African Journal of Biotechnology Vol. 8 (11), pp. 2397-2408, 3 June, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Sustainable development and bioeconomic prosperity in Africa: Bio-fuels and the South African gateway

Dorsamy (Gansen) Pillay[1,2*] and Edgar J. Da Silva[3,γ]

[1]Department of Biotechnology and Food Technology, Faculty of Applied Sciences, Durban University of Technology, P.O. Box 1334, Durban 4000, South Africa.
[2*]Discipline of Microbiology, School of Biochemistry, Genetics and Microbiology, Faculty of Science and Agriculture, University of KwaZulu-Natal, P. Bag X54001, Durban 4000, South Africa.
[3]Former Director, Division of Life Sciences, UNESCO, Paris 75015, France.

Accepted 14 April, 2009

African countries along with the co-founders of the New Partnership for Africa's Development (NEPAD) must use biotechnology as a valuable tool for socio-economic and sustainable development. National, regional and international consultations and debates ensure timely attention of peer-reviewed guidelines concerning significant issues like bio-risks, bio-safety, and bio-security that impinge on daily human existence and welfare. High–cost fossil fuel prices and national security concerns have sparked interest in bio-fuels in continental Africa. In brief, Africa is taking the lead in creating its own biotechnology agenda and roadmap to socioeconomic and sustainable development. The emergence of "Rainbow Biotech" serves as a catalytic portal amongst others for collaborative effort and continental development.

Key words: Bio-fuels, economic development, biotechnology, South Africa, Africa.

INTRODUCTION

The Republic of South Africa (RSA) has drawn attention, through its visionary and pioneering involvement in co-founding with Algeria, Egypt, Nigeria, and Senegal, a strategic New Partnership for Africa's Development (NEPAD). This partnership responds to a mandate of the Organization of African Unity's 37th Summit in Lusaka, Zambia, July 2001 calling for a socio-economic sustainable pathway for the emergence of continental Africa into the mainstreams of regional cooperation and international governance concerning biotechnology [Box 1].

Several African countries are pursuing independent biotechnological options to reduce their dependence on fossil fuel energy imports to conserve foreign-exchange resources, minimize pollution of the environment, and improve the quality of human, animal and plant life. Ghana, Kenya, Malawi, South Africa and Zimbabwe - sugar-producing countries- are exploring the option of large-scale production of bio-ethanol (Table 1). The potential of *Jatropha curcas*, an alternative bio-fuel source, has enthused bioeconomists and policy-decision-makers in Burkina Faso, Cameroon, Ghana, Lesotho, Madagascar, Malawi and South Africa.

Energy security is a crucial element in sustaining development and technological progress in Africa. The purpose of this review, therefore, is to provide an overview of biofuel activities in Africa, the potential for economic development and the concerns with the use of certain food crops as feedstock for bio-ethanol production.

GENETICALLY MODIFIED ORGANISMS (GMOS), GENETICALLY MODIFIED (GM) CROPS AND BIO-FUELS

GMOs and GM crops unite and divide African decision

*Corresponding author. E-mail: gansen@dut.ac.za. Tel: 00 27 31 3732576.

γDr. da Silva passed on after co-authoring this manuscript. This manuscript is dedicated to him for his iconic contributions in biotechnology to developing countries.

BOX 1 ***NEPAD***

PRIMARY OBJECTIVES

-To eradicate poverty;

-To place African countries, individually and collectively on the path of sustainable growth and development;

-To halt the marginalization of Africa in the globalization process and to enhance Africa's full and beneficial integration into the global economy; and

-To accelerate the empowerment of women and children.

THE PRINCIPLES OF NEPAD ACTION

-Good governance as the basic requirement for peace, security and sustainable political and socio-economic development;

-African ownership and leadership with participation by all sectors of society;

-Anchoring the development of Africa through its own resources and the resourcefulness of its people;

-Partnership between and amongst all African people;

-Acceleration of regional and continental integration;

-Promotion of the competitiveness of the African continent and its countries;

-Construction of a new international partnership that reflects the peer-equal relationship between Africa and the developed world; and

-Ensurance that all partnerships with NEPAD are linked to the UN Millennium Development Goals and Targets.

Source: *http://www.nepad.org/2005/files/inbrief.php*

makers and researchers in Africa. Whilst genetically modified crops are commercially produced in South Africa, an informal ban is in place in Zambia. Several West African countries, fiercely proud of their national initiatives, have now adopted a regional five-year plan of action for increasing food production through biotechnology. Much has been written about the pros and cons of the introduction of GMOs and GM crops into the African

Table 1. Bio-fuel production in Africa*.

Country	Bioethanol Production (ML) and Feedstock	Biodiesel Production (ML) and Feedstock
Kenya	3 ML; Sugarcane	
Ghana	6 ML. Sugarcane	
Malawi	6 ML; Sugarcane	
South Africa	416 ML Sugarcane	B and B3 type; *Jatropha* species
Zimbabwe	6 ML; Sugarcane	

*Extracted and adapted from Dufey (2006).

continent. Debate at times is fierce and divisive notwithstanding that mother nature has influenced the transformation of then wild wheat into the biotech wheat of today since 10 000 BC. Nevertheless, issues such as the longstanding ethical arguments of prioritizing "Food (Needs) over Fuel" in deference to current "Bio-fuel (Needs) over Food" cannot be glossed over. One such instance has been the use of sorghum normally used to produce beer the average human's elixir of recreation being channeled to produce a fossil-fuel substitute (Hazelhurst, 2007; Mayet, 2007).

BIO-FUELS AND ENERGY SECURITY IN AFRICA

Energy security (bio or fossil origin) like food security in Africa is a crucial element in sustaining development and technological progress in Africa (Leuenberger and Wohlgemuth, 2006). Some 39 least developed countries [LDCs] in the African continent face the never-ending problems of energy and food insecurities. In one case the bread-basket of southern Africa has been transformed into the bread bowl of the region. Traditional biomass fuels available on an insecure and non-sustainable basis help meet the energy and food cooking requirements of virtually all African LDCs in Africa (Box 2).

Trees and crops are greening the Sahara (Polgreen, 2007). Farmers in the Koloma Baba village in the Tahoua region of Niger use simple agricultural practices. Pits in plots of land are filled with manure just prior to a rainfall. The resulting slurry aids regeneration of soil fertility and conversion of barren land into an area of dense vegetation that with newly planted trees and crops that feed the economic, energy, and employment markets of the village. Amongst the new crop plantations, *Jatropha curcas*, a Latin American plant, widespread throughout the arid and semiarid tropical regions of the world, features prominently. A member of the *Euphorbiaceae*, this ornamental plant naturalised in many tropical areas is a drought resistant perennial living up to 50 years and growing on marginal soils. An inedible plant for humans and animals, the plant has spread from Mozambique throughout the different regions of sub-Saharan Africa.

Central hypothesis: The Jatropha System creates a positive reciprocity between energy production and environment/food production – Henning (1996).

Jatropha seeds contain about 35% of non-edible oil. Though it is widely used in traditional folk medicine in many parts of West Africa as a laxative by rural low-income communities, its use is discouraged and even considered as illegal. In Benin and Madagascar, oil from Jatropha has been used to manufacture medical soap. *Savon de Marseille*. Already, sub-Saharan Africa is considered as a major geo-source for bio-energy trade and regional development and production of bio-fuels (Johnson and Matsika, 2006). African expectations are that Africa will be the new Bio-fuel continent (Monkey, 2007).

Aspects of development benefit from investment in the use of the *Jatropha* system. These are: [i] the use of renewable energy, [ii] soil improvement and erosion control [iii] promotion of women, and [iv] emergence of a sustainable way of life for village farmers through genera-tion of bio-economic resources coming from innovative rural bio-industries and markets. Moreover, farmers have protected their gardens and food crops through the aesthetic hedge-use of *J. curcas* as a natural ornamental living fence that protects the environment and domestic farmland property. *Jatropha*, described as the '*Cinderella* of the plant world' by Palmer (2007) can be one of the solutions to problems of energy poverty in Africa. With increasing worldwide interest in this non-food human and animal crop, the possibilities are exciting. *Jatropha* oil can be used as a diesel substitute for rural electrification and transport. Its vigorous growth and root system protects against soil erosion. Net carbon dioxide (CO_2) emissions from the *Jatropha* cycle are zero. It can be the flagship of socio-economic development in the LDCs of Africa. The expanding spurt of activity (Tables 2 and 3) in harnessing this green gold throughout Central and Southern Africa is transforming the continent's "*hard-scrabbled ground*" face into a fertile vegetation layer that greens desert land in Niger (Polgreen, 2007). *J. curcas,*

Box 2. Food Situation in African Regions

A. *Percentage of population undernourished in African regions*

Region	Percentage undernourished			
	1969-71	**1979-81**	**1990-92**	**1996-98**
Sub-Saharan Africa	34	37	35	34
Near East and North Africa	25	9	8	10

B: *African countries obtaining 70% or more of the diet from cereals, roots and tubers (1996 – 1998)*

Central Africa

Democratic Republic of Congo (75)

Eastern Africa

Eritrea (78)

Ethiopia (79)

West Africa

Benin (74)

Burkina Faso (75)

Ghana (75)

Mali (73)

Niger (74)

Togo (77)

Southern Africa

Lesotho (80)

Madagascar (74)

Malawi (74)

Namibia (79)

Zambia (79)

Source: FAO corporate repository --- Assessment of The World Food Security Situation, 27th Session, Rome, 28 May - 1 June 2001:

http://www.fao.org/docrep/meeting/003/Y0147E/Y0147E00.htm

drought-resistant and frost hardy thrives in Zambia and Zimbabwe and is ideal for production of bio-diesel products.

Use of natural, renewable and biodegradable bio-diesel and bio-fuels reduce the risks of groundwater and soil pollution whilst offering impressive environment-friendly qualities across the spectrum of domestic activities to those ranging from the industrial sector. The benefits of investment in *J. curcas* are multiple. These range from eradication of the poverty of job opportunities, the em-

Table 2. Bio-fuel activities in Africa*.

Country	Activity/goal	Socio-economic benefits and opportunities
Angola	Joint Brazilian (Petrobras) - Italian (Eni Spa) - Angola initiative tapping vast potential of biofuel production. 3-partner cooperative benefits are: reinforcement of South-South shared technical knowledge; North-South teamwork ensuring biofuel security via Euro-African-South American partnership; and elimination of Angolan rural poverty. With Portugal a biodiesel plant near Ambriz in the Bengo province using oil from the African oil palm is scheduled to start in 2008.	institutes new source of income and job opportunities for Angolan farmers and researchers *via* South-North-South cooperation. Brazilian partner provides technical expertise; Italian partner provides financial resources for construction of biodiesel plant and Angolan partner provides investment openings for biofuel production and export to financial partner. Opening of new labor markets and rural industries.
Burkina Faso	Burkina Faso, landlocked nation in West Africa enters partnership with Taiwan, China for the production of sweet sorghum based-ethanol.	Development of exchange program to train Burkinabese students in Taiwan to use sweet sorghum for ethanol production.
Cameroon	Biodiesel production from palm oil to develop a new biofuel foreign-exchange market.	Development of oil palm plantations for generation of income and new labor markets.
Democratic Republic of Congo	Biodiesel production from palm oil is envisaged through a Spanish enterprise '*Aurantia*' to build 4 oil palm mills.	Production of biodiesel from palm oil in line with feasibility studies dealing with logistics, labor opportunities, and environment- friendly infrastructural inputs.
Ethiopia	Ethiopia-UK collaboration from 2005 results in the first operational *Jatropha* nursery.	Reduction in rural poverty through creation of employment opportunities.
Equatorial Guinea	Development of methanol plant on Bioko island.	Production at a gas-fired power station to supply high-grade electricity.
Ghana	Oil palm production - establishment of the Bio-fuel Implementation Committee in 2005.	Focus on development of regulatory protocols for biofuel production, use of biodiesel and bioalcohol as substitutes for fossil-fuel imports.
Kenya	In 2006, half a million *Jatropha* seedlings planted in the Eastern, Rift Valley and Nyanza Provinces.	Focus on halting the onset of desertification and aiding reforestation activities.
	Fossil-fuel substitution in Kenya using biogas.	Development of capacity building in fuel substitution through a micro-financing approach in Kenyan schools.

Table 2. Contd.

Mali	Mali-FolkCenter Fuels from Agriculture in Communal Technology (FACT Foundation) in Eindhoven, Netherlands; and the Regional Economic Commission for West Asia (ECOWAS).	Women produce locally biodiesel to run *posho* (corn meal) mills and produce soaps, cosmetics and biofertilizers to strengthen rural bioeconomic prosperity.
Malawi	The Biodiesel Agricultural Association encourages farmers to strengthen the energy sector through the planting of *Jatropha curcas*.	Benefits: savings in foreign exchange expenses; minimization of pollution of the environment; and instituting employment and income generation activities.
Mozambique	Joint Mozambique- Norway collaboration in 2006 on African Green Conference "*Mozambique BioFuels*" highlights Mozambique strategic location as gateway to the landlocked countries of Malawi, Swaziland, Zimbabwe and Zambia.	Focus on production of bioethanol from sugarcane; of biodiesel from copra seed oil, cotton seed oil, sunflower seed oil, and *Jatropha curcas* to reduce foreign exchange expenses; minimize pollution of the environment; and expand labor and income generation activities.
Namibia	A Bio-Oil Energy committee oversees plantation of about 63,000 hectares of the *Jatropha* bush by 2013.	Development of an environmental-friendly biofuel.
Niger	Reclamation of desert land through innovative agricultural practices.	Simple innovative village agricultural practices fuel rural energy and feed markets.
South Africa	Development of a *Jatropha curcas* nursery to produce biodiesel in the North West Province. On-stream production by *Ethanol Africa* of biofuel at South Africa's first bioethanol plant in Bothaville in the Free State built by a German enterprise. Development of new technology to produce biodiesel. Organization of "*African Biofuels*" conferences aimed at helping the African continent on the merits and demerits of biofuel use as an alternative to reliance on fossil-fuel imports. Promotion of liquid biofuels in the City of Cape Town. Fiat will launch its Brazilian-built flex-fuel Uno in South Africa in late 2007 which runs on gasoline, ethanol or a combination of the two fuels as displayed at the Durban Auto Show [*Automotive World* - March 27, 2007].	Reduce dependence on high-cost fossil fuels in the transportation sector. Use of algae as a feedstock for biofuels production. State-of-the art and awareness conferences on the beneficial uses of biofuels [*http://www.africanbiofuels.co.za/Press.pdf*]. Reduction in dependence on fossil-fuels in the transportation sector.

Table 2. Contd.

Sudan	*Jatropha* -widely encountered in the Bahr El Gazal, Bahr El Jebel, Kassala, Khartoum, and Kordofan States.	Mainly used as a medicinal plant due to its molluscicidal properties.
Tanzania	Transition to *Jatropha* biofuels is in a nascent stage.	Reduction of dependence on fossil-fuel imports and developing ancillary rural industries.
Uganda	*Jatropha* grown in rural areas of the Karamoja region is an ideal bioresource for production of biodiesel ; Feasibility study shows molasses are an uneconomical feedstock which is used to produce local gin --*Uganda Waragi*. A flower farm in Mukono in Central Uganda has begun producing biodiesel using *Jatropha curcas*. Provision of energy services in rural areas.	Reinforces and improves women's' welfare and their participation in rural governance. technical collaboration with India and Mali is foreseen. Raw materials used for soap and lubricant manufacture offer new employment opportunities in financing Mukono's district markets. Facilitating access through biofuel energy use derived from Multi Functional Platforms (Doelle and DaSilva, 2007a).
Zambia	In the central province of Mkushi, *Jatropha* is planted to produce biodiesel. About 300,000 small-scale farmers of the National Association for Peasant and Small-Scale Farmers of Zambia are expected to grow some 150,000 hectares of *Jatropha*. Promotion of bio-energy use in Zambia and establishment of a bio-oil processing plant in Kabwe aids national economic progress. Currently, a total of 400,000 *Jatropha* plants are being grown by 5,000 farmers in the Chibombo and Kapiri Mposhi districts.	sustainable agriculture of *Jatropha* crops helps in poverty alleviation. Self- empowerment for farmers, provision of new employment opportunities, and conservation of valuable foreign-exchange reserves.
Zimbabwe	*Jatropha curcas* (*Mujirimono*) is a cash crop for biodiesel production. A National Biodiesel Feedstock Production Programme focuses on achieving self-sufficiency in use of biofuels through *Jatropha curcas* plantations. The National Oil Company of Zimbabwe (NOCZIM) is set to grow 25,000 *Jatropha* plant seedlings to distribute to farmers for the 2006-2007 season.	alternative to fossil-fuel used in the transportation sector. Improvement of Zimbabwe's energy security through annual contribution of 360 000 tons of *Jatropha curcas* seeds for processing into 110 million litres of biodiesel by 2010. create national employment opportunities for research, production, and processing of biodiesel.
Regional initiatives		
Common Market for Eastern and Southern Africa (COMESA)	Fourth COMESA Business Forum recommends investment in biofuels [*Final Communiqué, May 18 - 19, 2007; Document CBF/IPPSD/1, May2007; Original English*].	Reduction in the dependence on fossil-fuels through use of liquid biofuels in the transportation sector.

Table 2. Contd.

Economic Community of West African States (ECOWAS)	Focus on poverty reduction and the development of national and regional economic infrastructure.	Focus on health, rural development, and small-scale enterprises that contribute to national and regional bioeconomic prosperity.
Economic Community of Central African States (ECCAS)	Focus on creation of an awareness of the potential benefits of using clean and green biofuels.	Focus on rural development and small-scale reduction in dependence on the use of fossil-derived fuels.
Desert Margins Programme (DMP)	A collaborative effort convened by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) that unites 9African countries with desert margins that ring the heart of Africa: Botswana, Burkina Faso, Kenya, Mali, Namibia, Niger, Senegal, South Africa and Zimbabwe.	An answer to eradication of the twin scourges ---*poverty and environmental degradation* reinforcement of rural energy, food and market enterprises in disadvantaged and poverty-prone non-urban and nomadic communities.
Southern African Development Community (SADC)	Assessment of economic benefits accruing from production of biofuels in the SADC region – Angola, Botswana, Democratic Republic of the Congo (*since 8 September 1997*), Lesotho, Madagascar (*since 18 August 2005*), Malawi, Mauritius (*since 28 August 1995*), Mozambique, Namibia (*since 31 March 1990*), Seychelles [*joined SADC on 8 September 1997 and left on 1 July 2004],* Swaziland, South Africa (*since 30 August 1994*), Tanzania, Zambia and Zimbabwe.	Feasibility study for the production and use of biofuels – *Straight* or *Recycled* vegetable oils [SVO or RVO] in the SADC region as an answer to the reduction of dependence on high-cost imported fossil fuels [*http://www.nab.com.na/jdocs/biiofuels_study_final_report .pdf*].
North-South and South-South Cooperation		
North-South Cooperation	Development of the biodiesel industry in Lesotho, Tanzania and Zambia.	Development of small- and medium-scale industries; job opportunities; and acquisition of financing through the African Sustainable Fuels Centre, Cape Town, RSA.
	India helps West Africa develop biofuels. Potato Value Chain Development in West Africa (Guinea-Senegal). Green OPEC member countries are: Bénin, Burkina Faso, the Democratic Republic of the Congo, Gambia; Ghana; Guinée; Guinea-Bissau;Madagascar;Mali; Morocco;Niger;Sénégal; Sierra Leone; Togo; Zambia. The island states - Mauritius, Madagascar and Reunion [French territory] in the Indian Ocean team up in a collaborative effort wherein Mauritius, Malaysia and China provide the required *savoir-faire* and technical expertise whilst Madagascar and Réunion provide land for plantations.	provision of US $ 250 million from India to boost biofuel production in 15 West African countries. Supported by Common Fund for Commodities, the potato sector in West Africa is integrated into competitive markets. Creation of mechanisms to; 1) Share financial burdens of high oil prices in solidarity system that protects ongoing national projects aimed at socio-poverty alleviation; and 2) Institute financial governance of large-scale use of biofuels in continental Africa that facilitates African oil producing countries to invest in biofuels in non-oil producing African countries. Reduction of crippling dependency on rising fossil-fuels oil costs that erode the bioeconomic prosperity of These island states.

Table 2. Contd.

Globalized Cooperation		
International Sugarcane Biomass Utilization Consortium (ISBUC)	Established after meetings in Mount Edgecombe, RSA (July 2006) and Alagoas, Brazil (November, 2006) under umbrella of the International Society of Sugarcane Technologists with representatives from institutions in 8 sugar-producing countries: Australia, Brazil, India, Mauritius, South Africa, Swaziland, Thailand, USA.	Promote use of sugarcane biomass residual products for production of bioenergy and biofuels.

Source: Compiled by E.J. da Silva.

Table 3. Non-edible and edible oils possessing bio-diesel potential.

Type	Oleaginous Plant Sources	Remark
Copaiba	An oleoresin tapped from the plant *Copaifera*.	Once known in Africa, now used in Brazil as a source of biodiesel.
Jatropha oil	*Jatropha curcas* is the most widely used species from amongst the over 80 species of the *Jatropha* plant.	Considered for use in several African countries as a biofuel.
Milk bush	*Synadenium granti* from the Family *Euphorbiaceae* – a poisonous plant widely found in Africa.	Under study in Brazil as a source of biofuel.
Edible oils		
Cottonseed oil	*Gossypium herbaceum*	Major food oil used in food processing.
Palm oil	*Elaeis guineensis*	Tropical oil now tapped to make biofuel.
Olive oil .	*Olea europaea*	Used in cooking, cosmetics, soaps, and as lighting fuel for traditional oil lamps.

powerment of the feminine labour force in villages, to the generation of independent income resources that sustain feminine human dignity and financial independence [United Nations Development Programme (UNDP) United Nations Industrial Development Organisation (UNIDO), 2001].

Recent times are witness to fluctuating energy prices in upward spiraling costs. World-wide, climate change and pollution of the aerial environment continues with disastrous consequences coming from dependence on finite fossil-fuels. Mindful of the coming positive and negative impacts of the era of "*l'après pétrole*" foreseen to begin later in this century several countries are already investting in the changing face of agriculture. With the advent of nutraceuticals agriculture was the new health sector. Today with increasing use of bio-refineries especially in the USA, the European Union and in the BICS [Brazil; India, China and South Africa] group, agriculture is now the new energy sector as well as the fulcrum of a "*nouvelle économie*" (Le Monde, 2007).

BIO-REFINERY CONCEPT

The bio-refinery concept involves the integration of bioconversion processes and equipment to produce bio-

fuels and chemicals from biomass within a singular large-scale facility (Doelle and DaSilva, 2007b). A variety of bio-industrial process tributaries yielding multiple bio-based products and bio-fuels are the bases of the bio-refinery thesis. The bio-refinery concept is similar to current day petrorefineries that produce multiple fuels and products from petroleum oil. The bio-refinery concept is of relevance to rural and village communities given that all waste is recycled. The cyclic nature of the zero-emission biotechnology process ensures that all components can provide the 6Fs- fertilizer, fiber, food, feed, fuel and filling materials needed for routine daily life.

Domestic security is guaranteed by reducing dependence on foreign oil. Bio-fuels from 'energy crops' including sugarcane, corn, soybeans, and oil palms aid in helping fight global warming. African countries contribute less than 1% to global CO_2 (Dufey, 2006). Bio-fuel production will further help with fuel security and could be exported to developed countries. Such visionary action would result in valuable foreign-exchange earnings. The global bio-fuels market offers important opportunities in bringing together the economic, environmental and social agenda both in developing countries and globally (Dufey, 2006). International trade barriers, especially tariffs and subsidies, need to be relaxed to enable the developing world reap the benefits of the emerging bio-fuels trade. Certification schemes need to be established for accountability of the environmental and social conditions in such countries. Poor working conditions associated with the cultivation of some energy crops such as sugarcane and palm oil and large-scale bio-fuel production could result in serious environmental consequences (Dufey, 2006).

Cellulosic ethanol derived from virtually any plant matter including farm waste looks particularly promising. Cellulosic conversion technology could reduce the cost of producing ethanol by as much as 60 cents per gallon by 2015 as forecast by the US Department of Energy. Green groups see cellulosic ethanol as a carbon neutral energy source to fight the build up of atmospheric carbon dioxide responsible for global warming. The more important need is to create an awareness of these parameters in the African communities and with policy-makers in order to leapfrog the growing gap that anchors the existing divide between the industrialized and the least developed nations in continental Africa.

Rising oil prices and growing climate change concerns are driving investment and innovation in the bio-fuels sector. Developed and developing countries increasingly look towards renewable bio-energy to replace fossil fuels (Table 2). Bio-fuels, when burned, have fewer emissions than traditional hydrocarbon-based fuels. Furthermore, bio-fuels, generally derived from plants, absorb carbon from the atmosphere as they grow and offer the potential to help mitigate climate change. According to Monkey (2007), Africa could potentially become the world's biggest supplier of bio-diesel with Norwegian, Indian and British companies moving quickly to secure massive tracts of land on the continent for *Jatropha* plantations.

CONCERNS: *JATROPHA*, BIO-FUELS

Concerns have emerged on the use of *Jatropha* and corn as sources to feed the bio-fuel industry. The northern hemisphere turns to corn for the production of bio-ethanol whilst the southern hemisphere turns to the inedible *Jatropha*. The transformation of land that yields food crops into acreage that yields fuel crops needs attention as the transportation sector gains in priority in relation to bigger airports and highway construction. *Jatropha* – the agro-fuel plant for the non-industrialized nations grows on wasteland but needs time to be available continuously in critical mass. The rising costs of imports of fossil-fuels are impacting seriously on the national economies of especially the developing world. In the developed world, the emphasis is on increasing use of clean and green bio-fuels to reduce carbon dioxide emissions. Southern Africa is expected to be the launching pad for new export markets within the framework of bio-energy trade and regional development [(Economic Commission for Africa (ECA), 2006; Johnson and Matsika, 2006).

RAINBOW BIOTECH – A Portal for African Sustainable Development and Bio-economic Prosperity

The southernmost country of Africa with veins of diamond and arteries of gold is a land of bio- and unique cultural diversity in its fauna and flora (features characteristic of 4 other countries: Brazil, China, India and Indonesia), its geography and topography, people, and political history. Amongst all the countries in continental Africa, the Republic of South Africa (RSA) by virtue of its past and present shared history has been at the forefront in the promotion of biotechnology (Table 4) to achieve national goals [Department of Science and Technology (DST), 2001, 2002). The skeins of academic commitment, responsibilities and accountability have strengthened the fabric of RSA national development that enriches international cooperation through for example, the IBSA [India, Brazil and South Africa] initiative for international co-operation [Research Information Systems (RIS), 2006). The possibility of a novel bio-fuel industry is now becoming a reality [Department of Minerals and Energy (DME), Republic of South Africa (RSA), 2006).

CONCLUSIONS

Poverty and its offspring – hunger – feed rebellions and revolutions that impact on the stability of national and

Table 4. National Republic of South Africa (RSA) biotech excellence and contribution to emergence of a better Africa.

Activity	Achievements	Remarks
Biotechnology enterprises	106 companies [inclusive of 47 core and 59 non-core biotech companies/NGOs] are in Gauteng (41%), the Western Cape (37%) and Kwazulu Natal (15%).	Traditional brewing and food excluded; majority of core companies are in health (39%) and support services (13%) with near even representation in the environmental, food, plant, animal and industrial sectors.
Research Groups	679 research groups in SA with breakdown as: 1)Biotech→296 2)Potential Biotech →205 3)Biotech services→178	Stakeholders in human health, plant, food and beverage sectors were from the Western Cape, Gauteng, Kwazulu Natal and the Free State.
Biotech relevant projects	911 projects were in sectors of: human heath, animal health, plant biotech, the food industry, the industrial, food and environmental sectors.	Projects conducted primarily by Western Cape, Gauteng, Kwazulu Natal and the Free State.
Human Resources	1 020 skilled persons involved with 950 coming from academic sector.	Nearly all R&D personnel possess required training.
Biotech Patents	200 biotech patents filed with the South African Register of Copyright Designs and Patents.	Deals with bio-intellectual property capital of RSA.
Support structures	Regional Innovation Centres (BRICS); National Bioinformatics Network, etc.	

[Source: http///www.oecd.org/dataoecd/è/37:3603699&.pdf].

international governance. Several of the least-developed countries of sub-Saharan Africa have low-income earning groups and are prone to fossil-fuel energy poverty and food deficiency. These energy- and food-deficient nations with just the bare biotechnological minimum in *savoir-faire* to feed themselves are perpetually vulnerable and disadvantaged in the global arena of governance, employment and trade. Poverty, an integral component of their national fabric, is the last socio-economic disease that sows social unrest and erosion of human-power resources in these countries. It devalues and endangers the bio-safety and bio-security of biodiversity and the legacy of the environment to be bequeathed to future generations.

Lack of respect for gender equivalence, child labour exploitation, bonded labour slavery, discrimination and racism in their varied nuances need to be eradicated. The delivery instruments are political will, provision of education, and investment in low-cost high-quality multipurpose biotechnologies such as the integrated biogas systems and the recycling of wastewaters. These simple to implement small- or village-scale bioprocesses as proven in Brazil, China and India uplift human dignity, empower endeavour, enthusize the morale spirit and conserve values. The sense of accomplishment and satisfaction of time well-spent in acquiring food, feed, fibre and fertilizer for one's family in an urban, rural or village settings indicate that Africa is setting its own biotech agenda for sustainable development. Biotechnology, an important tool for economic and sustainable development through NEPAD envisages partnerships and participation of stakeholders for economic advancement at the village, urban and national levels (Pillay and DaSilva, 2001). The emergence of "Rainbow Biotech" indisputably can serve as a catalytic portal amongst others for overall continental development (Louët, 2006; Pincock, 2006; RIS, 2006).

ACKNOWLEDGMENTS

The authors acknowledge Dr. C. Montague (*LifeLab,* Durban) and Prof. B.A. Prior (University of Stellenbosch) for their advice and comments in the pre-reviewing of this contribution.

REFERENCES

Department of Minerals and Energy (DME), RSA (2006). Draft biofuels industrial strategy of the Republic of South Africa, November, p.15.

Department of Science and Technology (DST), RSA (2001). A national biotechnology strategy for South Africa, June, p. 82. [www.dst.gov.za/publications/reports/dst_biotechnology_strategy.pdf]

Department of Science and Technology (DST), RSA (2002). South Africa's national research and development strategy, August, p. 82.

Doelle HW, Da Silva EJ (2007a). Biorefineries - concept for sustainability and human development In: Biotechnology [Eds. Doelle HW, DaSilva EJ], in Encyclopedia of Life Support Systems (EOLSS) developed under the auspices of the UNESCO, EOLSS Publishers,

Oxford,UK [http://www.eolss.net].
Doelle HW, Da Silva EJ (2007b). Biorefineries: A contribution to the human face of biotechnology, ABDR Special Issue on Biorefineries/prospects, problems and perspectives for developing countries, Ed. DaSilva EJ.
Dufey A (2006). Biofuels production, trade and sustainable development: emerging issues. International Institute for Environment and Development, London, UK, p. 55 ISBN 978-1-84369-643-8 (formerly 1-84369-643-6).
ECA (2006). Sustainable energy: A framework for new and renewable energy in southern Africa. ECA/SATPUB/2005 - March 2006, p. 26.
Hazelhurst E (2007). Biofuels demand threatens to drive farm prices higher. July 6. [http://www.busrep.co.za/index.php?fArticleId=3919355&fSectionId=552&fSetId=66].
Henning R (1996). Combating desertification: The Jatropha project of Mali. West AridLands Newsletter. [http://ag.arizona.edu/OALS/ALN/aln40/jatropha.html].
Johnson FX, Matsika E (2006). Bio-energy trade and regional development: the case of bio-ethanol in southern Africa. Energy for Sustainable Development X: pp. 42-53.
Le Monde (2007). Economie – Dossier, Les biocarburants redessinent la carte de l'agriculture mondiale, Mardi, 3 Avril.
Leuenberger H, Wohlgemuth N (2006). Biofuels and Energy Security in Africa. http://www.gfse.at/fileadmin/dam/gfse/gfse%206/ PLENARY_IV/GFSE2006.pdf].
Louët S (2006). Rainbow Biotech - South Africa's emerging sector, Nat. Biotechnol. 24: 1313-1316.
Mayet M (2007). Opening Pandora's Box: GMOs, fuelish paradigms and South Africa's biofuels strategy; February 22; [http://www.gmwatch.org/archive2.asp?arcid=7565].
Monkey G (2007). In Fuel-Tech, Bio-Fuel Vehicles, March 4, [http://gliving.tv/vehicles/will-africa-become-the-bio-fuel-continent/#more-76].
Palmer K (2007). Green energy from Africa. Newsweek, February 19 issue.
Pillay D, Da Silva EJ (2001). Biotechnology in Africa: Partnerships and stakeholders for economic progress. Proceedings of the Biotechnology in Africa Conference 1, 20-21 (see also http://www.africabio.com/projects/projects.htm).
Pincock S (2006). The long journey home: Is African science long plagued by a lack of equipment and resources – poised for a comeback? Scientist. 20: p. 44
Polgreen L (2007). Trees and crops turn back the Sahara. International Herald Tribune, Paris Edition, Monday, February 12.
Research Information Systems (RIS) (2006). India-Brazil-South Africa (IBSA) economic cooperation: Towards a comprehensive economic partnership. RIS Policy Brief [prepared at request of Ministry of Commerce and Industry, GOI], June 26: 1-6.
UNDP/UNIDO (2001). Energy for poverty reduction: The concept of the multi-functional platform as a regional project, May, 14 [http://www.ptfm.net/old/conceptpaper.pdf].