The Opportunities and Challenges of Wood Waste Biomass and a Case Study on Biofuels in South Africa

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ABSTRACT
The continuous drive for economic growth and the need to improve living standards in South Africa place significant demands on the country to provide secure and reliable energy to support the planned growth. Wood waste biomass as a renewable energy source is likely to expand South Africa's energy supply by reducing reliance on fossil fuels. The labour intensive methods in which biomass feedstock is generated has also provided a great incentive for a government focussed on employment creation to consider biomass to energy projects. The government's White Paper on Renewable Energy set a target of 10 000 GWh of energy to be produced from renewable energy sources, mainly from biomass, wind, solar and small-scale hydro, by 2013; however, the target was not met. This paper looks at the opportunities and challenges of biomass to electricity and biofuels in South Africa with a particular case study for woody biomass to bioethanol.

1. INTRODUCTION
Wood waste biomass as a renewable energy source is likely to expand South Africa's energy supply by reducing the reliance on fossil fuels. The government's White Paper on Renewable Energy outlines a long-term vision of a sustainable, completely non-subsidised alternative to fossil fuel. It set a target of 10 000 GWh of energy, equivalent to providing electricity to 300,000 households per annum (based on 3,319 kWh per household), to be produced over a 10 year period and to be generated mainly from biomass, wind, solar and small-scale hydro. The White Paper's anticipated progress with respect to the development of biomass and biofuels in terms of their contribution to energy production in South Africa has been slow to take-off. However, the development of biomass as an important energy source in South Africa is likely to change soon due to: the inclusion of 40 MW of biomass energy in Round 4 of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP); the recent formation of the Biomass Action Plan for Electricity Production (November, 2014) to enable and promote the use of biomass with medium and long term targets for electricity production; and the imminent implementation of the Mandatory Blending Regulations.

1.1 Electricity
Historically, the electricity market in South Africa was under the control of the government and dominated by a single large state owned power generating utility company, Eskom. However, the inadequate power-generating capacity by Eskom has not only lead to an energy and economic constraint but it has paved the way and provided opportunities for private companies to enter the energy market.

Trends and developments around the world, such as declining costs of renewable energy technologies and the distributed nature of renewable energy technologies, in addition to South Africa being a very good renewable energy resource country, has transformed South Africa's electricity supply arrangement.

Commercial applications for biomass-to-energy have been limited in South Africa. Only two biomass independent power producers (IPPs) have successfully participated in the first four bid windows of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). However, according to the State of Renewable Energy in South Africa (DoE, 2015), it is anticipated that electricity production using biomass offers significant potential at competitive costs if utilised in cogeneration applications. Biomass cogeneration projects are expected to be generally small (less than 50 MW with many below 20 MW) and distributed across the industrial centres or in the sugar and forestry areas of South Africa. Cogeneration plants producing electricity by using biomass from sugar and forestry areas offers the most positive future for biomass to electricity at competitive costs in South Africa.

1.2 Biofuel
Currently, there are no mandatory blending requirements for biofuels; however, promulgation of the Biofuels Industrial Strategy of the Republic of South Africa is imminent. The delays in government policies,
regulations and incentives for biofuel development in South Africa has resulted in few commercial biofuel projects. Limited feedstock material is suitable or legislated for conversion to biofuels in South Africa. Furthermore, food security concerns in the country has meant that finding a sustainable feedstock that is not considered a food crop, limits the feedstock supply and choice to only certain first generation and second generation biofuels. Technologies suitable for feedstock conversion to biofuels often require a large amount of water. In a country where water scarcity and droughts are prominent, careful consideration has to be made in selecting optimal technologies for biofuel production. The large capital and operating costs of suitable technologies and associated infrastructure to produce, distribute and blend biofuels has hindered biofuels development. Land prices, land uses and land compensation introduce further multiple socio-economic conflicts to the mix of challenges for biofuels development in South Africa. As part of the Biofuels Blending Regulations, the government has therefore provided for a price support mechanism in the pricing of biofuels designed to support the production economics to a level where they can reach a return on assets (ROA) of 15%.

Interest in biofuels ranges from the pursuit of fuel security, the need for carbon neutral or less carbon intensive fuels, the development of rural farming economies and opportunities for job creation. Cellulosic ethanol is a second-generation bioethanol, and has a number of advantages over conventional fuels. For example, it comes from a renewable resource of various non-food based plant materials i.e. biomass, and not from a finite fossil fuel resource. Ethanol, as a liquid biofuel, burns cleaner than fossil fuels; the lifecycle greenhouse gas (GHG) of ethanol in comparison to a petroleum-based counterpart, will reduce atmospheric carbon dioxide by 20% to 60%, depending on the type of fuel and feedstock (raw material), being used (Cai et al. 2013).

2. BIOFUELS CASE STUDY

This section provides a case study on woody biomass to bioethanol.

2.1 Study Approach

The prefeasibility study undertaken included the following:

- Feedstock;
- Site Selection;
- Ethanol Product;
- Technology; and
- Financial Modelling.

Although project specific details remain the intellectual property of the client, a high-level overview of opportunities and challenges of the study are discussed in this paper.

2.2 Feedstock

Sugar, starch and vegetable oils are feedstock for conventional first generation biofuels. The South African Biofuels Strategy (2007) only allows for the production of first generation biofuels from sugar cane, sugar beet, soya beans, sunflower and canola. According to the Strategy, the following crops are proposed for the production of biofuels in South Africa: for bioethanol, sugar cane and sugar beet; and for biodiesel, sunflower, canola and soya beans. The exclusion of other crops and plants such as maize and Jatropha are based on food security concerns (Department of Minerals and Energy, 2007).

Cellulosic fibre, wood chips and micro algae are examples of second-generation biofuels because they are biofuels produced from a sustainable feedstock that is not considered a food crop. Cellulose fibre and lignin can be recovered from underutilised agricultural material (such as wood chips) or dedicated crops (such as bamboo) and used as a second-generation biofuel (a non-food feedstock).

Cellulosic ethanol is chemically identical to first generation bioethanol (i.e. C2H5OH). However, it can be produced from different raw materials via a more complex process of cellulose hydrolysis. Instead of using valuable food crops to produce ethanol, this process can use agricultural residues, energy crops, lignocellulosic raw materials and organic wastes. These materials are more abundant and considered more sustainable than food crops.

Woody biomass is commonly divided into three main groups: (i) forest and plantation wood, (ii) wood processing industry by-products, wastes and residues, and (iii) used wood waste (as shown in Figure 1 below). All three of these main woody biomass groups as well us agricultural residues and organic municipal
waste were considered as feedstock for this study, with a requirement for >200,000 tonnes per annum of sustainable feedstock including wood chips, log wood, sawdust, bark and cuttings etc. for the proposed plant to produce second generation bioethanol.

2.3 Site Selection

The feedstock and site selection assessments were undertaken concurrently. In terms of the ‘siting’ for the proposed plant, an important factor included a guaranteed constant, large, sustained supply of woody biomass for the project’s viability and success. As such, the focus for siting the proposed plant existed in the location of largest feedstock supply. Suitable sites for the proposed plant were determined through a spatial mapping exercise.

The broad areas of interest defined were primarily based on economic viability i.e. close proximity to feedstock and transport infrastructure, followed by environmental and social viability. Areas which had the highest concentrations/density of potential feedstock providers (all within close proximity of each other, including plantations and sawmills) presented the greatest opportunities for a constant, sustained, large volume and cost competitive (due to the large number of companies within the area) feedstock supply. The fact that transport cost was likely to be the single largest individual operational cost item for the proposed plant suggested that locating a plant within the area of the highest density of feedstock providers would make the proposed plant more economically viable. As such, areas of interest were concentrated in the eastern regions of South Africa, spanning the KwaZulu-Natal and Mpumalanga provinces; and the southern regions of South Africa, spanning the Eastern and Western Cape near coastal areas (as shown in Figure 2).
Targeted consultations and questionnaires were directed at suitable feedstock providers to determine the type, quantity and location of the feedstock providers. Letters of Intent (LoI) and positive responses were received from companies to secure the feedstock supply over an extended period.

Other important considerations in the siting of the proposed plant included proximity to sensitive receptors, project mobilisation challenges by municipality(ies), sufficient land space, bulk infrastructure including electricity and water supply.

2.4 Ethanol Product

South Africa is following a number of countries with mandatory fuel blending including Brazil, China, Canada and India. In the August 2012, South Africa introduced the Mandatory Blending of Biofuels with Petrol and Diesel Regulations ("Mandatory Blending Regulations") promulgated under GNR. 671 of 23 August 2012, which incorporates minimum concentrations of 5% for biodiesel blending and a permitted range from 2% to 10% for bio-ethanol blending.

The effective date for the said regulations to come into operations was expected to be 1 October 2015; however, it is still pending. Challenges causing the delay in the implementation of the regulations include the time required to finalise the biofuels pricing framework as well as the development and installation of the requisite infrastructure for the manufacturing, supply and blending of biofuels. A Biofuels Implementation Committee (BIC) has been established to ensure that all the practical or operational aspects pertaining to the blending of biofuels with mineral petrol and diesel are resolved well before the Mandatory Blending Regulations come into effect.

The biofuel industry in South Africa is nascent; however, the pathway for integration into the existing fuels market will be a challenge. The following two avenues to market bioethanol product were considered in this study:

- To market raw ethanol product to third parties for blending, incorporation into the fuel chain, and onto final retailing, i.e. termed direct marketing of raw ethanol; and
- To blend raw ethanol with raw petrol (also termed RBOB or low octane petrol) to create a finished fuel product (such as E10) i.e. termed the blending of ethanol fuels. This finished fuel product would be sold to third parties.
The key elements of direct marketing include:

- Market access limited to companies engaged in fuel blending only;
- More consolidated and simplistic logistics chain with need to store and move less total volume of product; and
- Eliminates regulatory and price uncertainty since the direct marketing of bioethanol into the fuel market has not been established yet.

The key elements of blending of finished ethanol fuels include:

- Expanded market access to fuel suppliers, distributors, and direct to retailers;
- Expanded logistics chains with need to import, store, and move larger volumes of total product;
- Increased economies of scale associated with larger volumes;
- Vertical integration within fuels value-chain offers increased revenue opportunities based on both the value-added margins (blending tariff) and total gross volume;
- Eliminates dependency on government promulgation of the mandatory biofuels blending regulations;
- Less market uncertainty as a finished fuel product has increased intrinsic demand; and
- Increased opportunity to de-risk production by engaging partners in blending activities.

Due to critical criteria determining the siting of the proposed plant, the preferred location of the proposed bioethanol refinery was chosen to be in close proximity to the feedstock supply (as discussed in sections 2.2 and 2.3). A study of the transport economics also revealed that the logistics costs for biomass were significantly higher than that of bioethanol, further supporting this decision on plant location. Accessing the market with either raw ethanol or finished blended ethanol fuels would require liquid product to be transported by pipeline, rail or road to a depot or storage facility.

### 2.5 Technology

The identification of viable gasification technologies for an integrated biorefinery to convert woody biomass, waste tyres and/or organic municipal waste to produce cellulosic ethanol was assessed. A procurement process was developed to identify a viable technology from all potential technological solutions commercially available. A two-stage procurement process used an Expression of Interest (EOI) to shortlist potential technology suppliers for further detailed commercial and technical evaluation of the company and their proposed technology using a Request for Information (RFI).

Positive responses were received from three of seven selected technology companies that were sent RFIs for evaluation. The RFI included a commercial and technical questionnaire and evaluation matrix, which detailed the maximum score available and any limitations. The evaluation process resulted in a single chosen gasification technology provider that had the most viable technology for treating woody biomass and waste tyres to produce bioethanol. Key challenges identified during the evaluation included:

- Bio-refinery scale: economies of scales for plant sizing.
- Feedstock types and pre-treatment required.
- Process outputs to be sustainable.
- Large water demand for processing and cooling.
- Operational status history of proven plant efficiency.
- Large equity investment.
- High technology licence costs.

### 2.6 Financial

A financial analysis was undertaken to assess the expected return on investment based on an evaluation of the initial capital outlay, operating costs and expected revenue streams of the project. A financial model was also developed to evaluate the comparative financial feasibility of five potential development sites that were chosen from the initial feedstock supply and siting aspects of the study. The life cycle costs for the five sites were compared and it was concluded that the life cycle costs are similar and relative to the overall total cost of the proposed plant. The cost of supplying water and power to various locations played a minor role in site selection from a cost perspective. However, the financial model was most sensitive to the cost of feedstock supply, fluctuations in the bioethanol tariff and the Rand: Dollar exchange rate. Detailed financial aspects of the study are confidential and cannot be provided.
3. CONCLUSION

Biofuels development in South Africa remains an opportunity for the country to deploy technologies that will utilise its vast volumes of biomass for a holistic socio-economic benefit. There are however many inherent challenges including, being costly to produce based on proven international technologies, demanding relatively large amounts of water for production in a water scarce country, competing for food crops and land use, as well as complications with fuel industry and transport fuel mix. However, despite these challenges, biofuels are a way to create value broadly from otherwise low or no value biomass materials, to reduce greenhouse gases by producing a ‘green’ fuel and create jobs supporting agriculture, industry and rural development in South Africa. The country could take lessons from the successes in Brazil, North American and Europe. The mandatory blending requirement for biofuels in South Africa is imminent; the REIPPP and Biomass Action Plan for Electricity Production should enable and promote the use of biomass with medium and long-term targets for renewable electricity production.

REFERENCES


