# A Comprehensive Overview and Promotion of Bioenergy Systems for Social Development in South Africa

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*Abstract*--**The need for energy demand is dependent on the worldwide growth in population which keeps on rising exponentially. South Africa as part of the global arena is currently experiencing a major problem in generating electricity nationally. Eskom the entrusted company to supply electricity has over the years been generating power through burning coal. Faced with a huge energy consumption the country has become the leading carbon dioxide $CO_2$ emitter in Africa and the 12th largest worldwide. Biofuels and other alternative fuels have the potential to reduce the nation's dependence on imported fuels which currently stands at 70% of the petroleum consumed. In order to lower pollution levels South Africa has established several Biofuel policies and mandates such as the Biofuel Industrial strategy aimed at promoting the production and use of Biomass fuels. The purpose of this paper is to provide an overview, development trends and concretization of bioenergy in South Africa. The factors used in the design and implementation of energy policies regarding bioenergy is also discussed. The paper further exhibits the usefulness of biofuels in the management of the environment and integration of bioenergy as an essential contribution to the eco-system re-equilibrium.**

## I. INTRODUCTION

Energy is the life force of the modern society in fostering economy and development. Human work, spare time, social and physical well-being all depend on the supply of a sufficient and uninterrupted energy. The challenge of the demand for energy worldwide is growing at significant rate. This sentiment was echoed by Hsing Hung Chen [3] in their study of the renewable energy development in Taiwan. Chen indicated that the impact of the Fakushima accident in March 2011 changed the opinion of the people of Taiwan against the use of a nuclear power plant resulting in the Government of Taiwan passing the relevant laws and regulation to promote renewable energy. The European World Energy Technology and Climate Policy Outlook (WETO), [6] predicted an average growth rate of 1.8% per annum for the period 2000-2030 for primary energy demand worldwide. The increased demand is being met largely by reserves of fossil fuels that emit both greenhouse gasses and other pollutants. Those reserves are diminishing and they will become increasingly expensive. Gas fields expected to replace much of the current demand in oil and coal are also environmentally challenging as they emit mainly carbon dioxide, [16]. Currently, the level of carbon dioxide emissions per capita for developing nations is over 20% more than that for the major industrial nations. As developing nations industrialize, this will increase substantially, [7]. By 2030, carbon dioxide emissions from developing nations could account for more than half the world's carbon dioxide emissions. Industrialized countries should therefore lead the development of new energy systems to offset the substantial increase of $CO_2$ emissions, [7]. It is of utmost importance to have safe and clean energy resources. New technologies for the long-term supply of energy together with environmental sustainability are necessary as the world is confronted with critical challenges such as diminishing and increasingly expensive fossil energy as well as environmental damage caused by a series of pollutions, greenhouse gas generation resulting in climate change and global warming, droughts and floods, scarcity of pure water, high temperatures, UV exposure resulting in cancers and other global environmental dilapidation threats, [15]. In spite of the diversification of the South African energy systems, clean coal technologies, safe and efficient cooking fuels and appliances, bio-fuels as well as biomass, energy is still seen as a concern and a challenge to the local industry and the community at large, [18]. South Africa is currently experiencing a major problem in generating electricity nationally. Eskom the entrusted company to supply electricity has over the years been generating power through burning coal. Faced with a huge energy consumption the country has become the leading carbon dioxide $CO_2$ emitter in Africa and the 12th largest worldwide.

### *A. Bioenergy in Emerging Economy*

The projections of biofuels by 2050 can meet the global need for energy supply up to 27% as published by the International Energy Agency (IEA) in their 2011 report on "Roadmap Biofuels for Transport", [20]. The buying-in of emerging economies in the Bioenergy systems through policies development has initiated bioenergy awareness and resulted in steadily improving for the past 5 years resulting in substantial opportunities in the exploitation of bioenergy systems. Figure 1 below depicts the share of the countries with renewable energy policies versus income group from 2004 to early 2015. The Figure 2 identifies and classifies World countries and their GDP to match the income group portrayed in Figure 1.

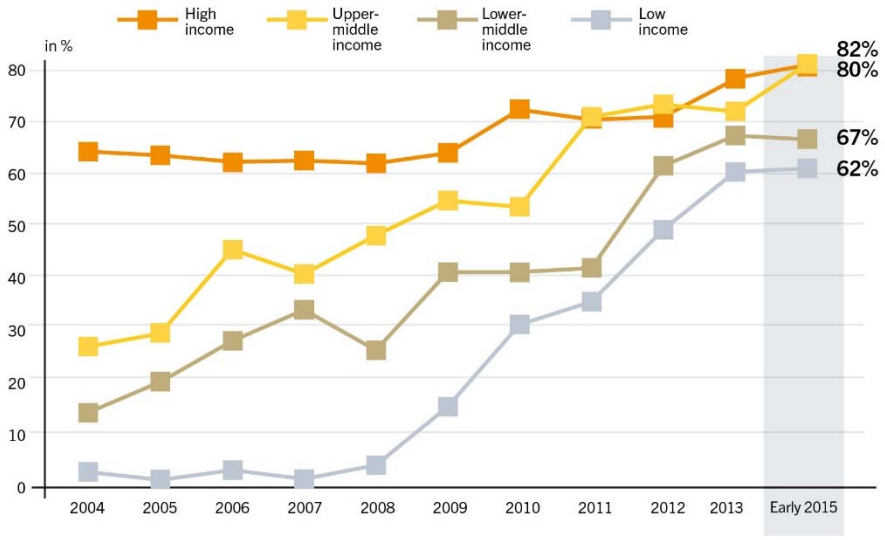


Figure 1. Share of countries with renewable energy policies, by income Group, 2004 – Early 2015. Source: [21]

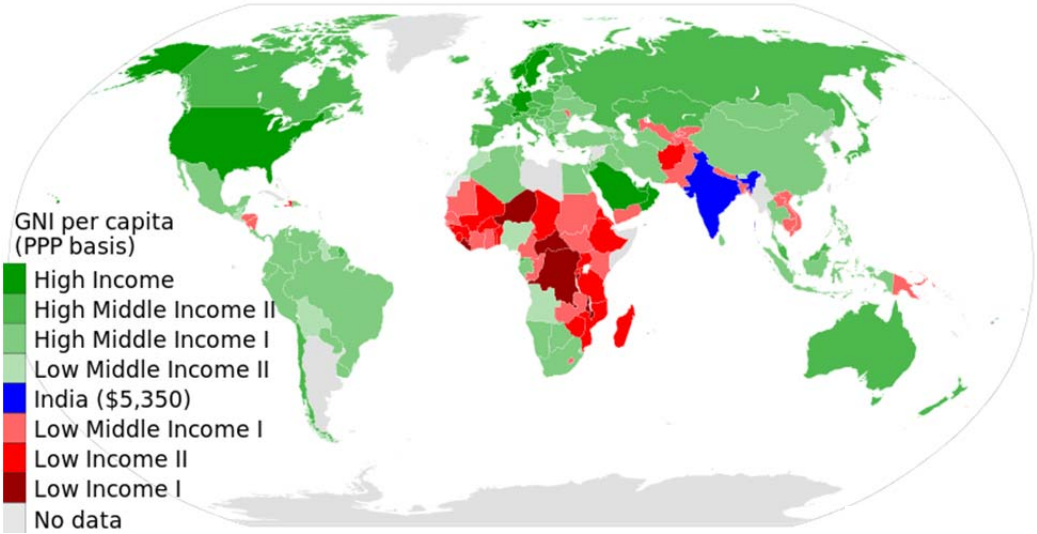


Figure 2. GNI per capita, PPP 2014. Source [24]

*B. Bioenergy in Southern African Region*

The production of modern bioenergy in Africa is limited especially in Southern Africa where the sector is in its infancy, [17]. Figure 3 below, indicates that Southern Africa has the potential to increase bioenergy production in line with both the South American and Asian countries but the potential is limited by poor conversion efficiency and technology transfer. A key role of bioenergy development in the Southern Africa region and in South Africa particularly is to improve energy access to support livelihood and social development. It is therefore essential to appreciate the nature, location and magnitude of different energy demand vectors to understand whether the main requirements are for large or small scale electricity, liquid fuels, syngas, fertilizer, chemicals or heat. Information about the demand sectors exists at national level, but has not previously been considered alongside bioenergy supply/resources in specific regions. There is potential for increased levels of bioenergy deployment in Southern Africa to deliver socio-economic benefits including improving rural energy access, reducing costs of energy provision and providing economic and socially sustainable development by boosting rural agriculture and facilitating participation of rural communities in the agricultural value chain. Bioenergy can deliver energy access to rural communities to reduce energy poverty associated with poor social mobility. Schools benefit substantially from energy for light, cooking and computing facilities. Energy access can also allow small businesses to develop as goods can be transported to market and there may be particular synergies here with biomass transportation infrastructure being used for transport of other goods and services, [23].

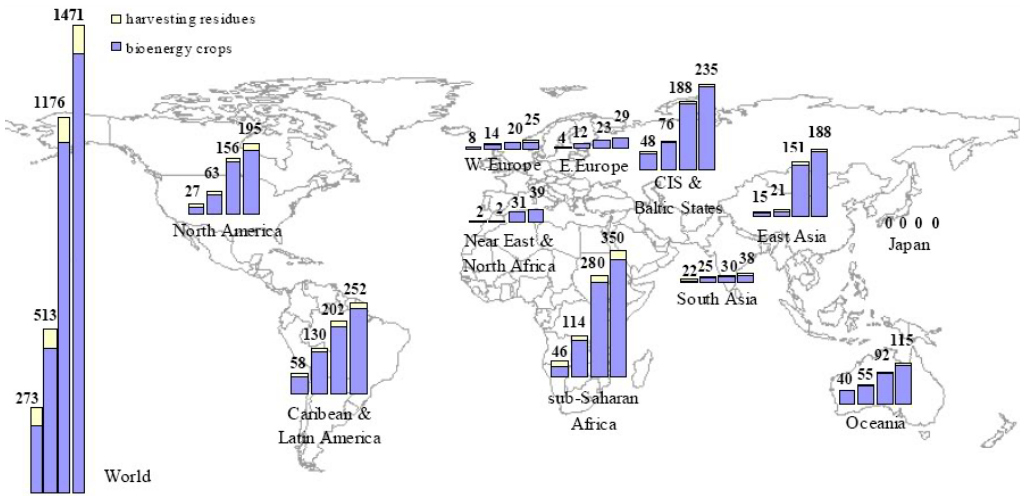


Figure 3. Projected global Biomass Supply. Source: [23]

## *C. Bioenergy and Food security*

In Africa as a whole, the real potential of bioenergy is in social development. It is therefore important that Africa's vast resources are used to develop a bioenergy sector that is inclusive, innovative, socially acceptable and financially viable, and balanced with adequate and sustainable food production. However, to date bioenergy in Southern Africa has been limited by, among other factors, poor conversion efficiency and technology transfer, poor feedstock availability and poor access as well as affordability. In addition, the lack of supportive policy guidelines and an effective implementation strategy is exacerbated by the food-fuel debate, which leaves policy makers uncertain as to how to proceed in the light of food insecurity coupled with water scarcity, especially in Southern Africa, [2].

Sunflower, soya, and canola are promoted as feedstocks for biodiesel, while sugarcane and sugarbeet are the choice of feedstocks for bioethanol. The government has stated that maize, South Africa's staple food, could not be used in the production of biofuels, in order to ensure food security and to reduce the risk of high prices. The government has also promoted the use by farmers in the former "homelands", previously disadvantaged black areas, to produce the feedstock. However, Letete [11] and Amigun et al. [1], have highlighted that these small-scale farmers are sceptical of these new ventures and generally are not willing to engage in farming crops that they are not familiar with. Overall, the combination of the preference given to previously disadvantaged farmers and the exclusion of maize as feedstock has, undoubtedly, slowed down the establishment of an agriculture-based biofuels industry in South Africa, [12].

## *D. The South African policy structure to create and promote bioenergy.*

Figure 4 below illustrated the progress made by both developing and emerging economies with regard to policy development. The indication is that South Africa developed some of its energy policy well over ten years ago.

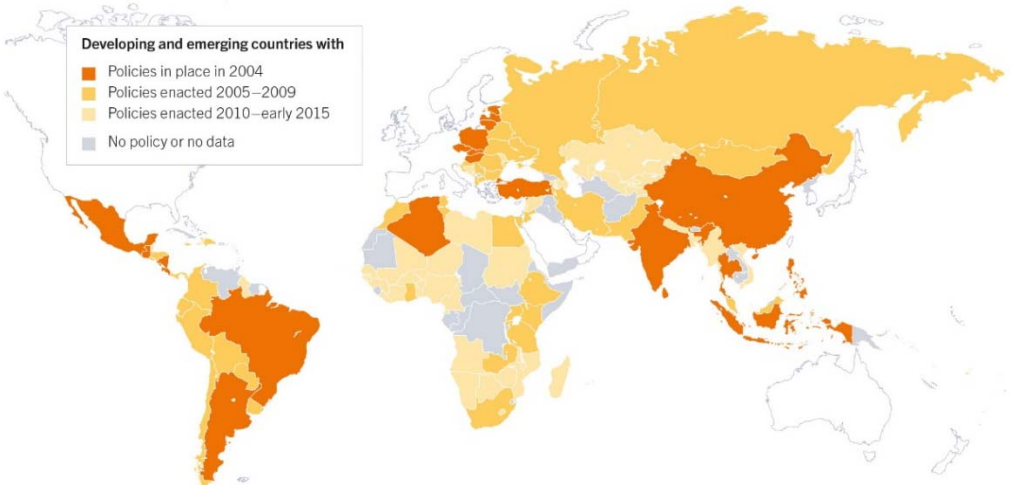


Figure 4: Developing and Emerging Countries with Renewable Energy Policies, 2004, 2009, Early 2015. Source [21]

According to Brent [2], the South African National Biofuels Industrial Strategy originally focused on a short-term five-year pilot programme to achieve a 2% penetration of biofuels in the national liquid fuel supply, or 400 million litres per year to be based on local agricultural and manufacturing production capacity. This target represented about 30% of the national renewable energy target for 2013, of 10,000 GWh of energy consumption set out in the White Paper on Renewable Energy. Before the release of the strategy, commercial sugar producers and maize farmers represented the majority of the parties looking to drive the South African biofuels industry. In 2015, however, progress in the development of the country's biofuels industry was very modest, particularly in terms of investment. The only real accomplishments by then had been the approval of R3.2 billion by South Africa's Industrial Development Corporation (IDC) and the Energy Development Corporation (EDC) – for two bioethanol plants that should collectively produce about 190 million litres per annum of bioethanol from sugarcane and sugar beet; and for the planned erection by Rainbow Nation Renewable Fuels Ltd of a 1.1 million tonnes per annum soybean crushing facility that will produce and distribute about 228 million litres of biodiesel. Additionally it is highlighted that no commercial biofuel plants have been established in the country. Only biodiesel is currently being produced for the transport market, by the more than 200 small-scale initiatives that use recycled vegetable oil, most of which were established long before the strategy was released in 2007. As a result, until lately, there has been no assurance that commercial biofuel production will actually occur. Some analysts in the research fields attribute this to the absence, until now, of obligatory nationwide blending of biofuels into conventional liquid fuels.

*E. Mandatory blending of fuels*

In 2011, the national Department of Energy (DoE) published draft regulations for public comment on the mandatory blending of biofuels with petrol or diesel. The regulations strive to promote the blending of locally manufactured biofuels into the existing petrol or diesel pool. It also seeks to ensure that biofuel manufacturers receive a fair price for biofuels supplied to blending facilities, while also sending out a clear signal to investors with regard to securing the off-take of biofuel use by oil companies. The finalised regulations were released a year later and stipulated the standards to be followed–blending a minimum of 5% (by volume) of biodiesel into diesel, and between 2 and 10% (by volume) of bioethanol into petrol, [2]. The national Department of Energy DoE, [5] recently gave notice that the regulations would come into effect in October 2015.

*F. Arable land to be used*

The government documentation debates about new and traditional land currently underutilised to be found in the former homelands, but these debates were not transparent, [11], They also investigated the agricultural area of QwaQwa in the eastern part of the Free State Province and discovered that there were three types of land in this area that could be classified as currently underutilised:

- *Land owned by emerging black farmers*: Since the late 1990s, the South African government has been awarding agricultural land to emerging black farmers, through various schemes, as a means of land reform. Because of the lack of financial, management and, in some cases, technical skills, most of these farmers have been struggling to operate the farms effectively, sometimes even leading to the total abandonment of the farms.
- *Communal land*: This is generally composed of a number of large pieces of land in the rural areas that are used for agricultural purposes by the whole community. All farming carried out on this land is purely subsistence in nature.
- *State land*: In the former *homelands*, there are usually areas of state-owned land that are of agricultural quality and which were meant to be demarcated for agricultural purposes, but which were never allocated to any-one under the apartheid regime. This type of land is usually left unused, illegally used by the local community for grazing purposes, or used for cultural activities.

The use of the first two types of land above for biofuel production is bound to conflict with food supply. While the little that the emerging farmers are able to produce at the moment is currently being sent to regional silos that feed into the national food industry, the land used for communal subsistence farming is vital for the survival of these communities. In many cases, the community cannot afford to use it for anything else. The formal demarcation of state-owned land, on the other hand, is usually a lengthy process where decisions rest with the highest authorities in the national department. Thus, it remains unclear to many stakeholders as to what land is referred to as new, additional or currently underutilised, a fact that can potentially hamper the involvement of many interested parties in the biofuels industry,[12].

*G. Implications of other national policies and strategies*

At a national level, a number of other policies and strategies now exist in South Africa to support the production of biofuels and more continue to be developed. However, it is also important to note that new policies do not in themselves create an enabling environment for biofuels programme development and implementation. This requires a balanced mix of professional, technical, financial and legal service providers, innovative funding, interdepartmental leadership and championing projects for success. Nevertheless, the key overarching policies and strategies that underpin the

development of the biofuels industry, regardless of the abovementioned uncertainties, are as follows, [2]:

- to design, establish and secure appropriate funding to catalyse the generation of power from renewables, and associated industrial development;
- to effectively implement industrial and renewable energy policy, planning and procurement programmes to mitigate climate change consequences in achieving economic development goals domestically;
- to demonstrate and share learning from innovative large-scale collaboration to mobilise investment in climate change-compatible infrastructure and green growth;
- to enable public partnerships to leverage funding, including private sector investment, in a manner that supports South Africa's efforts to move towards a greener economy that offers sustainable social development and economic up liftmen.

National Development Plan (NDP): A fundamental aspect of the National Development Plan, which was released by the National Planning Commission with a vision for 2030, is the need for South Africa to move away from the unsustainable use of natural resources and to transition to a resilient, low-carbon economy. To this end, the NDP includes proposals to:

- support a carbon-budgeting approach, linking social and economic considerations to carbon emission reduction targets;
- introduce an economy-wide price for carbon, complemented by a range of programmes and incentives to raise energy efficiency and to manage waste better;
- Simplify the regulatory regime to encourage renewable energy use.
- The plan then suggests that with a realistic strategy and global partnerships, South Africa can manage the transition to a low-carbon, resilient economy at a pace consistent with the government's public pledges – without harming employment opportunities and competitiveness.
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*H. Bioenergy contribution as a response to energy demand*

One key advantage of bioenergy systems over other renewable energy forms is that they can service a wide variety of energy demands with a range of intermediate energy vectors. It is therefore critically important to understand the nature of the existing and projected future energy demands when designing implementation schemes.

A growing population and continued economic growth mean that demand for energy is set to increase across Africa; it is therefore vital that any vision for bioenergy takes changing energy demands into account. At the household and community level, energy provision will need to go beyond meeting basic needs to consider how interventions may be tailored to local contexts and to meet household needs, productive uses and community services. At the local level, this will require an understanding of the communities and their energy needs. This may involve the use of models to assess future energy demand at different scales, and/ or household surveys to explore peoples' aspirations and the role of energy within these. A key question is therefore to what extent bioenergy can meet future demand given the local context. While the energy demand may exist, the form in which the bioenergy is presented may not be appropriate, [23].

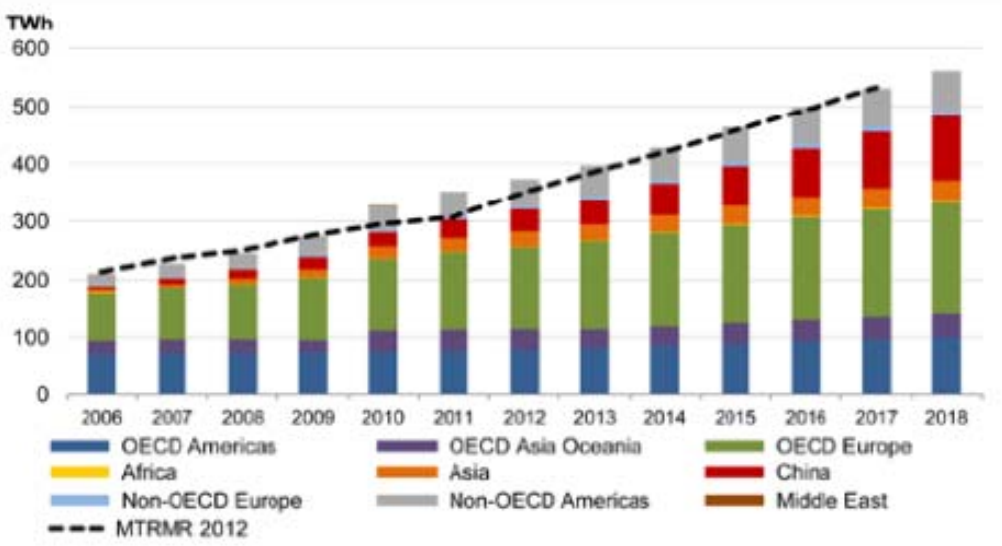


Figure 5: Bioenergy generation and projection by region. Source [19]

## II. MAJOR CHALLENGES TO THE DEVELOPMENT OF BIOENERGY SYSTEMS IN SOUTH AFRICA

- Competition between food and biofuel
- Conversation of land as an asset in the production of biofuels
- Delimitations in the alternative for biomass fields
- Lack of knowledge and professionals in bioenergy systems

The current implementation of bioenergy systems is constrained by a lack of proper analysis of interlinkages between bioenergy production, food security and environmental sustainability–coupled with poor quality data for existing energy and water consumption and food security. Most bioenergy systems are being evaluated from the perspective of being in competition with food production and environmental systems, rather than for their complementary role Lynd & Woods [14].

The question that remains is whether African populations are worse off with the implementation of bioenergy systems than without them, [13]. The opportunities for the integration of bioenergy directly into food systems include being an enabler of both energy and food security for the poor. This is in direct contrast to considering bioenergy and food systems as separate and competing systems. This new dimension creates a better understanding of multiple benefits that can be gained if bioenergy systems and food systems are handled as integrated systems that depend on and complement each other. A study based on a market system approach by the joint initiative of the Food and Agriculture Organization of the United Nations and the Policy Innovation Systems for Clean Energy Security consortium on the impact of small-scale bioenergy initiatives on rural livelihoods revealed that bioenergy has the potential to improve rural livelihoods by offering new economic choices to rural communities, [2].

### *A. Biofuels and environmental Challenges*

Comparable to conventional fuels, biofuels are associated and related with emissions to the environment through their developmental processes. Emissions association are from the various products, resulting from the processes, as biofuel production ordinarily yields one or more co-products. An illustration of this can be the bagasse from sugar cane, highly-valued for power and heat production. The Life cycle assessments of biofuels are usually based on comparative studies orientated with the intention of analyzing alternatives amongst fossil or bio-based options. In order to lessen environmental burden, alternatives options linked to the market demand should always present the strengths and weaknesses with certain dependence. This is the case especially for bio-fuels. The growing demand for fuel crops may only be attained through the expansion of cropland. Indirect environmental impacts on expanding agricultural land for biofuel production, results in impacts such as the destruction of natural habitats, rainforests or savannahs, may result to environmental dilapidation and direct threats to the ecosystem. In the worst cases, for example, the greenhouse gas (GHG) emissions from biofuel production may be higher than from an equal amount of fossil fuels, [4].

Biofuels may also change the geographical distribution of the environmental burden of feedstock production within a country or a region, across borders, and also from developed countries to developing countries. The extent to which the co-products of biofuel production displace other products and their environmental impacts depends on the elasticity of demand in the relevant markets (the more inelastic the

TABLE 1: BUSINESS MODEL INNOVATIONS THAT PROVIDE SMALL-SCALE OPPORTUNITIES IN BIOENERGY SUPPLY CHAINS, [2].

| | FARMING | MILLING | REFINING | DISTRIBUTION | END USES |
|---|---|---|---|---|---|
| Business arrangements to include small-scale owners and enterprises | Outgrower schemes<br>Purchase contracts<br>Land leases<br>Sharecropping<br>Management contracts<br>Joint ventures<br>(e.g. community land inputs = shares in the business) | Cooperative mills<br>Share ownership<br>Small-scale facilities aimed at local end-uses<br>Supply contracts with larger refineries and distributors | Limited options given high capital costs of biorefineries | Intermediary traders<br>Transport contractors<br>Utilising existing distribution systems<br>(e.g. networks of rural retail outlets aimed at farmers) | Sliding-scale energy pricing<br>Subsidised multi-function platforms<br>Subsidised improved appliances<br>Use of unrefined oil rather than refined biodiesel |
| Opptions for government policy support | Support to positive models through regulation, information, model contracts and brokerage<br><br>Underwriting community business involvement | Active promotion of small-scale milling operations, e.g. via supply of prototypes<br><br>Range of support to promising joint equity models | Employment laws<br>Holding developers accountable to job projections in approved investment contracts | Local content requirements | Support to off-grid energy schemes subsidies as above |

demand, the greater the substitution), the way in which the co-products affect supply curves, and other market and non-market factors such as political and regulatory. Uncertainties are due to the location of the facilities, which has a minor influence, and the interactions between unit processes in the value chain, [4].

The conversation about biofuel/food and land use has resulted in a lot of criticism as well as conflict. When has emerge out of this are discussions for the next-generation technologies on total biomass conversion. Food and next-generation of biofuels are already co-produced from oil-rich food and starch crops, as well as sugar. The most globally recognized and preferred biomass is currently lignocellulose, a component that is also seen as "second-generation" variety of fuels and chemicals presenting opportunity of lots of benefits in agricultural development. Lignocellulose refers to a plant dry matter, a biomass, also known as lignocellulosic biomass. This is an abundant raw material on Earth used to produce bio-fuels, especially bio-ethanol fuel. It is composed of carbohydrate polymers (cellulose, hemicellulose), and an aromatic polymer (lignin). Lignocellulosic that could be produced as agricultural waste in the grain-based industries and would be appropriate entry point in the development of biofuels from agriculture and forestry residues Brent, [2].

Systems design should therefore be systematically investigated in the context of applicability in the Southern African region and policies to be elaborated for feasibility in the applications of lignocellulose. Boundaries in terms of accurateness on sectors to be mobilized for this purpose should be well investigated as well. Furthermore, the extents to which lignocellulose-based biofuel production and recycling planning for land reuse and forest repopulation should be looked at in a holistic approach for sustainability. The maturation of such investment in South Africa and the region should be through social development and this endeavor would have to rely on intensive education and training structures, development of financial institutions and regulation instances.

TABLE 2: GENERAL BIOFUEL PATHWAY WITH INPUTS AND ENVIRONMENTAL IMPACTS. SOURCE: [4].

| Inputs | | Impacts |
|---|---|---|
| Land | Crop production: FARMING | Land conversion |
| Energy | | Biodiversity loss |
| Water | Processing: BIOFUEL PRODUCTION | GHG Emissions |
| Fertilizer | | Soil Erosion |
| Pesticides | Use: BIOFUEL COMBUSTION | Water pollution |
| Equipment | | Air pollution |

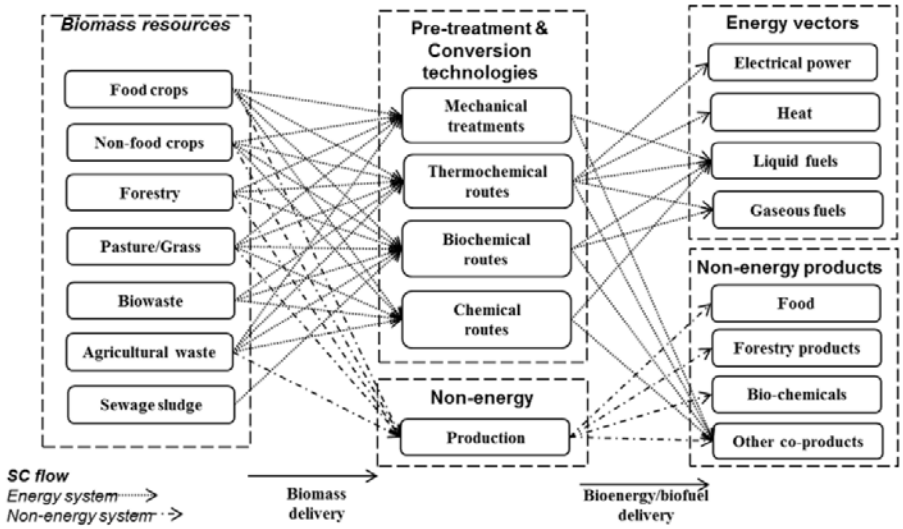


Figure 6: Framework for multi-objective optimisation model for the optimal strategy design of bio-refinery processing routes. [23].

*B. US bioenergy outlook: Case, feedstocks, and considerations for policies*

In the US critics brought about suggestions on biofuels from crops that has a low energy ratio and a large greenhouse gas footprint, [22], [9]. These critics focused mostly on food and feed crops used for biofuels basically produced from first-generation feedstocks like soybean for biodiesel production and maize grain for ethanol production. Second-generation feedstock for bioenergy production is grass-based or the cultivation of lignocellulosic crops, of such are perennial grasses Miscanthus and Switchgrass and these have shown many advantages over first-generation, food-based, feedstock, [10]. Miscanthus and Switchgrass are of large root carbohydrates reserves to be used given their rapid leaf growth as soon as the growing season begins.

US Federal agencies begun to work in partnership few years back to identify criteria and to determine indicators to assess the impact of expanding biofuel production and use in the US and globally. These agencies have identified criteria and indicators that muse on social and economic factors, environmental and land use changes, and issues on energy security. Over some criteria such as GHG reduction targets served of driving forces and more including measures of long-term soil quality, criteria air pollutants and other toxicants, and water quality and use. The have been efforts to measure current impacts as opposed to historical trends and develop suitable models to be used where measurements alone cannot be sufficient, [8].

## III. CONCLUSION

The designation of 2014 – 2024 as the International Decade of Sustainable Energy is a remarkable pronouncement for South Africa. This further highlights the increased global emphasis on the provision of sustainable energy, particularly for the poorest. South Africa has a population of 53 million, of whom 64% live in urban areas. Although efforts to tackle deprivation have led to reductions in the number of people living in poverty, it remains a critical issue with the following figures: in 2011, 46% of the population of South Africa lived in poverty and, of these, 20% lived in extreme poverty. In terms of electricity access, electrification has increased from 77% of the population in 2002 to 85% by 2012. However, for many households, access to electricity remains limited and restricted to lighting services. To transform lives, access should go beyond meeting basic needs, [26]. Bioenergy therefore has the potential to increase flexibility and can lead to social development goals; alternatively bioenergy expansion might aggravate existing demand for land and water. It is important that case studies of bioenergy development in South Africa and the neighboring countries be explored further to better understanding and cope with new situations of bioenergy systems integration in the Southern Africa.

The biofuels industry in South Africa, although supported in essence through a formal national strategy since 2007, has struggled to become a flourishing industry compared to other parts of the world. Conversely, the recent policy intervention, in the form of mandatory blending with conventional fuels, provides a positive signal to the sector, [2]. The sector still faces a number of sustainability challenges, specifically pertaining to the competition for land–with potential implications for food security and the availability of water resources. Thus, much of the debate has revolved around how biofuels would integrate the conventional agricultural production systems, and how new technologies may benefit the evolution of the biofuels sector in the South African context.

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