or agriculture, or tree plantations dedicated for biofuel production that do not compete with arable lands for agriculture. This prospect of consuming waste residues and making use of abandoned land has considerable potential to '*promote rural development and improve economic conditions in emerging and developing regions'*[1]. Southern Africa is one such region that can benefit from the abundance of biomass, especially lignocellulosic residues from forestry and agriculture. There is little technical research that has been made on the production of 2G biofuels from such residues in Southern Africa because such research is capital intensive and beyond the reach of most developing nations [6]. However, this should not preclude reviews, especially on potential socio-economic impacts. The experience in this region is that inadequate socio-economic studies were made for non-edible oil crops like Jatropha (for biodiesel) and this led to the collapse of a number of projects, and in some cases like Mozambique, a significant disruption of the socio-economic fibre of residents [7]. This paper therefore seeks to avoid such consequences of under-informed decisions by suggesting potential socio-economic implications of 2G biofuels projects. These projected implications are based on reviews of the progress in 2G biofuels technical research, the biofuel potential of southern Africa, global and regional policies and past biofuels projects in this region.

2. 2G Biofuels research overview

A review of Scival metrics reveals that 2G biofuels has been on a steady and impressive rise, as shown in Fig 1.

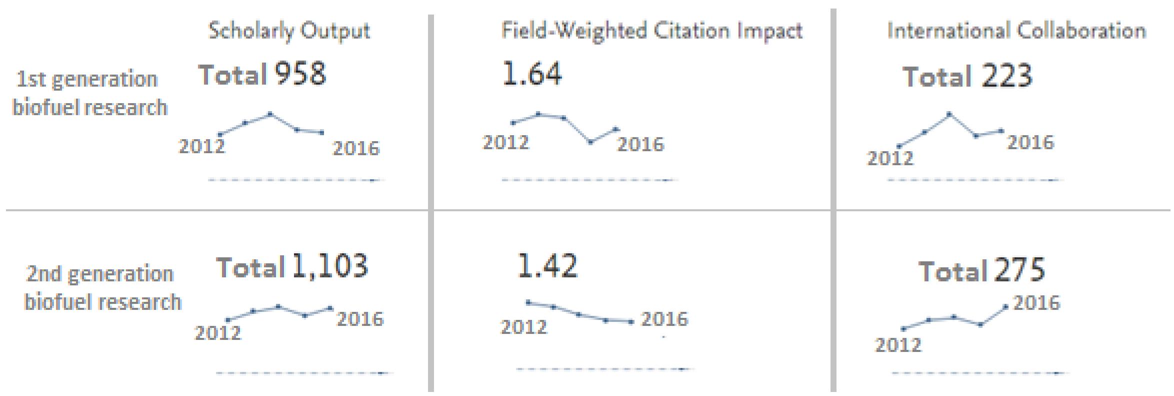


Figure 1. Trends for 1G and 2G biofuels ***(www.scival.com)*.**

Indeed a lot of resources have been invested in R&D, including the commercialization of these 2G conversion technologies

Bacovsky et al. classify biofuels into 1st, 2nd and 3rd generation biofuels mostly based on the state of development/commercialization owing to the ongoing research around the feed stocks to be used [8]. Table 1 gives a summary of these categories, along with the potential conversion technologies that can be used.

Table 1. Classification of biofuels

Class of biofuel	**1st generation *bioethanol and biodiesel***	**2nd generation: *Lignocellulosic bioethanol and biodiesel***	**3rd generation *biodiesel***
Example feed stocks	*Ethanol feedstocks*: sugar and starch sources; sugarcane, sugar beet and corn potatoes (starch)	Lignocellulosic feed stocks for both *ethanol and biodiesel:* biomass e.g. agricultural and forest residues & specific, fast growing coppices converted through hydrolysis to	3rd generation feed stocks for *biodiesel*; mainly algae.

	Biodiesel feedstocks: edible crop and vegetable oil: Rape oil, sunflower oil	ETHANOL. Black liquor from pulp and paper industry. Oils from non-edible oil crops like Jatropha *for biodiesel*	
Conversion technologies: *(Simplicity decreases from 1st, 2nd to 3rd gen).*	*Biological:* Fermentation of simple sugars for ethanol & other alcohols *Chemical:* Transesterification of *edible oils* to produce biodiesel	*Biological:* Pre-treatment, enzymatic hydrolysis (EH) then fermentation of C5 and C6 sugars to produce ethanol *Thermochemical*: Fischer Tropsch used for biodiesel & other hydrocarbons. Catalytic synthesis of other alcohols also possible. *Hybrid*: Gasification-Fermentation (GF) can be used for bioethanol and other alcohols. *Chemical*: Transesterification and Hydrotreatment of *non-edible oils, animal fat or vegetable oil waste* to produce biodiesel	Extraction of oils (an intricate and expensive process) then trans-esterification into biodiesel
References	[2], [8], [9]	[3], [9]–[12],[13]	[14],[15]

The general convention, as seen from the classification, is that biofuels from feedstock that are food sources are 1G, while non-food resources constitute the 2G feedstocks [6], [8], [16].

The International Energy Agency (IEA) predicts that cellulosic ethanol and Biomass to liquids (BTL) biodiesel (largely from FT synthesis) will gain a greater mileage in use over counterpart 1G biofuels (Fig 2). This is with the exception of cane ethanol, which will withstand a longer test of time [17]. The major reason for this trend is that lignocelullosic biomass is an abundant and inexpensive renewable resource that has little or no threat for food resources, either directly or indirectly [9]. This is especially true if agricultural or forest residues are being utilized, especially in Africa, where food security is a sensitive matter [18]–[20].

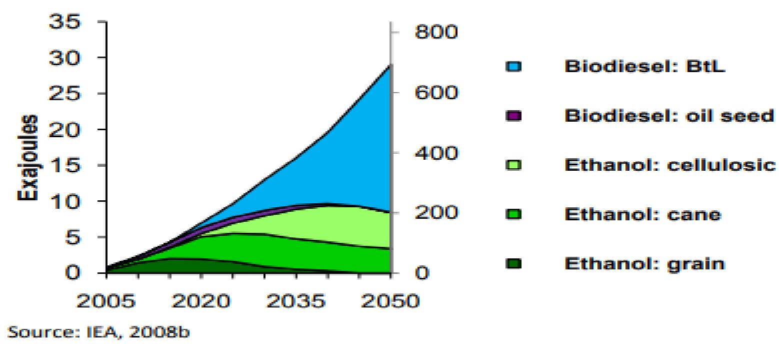
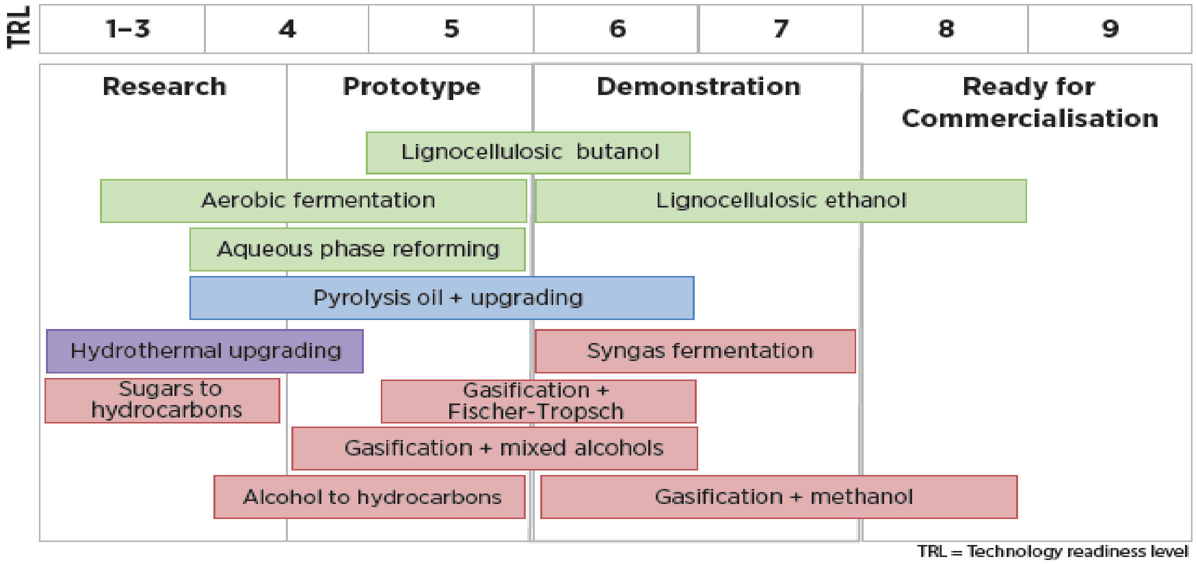


Figure 2. Biofuels share- a forecast

X. Ji and X. Long claim that the use of lignocellulosic residues as feedstock for ethanol production is cost efficient and could reduce the production costs by up to 50% [21]. However, Carriquiry et al. also point out that, though 2G feedstock costs (e.g. forest residues) can be lower than 1G by 30-50%, conversion costs can be very high [22]. The conversion technologies discussed largely by literature fall under chemical, biochemical, thermochemical and a hybrid between the last two. Fig 3 shows the commercialisation status of each of these technologies, while Fig 4 is a comparison of production costs for biofuels with fossil based fuels. Given the high market demand for biofuels (see sec 3.4), the major factors that will influence uptake of these technologies, especially in Southern Africa are:

- the technical and commercial maturity of technology [6]
- costs of production and subsequent final cost of biofuel [6]
- sustainability of feedstock supplies given minimum economic throughput and a supportive policy framework [18]–[20], [23].



Note: Colours represent the principal conversion process, hydrolysis (green), pyrolysis (blue), hydrothermal upgrading (purple) and gasification (red).

Figure 3. Commercialization status of various advanced biofuel conversion technologies. Source: [6]

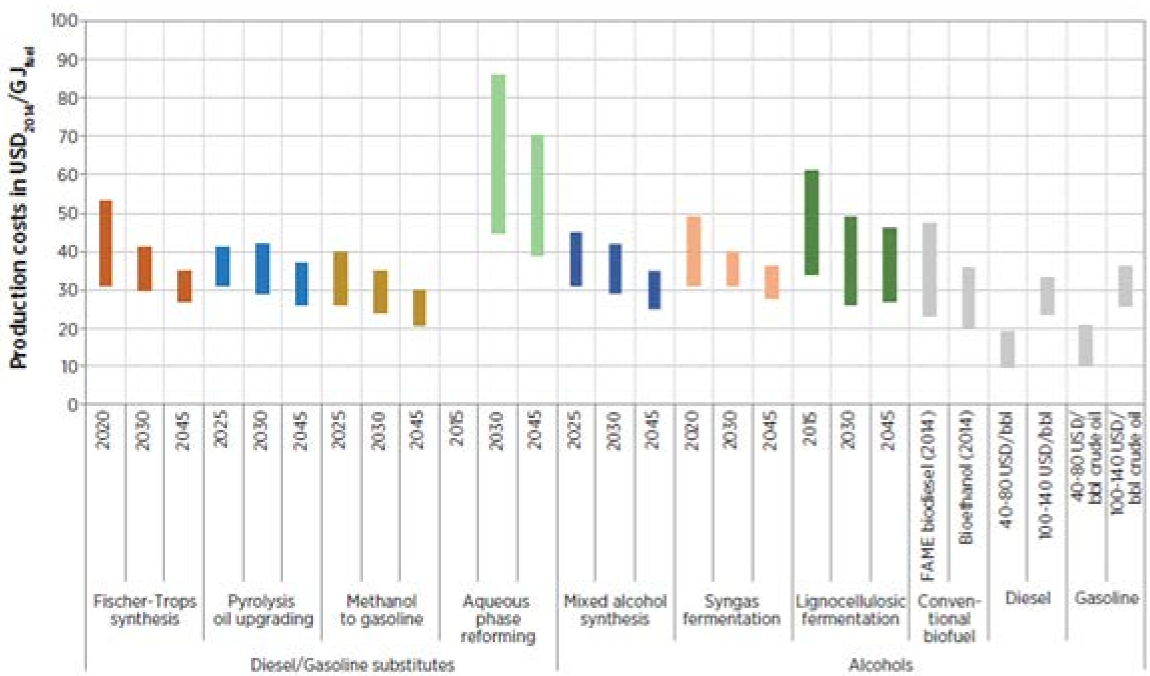


Figure 4. Comparison of fuel production costs for 1G, 2G and fossil based fuels [15]

3. Current energy demographics, policies and socio-economic trends in Southern Africa.

Having obtained a glimpse of the state of global R&D on 2G biofuels, it is also important to review the present state of biomass and biofuels production in the context of Southern Africa. It is pertinent to recall, from Table 1, that 2G biofuels refer to bioethanol, largely from lignocellulosic biomass and biodiesel from transesterification or hydrotreament of non-food oils.

3.1 Energy demographics and lignocellulosic biomass potential

Africa boasts of *a fifth* of the global biomass, but however, only accounts for <0.1% of global bio-fuels share [1]. Wood-based biomass is the dominant energy source of for Sub Saharan Africa for cooking, lighting and space heating [15]. About 81% of households use it, mostly through open fire stoves that are at most, 10% efficient [18]. This poses a health hazard in the form of chronic respiratory infections like pneumonia, lung cancer or chronic obstructive pulmonary diseases, especially for women and children who do most of the cooking [6], [24], [24]. The major, readily available biomass forms are woody biomass (forest plantations), forest & agricultural residues [15], [25]. Use of plantations, especially natural, would raise questions on sustainability, unless these are planted specifically for the purpose on lands that do not compete with agricultural interests [20]. Therefore this discussion will mostly focus on forest and agricultural residues since they represent an easier starting point with no ecological sustainability issues. The availability of such huge deposits of biomass feedstock for potential 2G biofuel production has been documented by various scholars [18], [26]. However, obtaining accurate data on the exact quantities of biomass from country to country is still difficult since information is scant [25]. Table 2 gives the biomass feedstock availability in various Southern African countries as a percentage of the total energy used [25].

Table 2. Indicators of traditional biomass usage in southern Africa (Adopted from [25] NOTE: statistics were collected using different methods and at different dates, therefore are not totally comparable)

HDI Rank	Country	Biomass& waste as % of national energy mix	% change biomass & waste 1990-2005	% of all households using wood fuels	% of rural households using wood fuels	Per capita charcoal consumption	% household electrification
162	Angola	63.8	-5	95			15
124	Botswana	24.1	-9	65	86	37.96	39
139	Congo	56.3	-13.1	84			20
168	DR Congo	92.5	8.5	95	100		6
172	Mozambique	85.4	-9	80		5.35	6
121	South Africa	10.5	-0.9	18	49		70
159	Tanzania	92.1	1.1	95	96		11
165	Zambia	78.7	5.3	85	89	71.08	19
151	Zimbabwe	61.9	11.5	73		0.32	34

International Renewable Energy Agency (IRENA) stipulates that bioenergy is a strategic asset in the future of Africa, especially in the light of the fact that it comprises 50% of Africa's total primary energy supply (TPES) and more than 60% of SSA's TPES [27], as Fig 5 illustrates . Estimates on Africa's collective biomass potential are wide and varied, being classified largely as energy crops, forestry biomass (plantations) then residues and organic waste. The estimates for 2020 show in Table 3, as follows:

Table 3. Estimates on Africa's collective biomass potential

Energy Crops	Forestry biomass	Residues (forestry & agric) and waste
Up to 13,900PJ/yr [1]	Up to 5,400PJ/yr	Up to 5,254PJ/yr

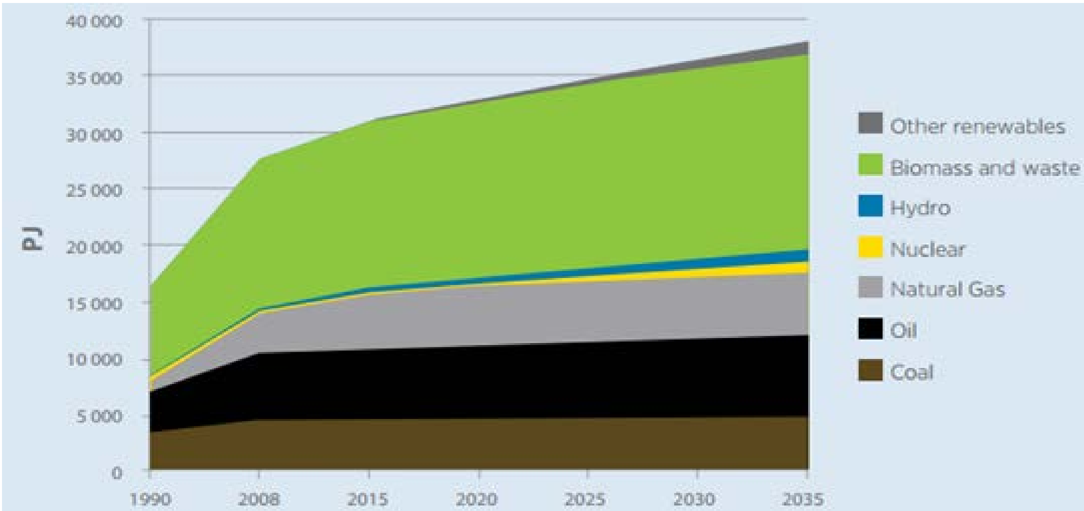


Figure 5. Total Primary energy demand for energy sources in Africa (IEA 2010)

A number of authors including Amigun etal., Pradhan and Mbohwa, Neupane and Rubin and Gasparatos et al. concur that biomass potential towards biofuels production is variable depending on the following mix of factors [17], [18], [19], [30]:

- **The energy and food crop availability depends on country policies and land availability**. For instance, use of maize corn to make ethanol is banned in South Africa [19], but is a major feedstock in the US [28]. Moreover, policies are gravitating towards using non-food crops or biomass so that food security is not compromised. Still, some, like energy crops, require more land, which is limited in the US and EU, but still relatively abundant in Africa[20], [25].
- **Forestry residues' availability will depend on the presence of a timber industry that processes lumber in saw mills**. Not all forestry biomass is eligible: use of timber from natural forests is not sustainable as it leads to deforestation and destruction of carbon sinks [28]. In the case were larger scale biofuel production is envisaged, growing plantations for that purpose can be considered though land issue, cost of feedstock (including comminution costs) on forestry conservation practices and alternative residue uses; while agricultural residues have to be carefully considered [29].
- **Wood processing, construction and paper industry wastes can be used where the conversion technology is not adversely affected by chemical elements that become constituents of such wastes.** In the cases where they contain toxic elements, pretreatment options have to eliminate them [30].
- **Agricultural residues availability will depend on agricultural facilities (land and inputs), climatic patterns, food demand & population growth**[25],[20]**.** Care should be taken to ensure sustainable harvesting of the residues since a total removal of the biomass cover will have some negative effects on agriculture [18], [28].
- **For both residues (agricultural and forestry), their availability will also depend on the biofuel plant location**. It would not be economic to have a very wide collection radius for the feedstocks as this will affect transport costs.
- **Organic waste availability will depend on a number of demographic patterns, including population growth.**

Evidently, the reason why southern Africa would have such a high percentage share of biomass and waste (especially residues) is due to a relatively high abundance of land for energy and food crops, a relatively stable and conducive climate, a vibrant timber industry, a thriving agricultural industry and a fast growing population rate which naturally raises the demand for agricultural and timber produce and the residues thereof [20], [25],[19].

3.2 Alternative lignocellulosic residue and waste uses

SSA is notorious in renewable energy literature, for underutilizing its energy resources, which are largely, 'undeveloped'[18], [24], [31], [32]. Jingura et.al remark that 'biomass is by far the most important renewable resource in SSA'[31]. However, the larger share of biomass resources, especially fuel wood, is used for cooking and heating through traditional, inefficient methods. The use of such unprocessed biomass along with inefficient conversion methods, not only impacts on human health as mentioned earlier, but also on the environment, through unsustainable use and deforestation[20]. Though it is agreeable that conversion to electricity would ameliorate the large electrification gap, for instance, in southern Africa (Table 2) and plans have been advanced to that effect, there is nothing on the table concerning the conversion of these *lignocellulosic wastes* to biofuels. These biofuels could substitute use of raw biomass as cleaner heating and cooking sources, with higher energy efficiencies [24], [31]. Moreover, literature argues that simple conversion of biomass to CHP via incineration obtains a lower value product in the context of value chain creation and socio-economic impact [14], [21]- a point for debate, since addressing energy (especially electricity) poverty could equally be important.

3.3 Biodiesel from trans-esterification of non-edible oils: an important learning experience

The other share of 2G biofuels is occupied by biodiesel from the trans-esterification of, especially, non-edible oils. Currently, there are *ca*66 commercial 2G biofuel plants in southern Africa, Jatropha occupying over 90% of this share [25]- showing there is need to start exploring the lignocellulosic conversion opportunities. Moreover, research has established that, in most cases, Jatropha has disappointed on the following expectations:

- **Expectation 1: It grows well on marginal lands with high yield in poor soils**. After experimentation, experts have concluded, on the contrary, that Jatropha requires specific conditions (soil pH>5,good amounts of nitrogen, potassium and calcium) and care for good yields [7]. Even Jatropha plantations on arable lands have fallen short of claimed growth rates and yields, ruling out poor soils [33].
- **Expectation 2: It can grow well in arid areas with minimal maintenance/care.** This was found to be false as Jatropha required considerable irrigation at early stages. This meant extra labour for subsistent farmers to meet both home and Jatropha water needs. It was also found to be susceptible to some pests and diseases, which at times affected other crops. Intensive use of water, chemicals & fertilizer use meant Jatropha was posing a competition for agricultural inputs [25],[7].
- **Expectation 3: It has positive energy balances and a low carbon footprint.** The fact that a lot of fossil-fuel based chemicals and fertilisers are required means the energy balance could be negative. Already, displacing huge chunks of forests with Jatropha negatively impacts on natural carbon sinks [20].
- **Expectation 4: It has no risk on food security:** Given the cited competition for arable lands, agricultural resources and labour/attention, Jatropha has since proved to have a considerable threat to food security. In the case of limited land availability, farmers may opt to replace land that was formerly allocated for food production to produce the cash crop [25], [33].

It is largely agreed that the Jatropha rush has proven catastrophic because not much was invested on a proper, independent socio-economic study which could have exposed the realities above. As a result, some projects have been stalled (e.g. Zimbabwe), while some studies in nations like Swaziland and Mozambique have warned that Jatropha projects risk worsening livelihoods and threatening food security[25]. Although 1G biofuel projects have largely been successful, the outcry against the use of edible grains or oils has gained traction especially with global humanitarian organizations. These policies will soon affect Africa, where food security is considered priority [1], [32], [34].
Except for South Africa, there are no definite biofuels policies that had been set in place in other Southern African countries, despite the fact that nations like Malawi and Zimbabwe have vibrant 1G biofuel projects[15], [20]. The only instruments that were enacted were blending mandates; in most of these nations, the formulation process has begun seeing that there is a global emphasis on these. These policies will most likely cover both 1G and 2G biofuels; maybe other advanced technologies as well. A 25% sample of well documented projects in Southern Africa by Matitz G. and Setzkorn K. (Table 4) reveals the following 1G and 2G projects currently being run in the region [25]:

Table 4: 1G and 2G projects being runt in Southern Africa

Project	**Southern African nations involved**
1G production of ethanol from sugarcane	Malawi and Zimbabwe, using both corporate and outgrowers schemes
1G production of ethanol from sugar beet	Republic of South Africa (RSA), through corporate schemes like Cradoc and Silver Sands
1G production of biodiesel from Soybeans and sunflower oil.	RSA through corporate schemes like MMI South Africa

2G production of biodiesel from Jatropha and Croton	Madagascar, Malawi, Mozambique, Malawi and Zimbabwe.

Evidently, southern Africa has not yet ventured into the conversion of already available biomass, especially in the form of forestry and agricultural residues. These require either the thermochemical, biochemical or hybrid conversion technologies. Given the recent progress made in commercializing these, southern African nations should now explore the viability and sustainability of such 2G biofuel projects, especially in nations whose biomass and waste mix are over 50% of the national energy mix. Southern African countries like Botswana (has lowest biomass %), SA and Zambia have been exploring options of using energy crops like sweet sorghum: this would also be a good alternative for Zimbabwe and Malawi as well since the feedstock can be processed in the existing ethanol production facilities [25]. However, this does not sideline the adoption of 2G biofuel projects since the use of forestry and agricultural residues as feedstock could provide for a socio-economically and ecologically sustainable way of dealing with these vastly available waste resources without disrupting agricultural schemes and food security[20], [21].

3.4 Potential markets for the biofuels

Largely, the biofuels market is huge and only partly tapped considering the high demand for domestic and international supply of both bioethanol and biodiesel [1], [6]. International demand is driven by biofuel policies in US and EU, while local demand is driven by a quest for energy independence and higher trade balances by substituting fossil fuels imports [1], [15], [28], [33]. It has already been established that 1G biofuels are limited since they could only replace 40% of fossil fuel demand. Therefore tapping into the unlimited potential of lignocellulosic biomass is a wise prospect for southern Africa.

The demand for ethanol by-products like gel fuel is varied; the uptake has been low in some SADC countries, mainly due to higher costs of this fuel compared to traditional biomass, high cost of stove and inadequate information dissemination[35]. Fig 6 below summarises the potential global markets for biofuels:

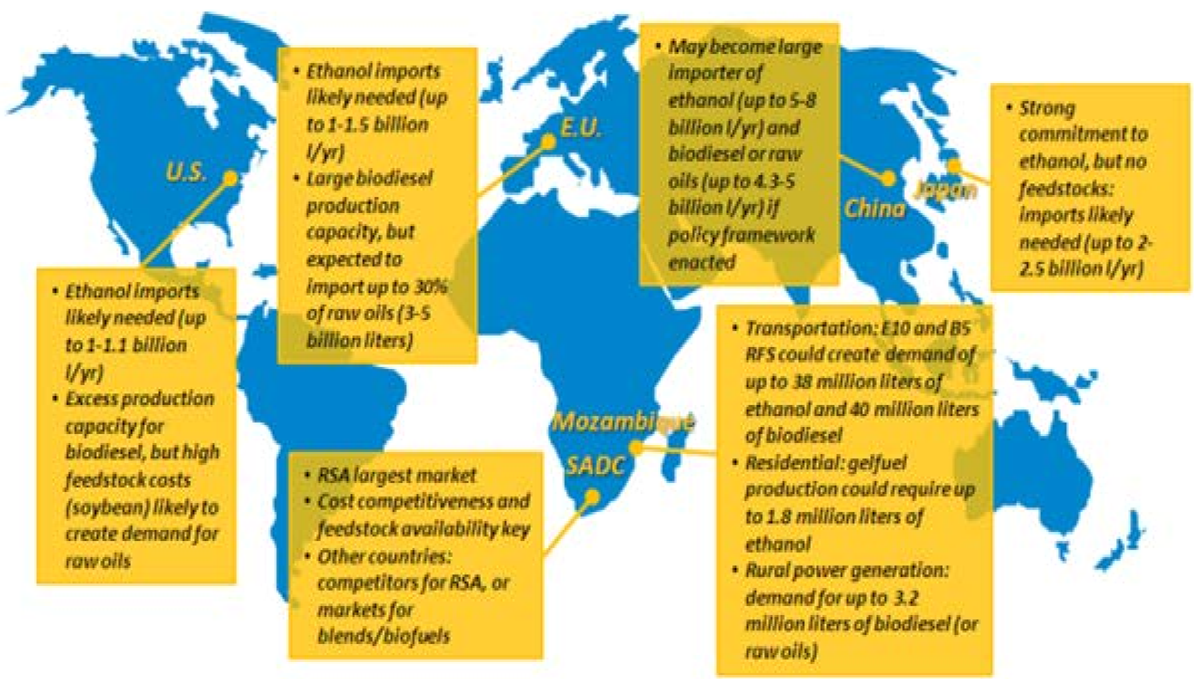


Figure 6. Potential biofuel markets. Source: Ecoenegy, Notes; SADC and South Africa

3.5 Policies and the fate of 1G biofuels

Although 1G biofuel projects have largely been successful, the outcry against the use of edible grains or oils has gained traction especially with global humanitarian organizations. These biofuel policies will soon affect Africa, where food security is considered priority [1], [32], [34]. Already South Africa has a policy restricting the use of corn/maize to produce bioethanol [19]. Indeed, South Africa is the first in Southern Africa to come up with some clearly defined policies around biofuels; with the National Industrial Biofuels Strategy launched in 2007[19]. The recent global emphasis on 2G biofuels [20], issues on food security and other socio-economic issues raised around biofuels have driven SADC to craft guidelines, while its nations have begun enacting specific policies to govern them (Table 5). To date, only 7 of the 13 SADC nations have set solid bioenergy strategies or policies; the rest are either at the initial stages or not started [19], [20], [36]. Ideally, these policies should cover both 1G and 2G biofuels; and probably other advanced technologies as well.

Table 5. Progress on policy developments for biofuels in Southern Africa.

<table>
<tr><th colspan="3">SADC Guidelines for setting up of biofuel policies, 2009. [37]</th></tr>
<tr><td>1. Biofuel production shall follow national relevant law and policies and, where applicable, international law.
2. Biofuel production shall be guided by free prior and informed consent by relevant stakeholders.
3. Biofuel production shall contribute positively to rural development through: - non-violation of human and labor rights, promotion of decent work and the well-being of workers - social and economic development of indigenous, local and rural people and communities - decentralized value-added processing and local participation in the entire value chain</td><td>4. Biofuel production shall contribute positively to local and national food security.
5. Biofuel production shall respect formal and customary land rights and land use rights.
6. Biofuel production shall contribute positively to national energy security.
7. Biofuel production shall contribute positively to protect natural resources, ecosystems that provide essential services and biodiversity.
8. Biofuel production shall contribute positively to availability and quality of water and air.</td><td>9. Biofuel production shall not lead to deforestation or forest degradation and where possible contribute to rehabilitation of degraded land.
10. Biofuel production shall contribute positively to climate change adaptation and mitigation.
11. Biofuel production shall contribute positively in reduction of greenhouse gas emissions.
12. Agro-ecological zoning should provide guidance on what feedstock to use and where to plant them</td></tr>
<tr><td colspan="3">SADC nations that have set up bioenergy policies or strategies [36], [19], [20]</td></tr>
<tr><td>Malawi
-Energy Regulation Act (2004)
-Liquid Fuels & Gas Act (2004). Used to regulate mandatory blending (20%).
-No specific policy document on biofuels</td><td>Mozambique
-National policy & strategy
-Investment criteria
-Dedicated biofuels agency
-Biofuel mandates for both bioethanol and biodiesel of between 5 to 10%
-Tax incentives</td><td>RSA
-National Industrial Biofuels Strategy of 2007
-4c/l fuel levy
-Biofuels Implementation Committee</td></tr>
<tr><td>Swaziland
-National Biofuels Task Force - National strategy & action plan
-Finalizing pricing model</td><td>Tanzania
-National Biofuels Task Force - Guidelines & investment criteria
-Dedicated biofuels agency
-Liquid Bioenergy Policy & Act being drafted</td><td>Zimbabwe
- has a National Energy policy that briefly touches on renewable energy and biofuels
-No detailed, dedicated biofuels policy.
-5-10% mandatory blends of ethanol
-Draft biofuel policy awaiting final approval</td></tr>
<tr><td colspan="3">Zambia
-Formed an inter-ministerial steering committee for biofuel development
-Biofuels Association of Zambia (BAZ) formed.
-US$150 000 set aside for research on biofuels
-Energy policy revised to accommodate biofuels, whose specific legislation is still being drafted</td></tr>
</table>

4. Socio-economic implications of research outputs to date

It is important to note from the onset that the main driver for biofuels in developing regions like Southern Africa is not ecological issues, but socio-economic causes like poverty reduction, employment creation, enterprise development and access to cleaner, cheaper and renewable energy [19]. Schumpeter also shares the same sentiments, emphasizing that sustainable development and climate change issues should have a focus on poverty reduction- a socio-economic drive [38]. With regards to the 2G biofuel production, one of the important inferences from the research outputs is that, for the ecosystem to be sustainable there has to be a thorough analysis of the feedstock availability and viable supply chain models [6]. The aim would be to establish whether or not the feedstock supply will be sustainable at the minimum or intended plant capacity, given the transportation distances. Amundson et al. demonstrate that, due to the relatively low energy density of biomass compared to fossil fuels, its transportation over longer distances becomes prohibitively expensive [39]. *Supply chain optimisation* therefore becomes a critical component in developing a viable framework for utilising biomass as a feedstock [40].

The quantities of feedstock available will also affect the kind of conversion technology to be used. For instance, the bioethanol lignocellulosic fermentation route depends on extensive monocultures, preferably agricultural feedstocks. If feedstocks are way less than 1,520ordinary dry tones (odt) per day, it may be uneconomic [12]. Also, in the case of the thermochemical and hybrid routes the amount of feedstocks will affect the gasifiers to be used and therefore the economics. Table 6 links pertinent 2G biofuel research outputs to potential socio-economic implications.

Table 6. Important research outputs and potential socio-economic implications for southern Africa

Important research outputs	Potential socio-economic implications
Growth in biofuels market & emergence of supportive policies, especially in the US, EU and China (Fig 7). Increasing demand for bioethanol and biodiesel from EU, China, Japan and RSA within SADC.	SADC countries have high biomass feedstock availability. Possible use of alternative and extensive supply of these feedstocks could be an advantage in meeting global biofuels demand, especially if they can have cost competitive schemes.
Consensus that 2G fuels will soon replace 1G biofuels due to vast availability and non-interference with agriculture and food security. 2G Jatropha schemes (popular in Southern Africa) have fuelled a lot of debates since they disrupt land schemes and compete for agricultural inputs; therefore not much better than 1G biofuels.	This will fuel R&D also in developing nations in lignocellulosic biofuel. Globally, 2G biofuels R&D has gained greater traction in past 5years compared to 1G biofuels. It is likely that southern Africa will also a shift from 2G biodiesel-from-jatropha focus to explore conversion of forestry and agricultural residues which are abundant.
Recent demonstration & commercialization successes of 2G feedstocks: especially biochemical, thermochemical and hybrid (Fig 3 and 4) [6], [8]. A high cost tag however is attached to these plants!	One of the main pillars of United Nations Framework Convention on Climate Change (UNFCCC) is technology transfer from developed to developing countries. It is imminent that successful commercialisations of these technologies will spill over to Africa, as was the case with biodiesel from Jatropha. Opening up to foreign direct investments (FDI) and joint investments, after conducting the right feasibility studies, could help shoulder such high capital projects.
Overall cost of producing 2G biofuels between \$0.39 & \$1.00/L	This is quite high considering that sugarcane ethanol from Brazil is at \$0.18/L with the most recent technologies[6]. When it comes to competition with markets in the EU and US, they may have some advantage; however they can never meet the demand alone. As global biofuel demand increase, it will have to be met by a quota from 2G feedstocks which are more abundant. Regional market will still be available.
Energy crop potentials e.g. for Botswana and Zambia.	These require more land and will compete, to some extent, with agricultural inputs & labour. This alternative should not sideline use of lignocellulosic residues, whose utilization does not disrupt agriculture and food security and also solves a waste problem

Vast availability of lignocellulosic biomass resources in Africa; with a greater percentage (>70%, except in RSA) being used in traditional cooking and heating schemes that are inefficient and pose a health hazard. Literature advocating for a shift from traditional to modern technologies- where the latter replace traditional as the case of conversion of biomass to ethanol gel which is at least 5 times cleaner & more efficient	Technology transfer, as UNFCCC stamps, will be key; from developed nations to developing. There are likely to be FDI's as was the case with Jatropha, especially where the feedstocks are sustainably available. A wider promotion of the use of ethanol gel in some nations will be required for mass uptake; more robust stoves and systems required. Means more ethanol production alternatives are required, especially where 1Gfeedstocks are already limited.
Demonstrating viable feedstock supply chains will be critical to operate plants at required scales. [6]	There is need for research to quantify feedstocks and develop viable, optimal supply chain models so that when companies are ready to transfer technology, there is groundwork information for the research.
Demonstrating potential value chains and socio-economic impacts will be critical to avoid presumptions as in the case of Jatropha	Since Africa was on the receiving end in the Jatropha cases, greater caution will be taken when accepting proposals for 2G lignocellulosic biomass.
Potential competition of CHP with Biofuels initiatives for, especially, woody lignocellulosics	There is a significant amount of energy poverty in southern Africa; therefore a proper cost-benefit comparative analysis should be carried out to evaluate which alternative could offer the most socio-economic and ecological benefits.
Consuming waste residues and making use of abandoned land (especially for energy crops) has considerable potential to '*promote rural development and improve economic conditions in emerging and developing regions'*[1]	This *strong* hypothesis still has to be proven in these regions. Emerging and developing nations have not participated much in the high profile technical R&D around the 2G technologies, due to the intensive financial requirements. However, feasibility studies can still be done to demonstrate supply and value chain viability and project socio-economic impacts.
Insufficient policy landscape for southern African nations as most biofuel policies have not been finalised	Since this field is capital intensive, investors have to be confident that the policies will be supportive. A clear, robust, supportive framework would liberate all stakeholder - including farmers, timber industry, fuel gel industry- to plan and invest at various points of the biofuel supply chain

Conclusion

Research and development in 2G biofuels is steadily gathering momentum; more recent forecasts already predict that they should occupy at least 18% of all biofuels by 2035 [6]. Older forecasts had predicted that first and second generation biofuels would have a 50/50 share by 2022 [41], however supply chain viability and technological setbacks slowed down the pace for demonstrating the sustainability of 2G biofuel production. The past 5 years, however, have shown fast rising interest in this research area (Fig 1), supported by the rate at which demonstration and commercialization projects have sprung up. Cellulosic ethanol commercial production tripled between 2009-2012, while HVO quickly clinched 2.4% of biofuels production since its launch in 2008 [6]. Companies like Lanza Tech and Ineos Bio have launched demonstration plants for the fermentation of syngas using a mixture of residues and industrial waste gases as feedstock, with promising results [8]. Although Jatropha disappointed in some cases, the energy and momentum has encouraged further research and helped characterize what should form a part of feasibility studies for 2G biofuel ventures [33]. Given all such developments, the landscape for 2G biofuels development is becoming brighter and the R&D output can now better guide policies and decision making going into the future.

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Biographies

Gratitude Charis is a full time PhD student at the Botswana International University of Science and Technology in the Department of Chemical, Materials and Metallurgical Engineering. He has a Masters in manufacturing systems and Operations management, a research experience spanning 7years and lecturing/tutoring experience of 3years. Gratitude has been involved in innovation research and writing for EU based SMES looking for funding from the European Commission for 4years. At least 50% of these projects concerned renewable energy and sustainability issues.

Dr Gwiranai Danha is a lecturer and researcher in the department of Chemical Engineering at the Botswana International University of Science and Technology. He has research interests in mineral processing, coal to liquid and waste to energy projects. He has published more than 16 publications in internationally recognized journals of high impact factors.

Edison Muzenda is a Full Professor of Chemical and Petroleum Engineering, and Head of the Chemical, Materials and Metallurgical Engineering Department at Botswana International University of Science and Technology. He is also a Visiting Professor in the Department of Chemical Engineering in the Faculty of Engineering and Built Environment, University of Johannesburg. He had previously served as a Research and Postgraduate Coordinator as well as Head of the Environmental and Process Systems Engineering and Bioenergy Research Groups at the University of Johannesburg. Professor Muzenda holds a PhD in Chemical Engineering from the University of Birmingham, United Kingdom. His research interests span waste to energy, green energy engineering, integrated waste management, volatile organic compounds abatement, as well as phase equilibrium measurement and computation. He has supervised more than 30 postgraduate students and contributed to more than 280 international peer reviewed and refereed scientific articles in the form of journals, conferences books and book chapters. Professor Muzenda is a reviewer for a number of reputable international conferences and journals and a member of several academic and scientific organizations including the Institute of Chemical Engineers, UK and South African Institute of Chemical Engineers. He is also an Editor for a number of Scientific Journals and Conferences and associate Editor of the South African Journal of Chemical Engineering. Professor Muzenda has, to date, organized and chaired several international conferences.