SUDAN'S BIOFUEL FOR TRANSPORTATION ROADMAP

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ABSTRACT

Transportation in Sudan is the major sector for consumption of petroleum products, using about 61% of total volume. Though Sudan is facing a possible fuel crisis following the separation from the south there has been no developed biofuels policy. Therefore a detailed roadmap of biofuel development is being devised to guide and promote the development of biofuels production and availability in Sudan, with biodiesel likely to be sourced principally from *Jatropha curcas* feedstock. This work will provide a national roadmap for development of Sudan's biofuel production for the transportation sector, including aviation. This roadmap will identify the key plantation regions, land availability, and agronomic, logistical, economic and social issues involved with development of a large domestic production of oil from *Jatropha curcas*. Also it will investigate the resources related to industrial scale production, detail the technology approaches of all stages of development, and schedule planning policies and incentives to industry within a specific timeline. This paper will cover logistical, economic, policy and sustainability issues involved in biodiesel production in the Sudan Biofuel Roadmap development.

Keywords: Biofuel, *Jatropha curcas*, Transportation, Roadmap.

1 INTRODUCTION

It is widely agreed that the production of transport fuel from biomass, in either liquid or gas form, holds the promise of a lowered net fossil-energy requirement and lowered greenhouse gas (GHG) emissions [1]. However, the future scenario of biofuel production on a sustainable basis over the coming 30 years is not yet clearly defined. There are many important issues to be addressed, including any food security and land competition issues involved with biofuels production, and the potential impacts of biofuels production on water resources, biodiversity and other aspects of the environment, including impact on soil and water supply. However, using non-food biomass feedstocks such as *Jatropha curcas* could help overcome most barriers and achieve sustainable, very low emissions, cost-effective biofuels production, and successful development of advanced biofuels.

2 SUDAN'S OIL SUPPLY

Sudan is one of the largest countries in Africa with a total area of 1,882,000 sq km, and a population of about 33.5 million (growth rate of 2.84% per year). Sudan's energy demand has significantly grown through the past 20 years. Oil consumption has rapidly increased as a result of country economic growth. While oil is the main source of energy, the transportation sector is the main user of the refined fuel products, consuming about 61% from the total crude oil volume presently produced. The major fuel used form is diesel, representing 50% of the total fuel consumption, whilst gasoline and jet A1 represent 23% [2]. The secession of South Sudan in 2011 with most of the productive oil fields has left Sudan with sharply reduced oil volumes to export (previously the main source of export income). Petroleum product subsidies accounted for about ¾ of tax revenues in 2011 and have been on the rise as a consequence of this secession and the related loss of oil production.

3 POTENTIAL OF JATROPHA CURCAS

For large scale, the major obstacle in producing biodiesel from vegetable oils is the relatively low volumes of oil available per hectare. While palm oil yield is the highest yielding source at about 4 tonne of oil/hector, most vegetable oil yields are less than 1 tonne of oil/hector. In general, these crops require good arable soils, temperate climate and relatively high rainfall. It is this situation that explains the strong interest in oil-producing perennial from tree species such as *Jatropha curcas*, Castor, Pongamia, Croton and Neem. But recently, *Jatropha curcas* has received the most attention and investment due to its perceived abilities to produce well in marginal sites with low and variable rainfall. With optimal management on good sites *Jatropha curcas* is now seen as having potential to produce the next highest yields (after the oil palm) at over 1.5 tonnes of oil per hector.

Obviously, this sort of yield will require intensive early pruning, genetically selected trees, a good soil quality and depth and fertilizing regime that maintain yields, and a supply of adequate water of good quality to each Jatropha plant’s root system at the right times. In addition the site has to be within Jatropha’s range of required conditions of average maximum summer temperatures and minimum winter temperatures, and have shelter from excessive wind and driven sand. Enough pollinating insects will need to be available at each flowering, and no pest insect or fungal disease can be allowed to affect flowering, fruit development, or plant health. Finally, the picking has to be done efficiently – as this process can constitute up to 80% of the variable costs. The pressed oil and seedcake must have a market value that is well in excess of all annual fixed and variable costs (in addition to labour), including interest on investment in land acquisition, seedlings and site establishment, and also on depreciation of capital equipment.

3.1 Jatropha Based-Biodiesel

Cost-effective large-scale production of biodiesel from non-edible oil feedstock requires that free fatty acid (FFA) levels be below 1%, or if higher, that a highly effective system should be developed to deal with high FFA levels. In practice, while properly extracted Jatropha oil should have FFAs below 1%, it is not unusual for levels to rise due to number of factors during storage and transport. In parallel with Sudan’s Biofuel Roadmap, the process of production of biodiesel from Jatropha oil has been studied in lab scale, and successful pre-treatment of high FFA percentages in Jatropha oil to reduce these to less than 1% has been achieved. With this low level of FFA a high yield of biodiel has been obtained and its specification has been complied with the international standards (ASTM D6751) [3].

With large-scale production of biodiesel from crude Jatropha oil (CJO), while the crude Jatropha oil is the largest input cost, the costs of the other used chemicals are also significant. When dealing with volumes of hundreds of thousands of tonnes of crude Jatropha, optimizing the inputs will be very important in achieving the best economic outcomes in biodiesel production and will significantly improve operating economics.

3.2 Jatropha Based-Aviation Fuel

The aviation industry is moving rapidly to introduce biofuels for use in commercial flights. It has been found that carbon emission can be decreased by 65-80% by using jet fuel from renewable feedstock such as *Jatropha curcas*, compared to petroleum-derived aviation kerosene [4]. Among the competing oil production crops, such as camelina, carinata and algae, Jatropha has been identified as one of the most cost-effective and sustainable feedstocks for renewable jet fuel production.

The annual fuel consumption of the aviation industry worldwide is in the order of 1.5 to 1.7 billion barrels of traditional jet fuel, which contributes about 2% to the current global greenhouse gas (GHG) emissions. The International Air Transport Association (IATA) assumes a 6% share of sustainable 2nd generation biofuels is achievable by 2020. On the another hand, The European Advanced Biofuels Flight Path Initiative plans to use 2 million tonnes of biofuels in the EU civil aviation sector by 2020, while Boeing supports a target of 1% of global aviation fuels by 2015 [5]. The target of the Sudan Biofuel roadmap is to introduce a certified jet fuel by 2018, and for this aviation biofuel to have a share of the aviation fuel market by 2024. However, the issue of approval for the product has to be addressed. This is vital in commercializing the biofuel into the international or even the local aviation market. The produced renewable jet fuel must comply with the strict international fuel standards so that no modification to the aircraft engine is required.

3.3 Significant Benefits from Jatropha by-products

In addition to the technical feasibility of Jatropha-based biodiesel and Jatropha to biojet fuel, research and development has produced household affordable cook stoves that can work well when fuelled by Jatropha seed or pelletized seedcake, cost-effective systems for pelletizing or briquetting seedcake, small-scale equipment suited to rural cooperatives for expelling oil, and affordable engines/gensets that will run on pure vegetable oil. All these can stimulate rural and regional economies, as a combination of industrial-scale plantings and small-holder plantings.

However, Sudan is to produce enough biodiesel from Jatropha to replace even 5% of its diesel fuel which is about 150,000 tonne of biodiesel. It will require up to 625,000 tonnes of Jatropha seed, and consequently up to 437,000 tonnes of seedcake will be produced as a residue. In this form it has an energy value of 5 MWh/tonne, and could be used as a fuel in smaller or larger energy plants, including combined heat and power plants.

In total, the 437,000 tonnes of seedcake have an approximate energy value of 2,185 gigawatt-hours (GWhr), and if used to fuel efficient combined heat and power plants, they could produce about 87 MW of electricity annually (assuming abut 5000 tonne to produce a MW-e). These CHP plants could be of any size from 5 MW-e to 20 MW-e outputs or more.

4 THE ROADMAP: ECONOMIC AND LOGISTICAL ISSUES

To enter into large scale production of Jatropha oil, obviously any scheme or project needs to be revenue-positive over time for investors. Any investment on the scale needed may expect net annual return from year four (i.e., income to the project after all costs and interest on investment for that year) to be positive, so that by year 10 all initial investment is paid off. Hence any overview of the economic and logistical aspects of the project must assess the realistic return on the investment, through making certain assumptions of costs, yields, etc.

The assumption is made that Sudan will produce enough biodiesel to provide adequate volume for a 5% blend with current fossil diesel use. This equates to needing 150,000 tonnes of biodiesel. At a yield of 5 tonne of seed per hector and recovered oil yield of 35% this will require about 125,000 hector of plantings, with a processing plant for every 5,000 -10,000 hector to allow economies of scale in the pressing plant. While preparation and establishment of the sites will be up to $3000/hector, the first years of any site will also produce no net income until perhaps year three or four.

Harvesting will require very large workforce from year 4 onwards. At a harvesting rate of 50kg/person/day, to harvest 1 hector (5 tonnes) in a day requires 100 people. At this manual harvesting rate 5000 people would take about 100 days to harvest the seed of 5000 hector (25,000 tonnes). To transport 5000 people every morning and night will take a fleet of perhaps 100 trucks or buses. Each site will possibly be requiring harvest at the same time and this affect the mobility of the harvest team. Obviously mechanical or faster, more efficient manual harvesting systems need to be urgently developed.

The transportation of the estimated 25,000 tonne of seed from each 5000 hector of plantings will require 2,500 return truck loads (assuming 10 tonne capacity), over a return distance of about 100 km, so entailing truck travel distance total of 250,000 km per harvest. Assuming at least 50,000 tonne of seed being processed at any one pressing plant the same or other trucks will be engaged in moving about 35,000 tonne of seedcake from this plant to some other site, and 15,000 tonne of Jatropha oil to a central processing plant.

5 SUSTAINABILITY

Ensuring the sustainability of feedstock-biofuel system requires an integrated assessment of the economic, environmental and social dimensions [6]. The sustainability of the overall large scale production of Jatropha oil is important, not only because of its positive or negative impacts within Sudan, but also because being able to qualify for a certification of sustainability means that crude Jatropha oil can be sold into the international market to the many buyers seeking a large, reliable and certified-sustainable source of supply.

The criteria of environmental sustainability that determine whether a biofuel is certified or not as sustainable fuel are agreed upon by the European Union and the United Nations. The Roundtable for Sustainable Biofuels itemises the criteria in its publications and website.

Within the Roadmap, in addition to the detailing of the biodiesel production from Jatropha to accord with these sustainability criteria, is the awareness that the planting of vast areas of a Jatropha monoculture comes with inherent risks. This includes negative impact on the labour pools in regional areas; water availability for food crops or over-use of water from aquifers, meaning inadequate long-term irrigation flows; the possibility of insect pests or fungal disease impacting the viability of whole plantations and decrease in final yields due to lack of development of management best practice. While these issues may not make the Jatropha oil or biodiesel production fail the criteria of environmental sustainability, they will certainly affect economic sustainability or social sustainability of the whole venture.

6 KEY POLICY ACTIONS

The situation in Sudan in early 2013 is that high subsidies on gasoline and diesel fuel make this one of the cheapest countries in the world for these fuels, even after removal of some subsidy has meant that pump prices are now double what they were in 2010. They are still below the real cost of production at US$0.65-0.70 per litre. Prices in neighbouring countries are significantly higher. (e.g., prices in Europe range between $2.00 and $2.60/litre for both types of fuel, while in the US with its artificially low prices cost per litre of both petrol and diesel to the motorist are at least double that in Sudan). Experiences in other countries show that most of the following policy issues must be in place for a successful introduction of Biofuels:

1. Legislation should be in place mandating a set blending ratio (usually 5-10%).
2. Subsidies on fuel should be replaced with more effective measures, so that the country can be more in line with trading partners without affecting the population’s economic conditions.
3. Distribution and storage issues need to be resolved to maintain adequate supply and high quality.

4. Quality and blending ratio of fuels need to be constantly monitored by a competent testing authority.
5. Introduction of incentives for vehicles capable of running on higher proportions of biofuel need to be considered.
6. Issues of excise or tax need to be resolved so that the biofuel is able to compete in price.
7. The possibility of using excise revenue raised on fossil fuel to cross-subsidise biofuels.
8. The industry – distributors, refiners and major users - must be supportive and part of the process from the beginning and not negatively financially affected
9. Neighbouring countries need to be encouraged to develop common polices on pricing and blending to prevent cross border smuggling and to allow transport vehicles to run between countries with no fuel grade or quality issues.

7 CONCLUSION

Production of 150,000 tonne/year of biodiesel from a large dispersed estate of *Jatropha curcas* is achievable, and it could be economically viable, and environmentally sustainable. The conversion of the Jatropha oil into biodiesel is relatively straightforward, though the optimizing of the process requires a very high management level of the pressing process, transport and economies of scale that allow the use of sophisticated high efficiency production machinery.

Success of this large commercial venture will lie in best practice at every stage, from selection of planting areas and the genetics of plants onwards. The outcomes will be firstly the proving of a new approach to supplying a high yield of vegetable oil from non-food production land; secondly the option to reduce reliance on fossil fuels for transport as these are replaced by various biofuels; and thirdly the creating of both a new industrial sector and also a new agricultural sector. A clear benefit of this new agricultural sector is the significant job creation and the potential for small holders in regional areas to sell into this market for the Jatropha seed.

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