BIOENERGY SYSTEMS SUSTAINABILITY ASSESSMENT AND MANAGEMENT (BIOSSAM) GUIDANCE PORTAL FOR POLICY, DECISION AND DEVELOPMENT SUPPORT OF INTEGRATED BIOENERGY SUPPLY INTERVENTIONS

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ABSTRACT

There is a growing recognition of the carrying capacity of natural systems and how these limits impact economic growth and development. As fossil fuels are being depleted, the era of cheap fossil fuels is ending and societies are more willing to pay for renewable energy sources that reduce greenhouse gas emissions. There are new opportunities for using bioenergy technologies that can contribute to a wider range of economic, social, and environmental objectives to facilitate sustainable development. There are several new bioenergy interventions (policies, projects, or programmes) that are being considered and these developments must be assessed in terms of their sustainability. Both public and private sector policy makers, decision makers, and technology developers (at the local, regional and national levels) require robust methods to guide structured assessments and the subsequent management of the proposed bioenergy systems.

BIOSSAM aims to enable the comprehensive and holistic assessment, monitoring and management of bioenergy interventions in order to facilitate planning for sustainable development.

<u>Key words:</u> bioenergy, sustainability, sustainable development, invasive alien plants, biomass, renewable energy.

1. INTRODUCTION

The South African economy is energy intensive, with a greater energy consumption per unit capita and total energy consumption per unit GDP, compared to several other developed and developing countries (e.g. India, Malaysia, Portugal, Poland, Hong Kong) [1]. South Africa's primary energy is supplied by fossil fuels (71% of primary energy from coal and 17% oil, 1% natural gas) and 93% of South Africa's electricity is supplied by coal-fired power stations [1, 2]. Although South Africa has large resources of coal[1], the use of coal as an energy source has a number of negative environmental impacts including the consumption of a non-renewable fossil fuel resource; the consumption of vast quantities of water and production of acid mine drainage (AMD); the mining of coal and the disposal of mining residues; and the generation of greenhouse gases (GHGs), sulphur dioxides, and solid fly ash residues [3].

The increase in global GHG emissions has resulted in global warming and the earth's temperature has increased by 0.74°C during the 20th century [4, 5]. Global warming and climate change has direct impacts on sea-levels, global weather patterns and ecosystems which has dire consequences for the future of all life on earth. The increase in GHG emissions is largely caused by the use of non-renewable energy sources (fossil fuels); approximately 2/3rds of anthropogenic carbon dioxide emissions since the beginning of the Industrial era comes from the combustion of fossil fuels [6]. Since approximately 90 percent of world's population growth is taking place in developing countries and their populations will be nearly ten times larger than industrialised countries in two generations, the proportion of global GHG emissions in developing countries (with a business-as-usual scenario) will increase from 27% in 1995 to 50% in 2035 [9]. South Africa is one of the highest GHG emitters in the world on a per capita basis (South Africa is the 13th greatest GHG emitter in the world), and although South Africa does not have mandatory emission reductions under the Kyoto Protocol, it does aim to develop a low carbon economy with a recently announced target of a 34% carbon emission reduction by 2020 and 42% by 2025 [7, 8]. There is a growing interest to reduce GHG emissions, diversify the energy mix and adopt bioenergy interventions as demonstrated by the recent local policies such as the Biofuels Industrial Strategy, the White Paper on Renewable Energy, Tradeable Renewable Energy Certificates and the Renewable Energy Feed-in tariff. Additionally, South Africa also has an urgent the need for increased energy generation capacity since the energy supply has already reached crisis proportions and there is an estimated demand of 25 to 40 GW by 2025 [1, 2].

Similarly, South Africa is considered a water-scarce country with approximately 65 percent of the country receiving less than 500mm of annual precipitation; a threshold that is considered as the minimum required for rain-fed agriculture [10]. With the projected rate of population growth and economic development, it is likely that the projected water demand will outstrip supply since the demand for water in South Africa is expected to increase by at least 50% in the next 30

1 South Africa is the 5th. largest coal producing country in the world; producing approximately 224 million tonnes of coal per annum and the coal reserves are estimated at 53 billion tonnes. With our present production rate there should be almost 200 years of coal supply left (International Energy Agency: http://www.eia.doe.gov/cabs/South_Africa/Full.html)

years [10, 11, 12]. South Africa's agricultural sector has a considerable demand for water (agriculture & irrigation-62%, forestry-3%, rural-4%, urban-23%, power generation-2%, mining & bulk industry- 6%; DWAF[2]) and this is an important natural resource constraint for bioenergy projects [13, 14]. Water is used directly in agriculture and industrial processing, but there is also the indirect water consumption from the use of electricity. This is consequence of the use wet cooling towers at the majority of coal-power stations, so that every 1 kWh of electricity generated uses 1.2 L of water and generates 1 kg carbon dioxide [15]. Additionally, there are wastes from the salts contained in the cooling water that are discharged into the environment; causing salination of the aquatic ecosystem [16]. Many of these factors are considered externalities and therefore are typically not considered in assessments of proposed bioenergy projects. However, all these challenges require a response such as adaptation that carries certain costs and benefits [17].

There are also the social aspects to consider when assessing a bioenergy intervention for sustainability. South Africa is a rapidly developing country with a high level of unemployment. There is an urgent need to stimulate the economy in rural areas of the country by providing energy services to these areas where millions of South Africans live in poverty. Bioenergy interventions offer a new opportunity for improved rural development by enhancing the agricultural potential and productivity of these areas.

BIOSSAM offers a coherent framework and associated tools for the assessment, monitoring and management of bioenergy for sustainable development. In this way BIOSSAM aims to provide public and private sector policy makers, decision makers, and technology developers (at the local, regional and national levels) robust methods to guide structured assessments and the subsequent monitoring and management of proposed bioenergy systems.

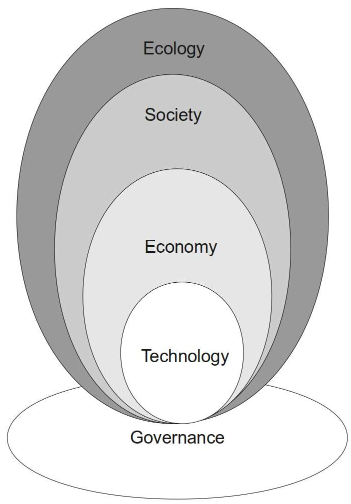
2. DEVELOPMENT OF THE BIOSSAM PORTAL

The aims of the BIOSSAM portal are to:

- Develop a sustainability framework, strategy and co-ordination point to implement appropriate technology solutions and transfer the technology to relevant communities in a manner that effectively responds to their needs.
- Assess bioenergy options based on technical, economic, social and environmental criteria to discover the most appropriate option.
- Monitor and manage the implementation of bioenergy programmes to ensure sustainability.

Sustainable development aims to meet current human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. Sustainable development has been conceived as interdependent and mutually reinforcing pillars of economic development, social development, and environmental protection [18]. In order to achieve sustainable development, Agenda 21 identified information, integration, and participation as key to helping countries to achieve sustainable development [19]. It also emphasises that everyone is a user and provider of information so that sustainable development should be achieved through social constructivism. The principle of sustainable development has been adopted by the business sector that recognises a triple bottom line to measuring organisational success with economic, ecological and social criteria. However, there is considerable difficulty in measuring sustainability since is no clear way to quantify the monetary benefits to the society and environment as there is with the economic benefits (profits). This makes it difficult for businesses to recognize the benefits of sustainable development and/or it results in the trade-offs of different goals.

A modern representation of sustainability has technology, economy and society constrained by the environment and attaining sustainability depends upon a platform of good governance (Figure 1).



<u>Figure 1.</u> The three spheres of sustainability. Technology, economy and society is constrained by the environment (ecological services) and rests on a platform of governance.

Energy interacts with society, economy and environment in several ways and energy is a ubiquitous meta-technology. Energy is a domestic necessity and also a factor of production; enabling a variety of services such as transportation, heating, and food production. The price of energy is a significant cost that directly affects the price of other goods and services [20]. The access to

2 Department of Water Affairs and Forestry (DWAF). http://www.dwaf.gov.za/Documents/Policies/NWRS/Sep2004/pdf/Chapter2.pdf

secure, sustainable and affordable energy is also seen as being essential for achieving the Millennium development goals such as the reduction in hunger and poverty, improving education and communication, enhancing health care services, and responding to climate change [21]. Energy sufficiency and security is a key to development and prosperity since it is essential for the total factors of production and the public services that improve the quality of life.

According to the stakeholder theory, the business entity should be used as a vehicle for coordinating stakeholder interests, instead of maximizing shareholder profit [22]. BIOSSAM was developed in response to the lack of a common framework for the assessment, management and monitoring of sustainable bioenergy interventions. BIOSSAM includes a toolbox that uses a participatory approach with multi-stakeholder engagement to aid in decision making. It provides a sustainability framework for the assessment, management and monitoring of bioenergy interventions, and combines public and expert opinion; thereby enhancing the likelihood of effective technology transfer and market success.

2.1 BIOSSAM strategic framework

A fundamental aspect of the BIOSSAM approach is the consideration of the various aspects of the economy, environment, society, technology and governance and a combination of both 'bottom-up' (broad-based participatory decision with multi-stakeholder opinion) and “top-down” approaches (academic and expert opinion) in the decision making process. This ensure that bioenergy interventions effectively address the needs and interests of the stakeholders while considering the natural, physical, financial, social and human capital of the region so that the development plans for sustainability. BIOSSAM utilises a life cycle approach in order to assess the true costs and benefits so that appropriate and efficient bioenergy technologies and processes can be applied to the conversion of biomass into valuable energy products with the benefits to the economy, society and the environment maximised.

The inception point for BIOSSAM is planning for sustainability by ensuring that there is broad-based, multi-stakeholder engagement and participation. These stakeholders should agree on a common vision and goals with associated sustainability criteria and indicators in order to measure the achievement of these goals. This was complemented by assessment of relevant social, financial, physical, natural and human capitals of the region and expert opinion used to generate feasible scenarios for the bioenergy intervention. A technology balance sheet was used to rapidly asses these potential options. To ensure that the potential options are viable in terms of the natural, financial, physical, social, and human capitals; a SURE-DSS [23] tool was applied to refine these options. Expert and stakeholder opinion was then used to decide on the most appropriate bioenergy option through the use of a participatory multi-criteria decision analysis (MCDA) approach. As part of a policy-making and long-term sustainability planning, a system dynamics (SD) modelling approach was then applied on the most suitable bioenergy intervention. The effectiveness of the bioenergy intervention in achieving sustainability also depends on feedback from management and monitoring that will take place upon implementation of the bioenergy intervention. The framework is shown in Figure 2.

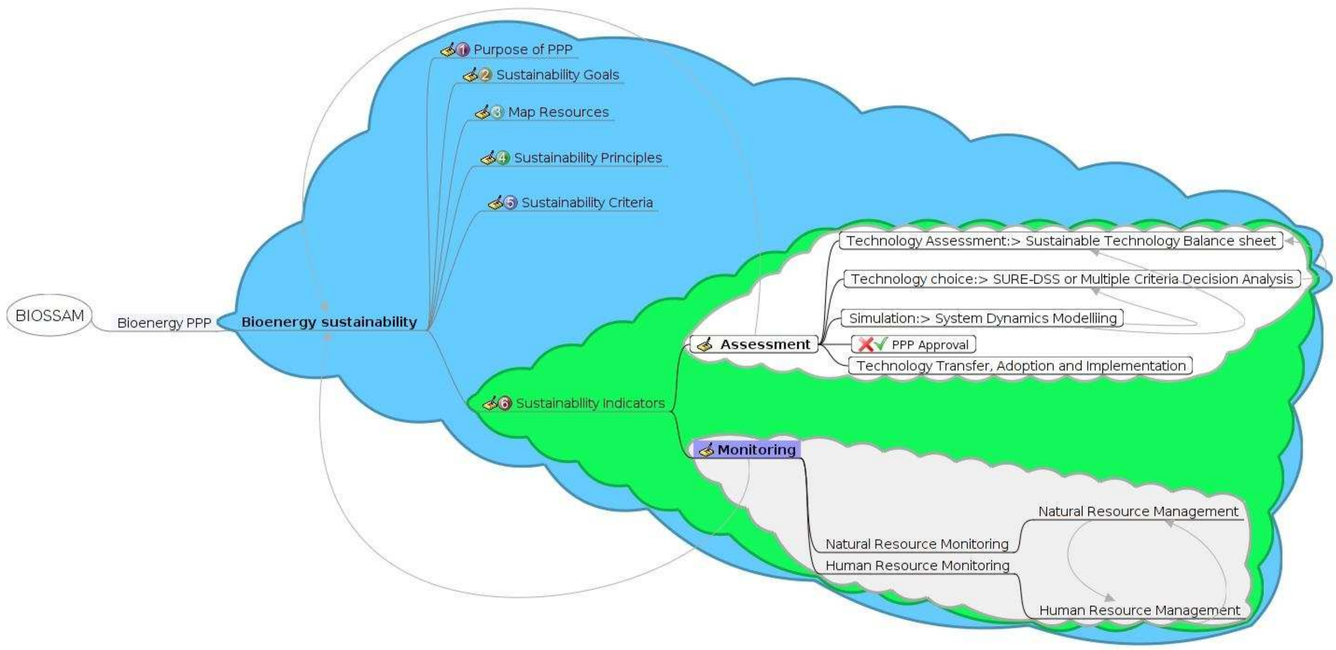


Figure 2. BIOSSAM framework. The BIOSSAM framework plans for the sustainability of a bioenergy PPP (policy, programme, or project). The steps involved are defining the vision, goals, principles and indicators that will be used to assess, manage and monitor the PPP. The toolbox for assessment and management of bioenergy interventions are the STBS, SURE-DSS, MCDA and SD (see text for details).

2.2 BIOSSAM toolbox

Within the BIOSSAM framework are a set of tools that are used to assess, monitor and manage bioenergy interventions. The toolbox is used to address fundamental questions relating to any bioenergy policy, programme or project (PPP). The toolbox is used to address fundamental questions:

(i) *How can the bioenergy intervention plan for sustainability?* The Sustainability framework engages with stakeholders along the value chain (from biomass production to use of the bioenergy product) to define a common vision of sustainability. The purpose of the sustainability framework is to identify opportunities and constraints so that the vision is realistic and achievable. Inevitably, there will be a trade-off between the economic, social and environmental aspects, but an essential premise of the sustainability framework is that these trade-off decisions must approved by all relevant stakeholders and not compromise the fundamental objectives defined by the sustainability goals [24]. Having established a common vision and defined goals with stakeholders, the sustainability principles, criteria and indicators were defined. A sustainability principle is a broad-based statement fundamental for achieving the sustainability goal(s). The sustainability criteria are management objectives required to achieve these principles. Sustainability indicators provide a measure of the sustainability criteria.

The principles, criteria and indicators are of necessity context specific; taking into account local, social, economic and ecological conditions and the relationships between them, as well as the unique group of stakeholders. Establishing the common vision together with goals, sustainability criteria and indicators at the start of the project facilitates a social constructivism approach in planning for sustainability. It also enhances the robustness of the bioenergy intervention as a result of the participatory approach which improves stakeholder "buy-in".

(ii) What are the feasible bioenergy options?

An initial step is to explore all possible bioenergy products from a given resource and present them conceptually in a biomass to energy superstructure (Figure 3). This enables scenarios to be developed that incorporate various technologies and processes to generate the desired bioenergy products. The sustainable technology balance sheet was used to compare the different scenarios within the entire value chain using a metric of the defined sustainability indicators.

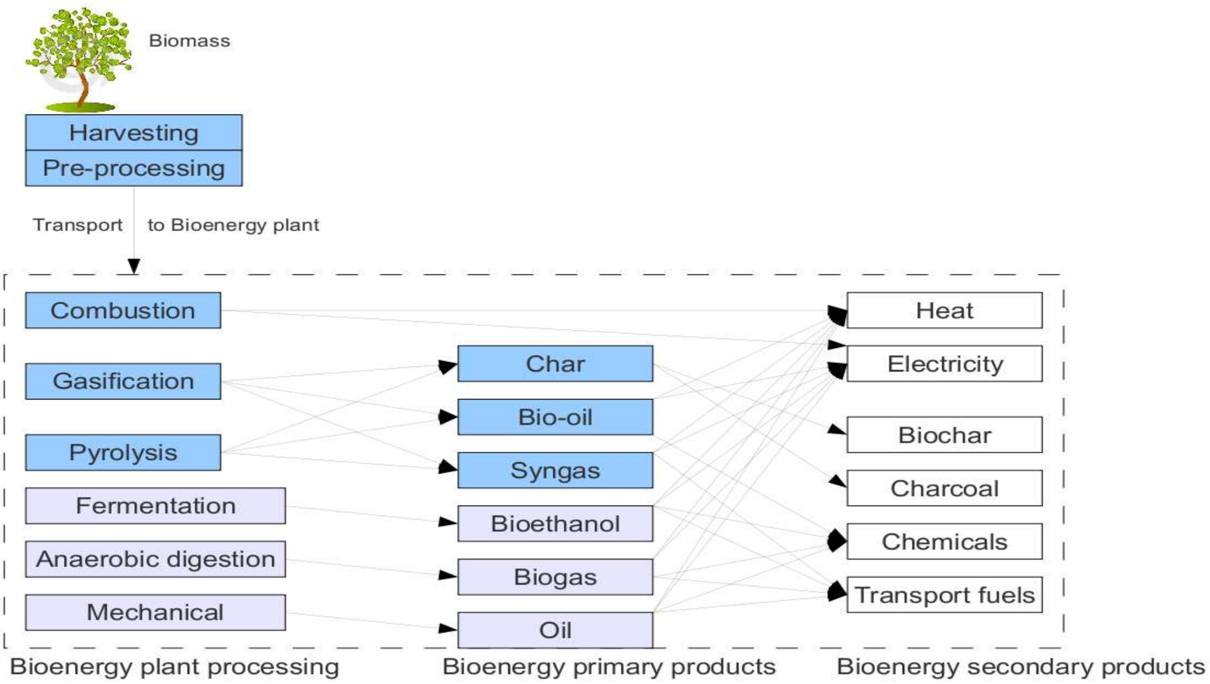


Figure 3. Biomass to bioenergy superstructure. The processes for conversion of biomass into valuable primary and secondary bioenergy products are shown. The dashed line denotes the boundary of the bioenergy plant. Boxes shaded dark grey denote thermal conversion and are the established commercial-scale processes for conversion of IAP biomass into bioenergy products, while light gray are mechanical and biological conversion processes that are not yet at established commercial scale for the conversion of IAP woody biomass into bioenergy products. The unshaded boxes represent the final bioenergy products that are delivered to market.

Scenarios are developed based on these conversion pathways. Each scenario is assessed using a life cycle approach that assesses the cost and benefits along the entire life cycle of the bioenergy intervention (from feedstock production to end-use, Figure 4). The metric for the assessment is the sustainability indicators that were defined in the sustainability framework.

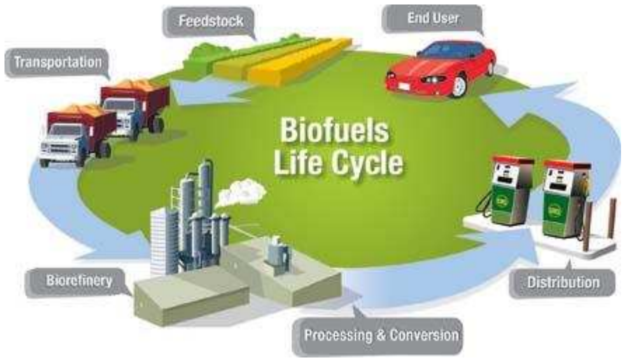


Figure 4. Biomass to bioenergy product life cycle or value chain. A typical life cycle for a bioenergy product from feedstock production to end-use of the bioenergy products is shown (Stakeholder workshop summary, 8 May 2008. Brent A.C., CSIR, NRE, Alternative Energy Futures research theme. http://www.csir.co.za/nre).

In order to decide on the most viable bioenergy options, a sustainable technology balance sheet (STBS) was applied for the rapid assessment of different options (see: Brent, A. and Peach, W.D. Development of the Sustainable Technology Balance sheet (STBS): a generic method to assess the sustainability of renewable energy technologies. Presented by Wildri Peach, at ICUE 2010).

(iii) What are the most appropriate bioenergy options? In order to determine if the proposed feasible scenarios best utilise the capitals of the area, the sustainable rural energy decision support system (SURE-DSS) tool was applied to the proposed scenarios. SURE-DSS is a complete software package designed by the renewable energy for sustainable rural livelihoods (RESURL) research project; funded by the UK Department for International Development (DFID) [23]. SURE-DSS is a multi-criteria approach and tool to enhance rural energy decision-making. It assesses the areas various capitals:- physical (houses, roads), financial (wages, investments), natural (water, land resources), social (network and local organisations), and human (education). SURE-DS was used to model the likely effects of a proposed bioenergy intervention on these community capitals.

(iv) *How to choose amongst several bioenergy options?* Multi-criteria decision analysis (MCDA) is a tool to support decision makers faced with making decisions when there are multiple conflicting criteria. The MCDA aims at highlighting these conflicts and to obtain a solution in a transparent and participatory process. The advantage of an MCDA is that rather than prescribing a "correct" decision, it helps the decision makers find the one that best suits their needs and their understanding of the problem. The Analytic Hierarchy Process (AHP) was chosen as the preferred method which was applied using Expert Choice software (Expert Choice, http://www.expertchoice.com) [24].

(v) How the chosen bioenergy option will affect other factors of the society, economy and environment? To understand the dynamics of the proposed bioenergy intervention and to provide policy-support and forecasting, a system dynamics approach was used. System dynamics (SD) is an approach to understand the behaviour of complex systems over time by considering the interactions and feedback loops of the system as well as time delays that can affect the behaviour of the entire system. A SD model consists of the feedback loops, stocks and flows and non-linearity created by the interaction of the physical and institutional structure of the system, with the decision-making processes of the agents acting within it. The Vensim software package (Ventana Systems Inc., http://www.vensim.com) was used to generate SD models using the established T21 approach (Millennium Institute) [25].

The BIOSSAM toolbox provides several points of stakeholder engagement and uses both "bottom-up" and "top-down" approaches. The stakeholder engagement and participation in the decision-making process enhances the likelihood of project success by facilitating technology transfer and adoption

3. IMPLEMENTATION OF BIOSSAM

3.1 BIOSSAM portal development

The BIOSSAM strategic framework provides guidance on how BIOSSAM can be used to effectively assess, manage and monitor bioenergy interventions, but to make this information more accessible BIOSSAM is being actively developed into a web-portal: http://www.csir.co.za/nre/energy_futures/biossam.html The portal provides access to the framework, assessment, management and monitoring tools and also provides links to bioenergy research knowledge nationally and internationally. The portal includes RSS feeds to bioenergy news, press releases and publications, as well as a blogging platform to voice opinions, enhance debate and discussion and provide opportunities for networking with other members of society. In addition, the portal documents current and developing projects at the CSIR that are case studies to demonstrate the test the BIOSSAM approach and illustrate the effectiveness of BIOSSAM.

3.2 Application of BIOSSAM: Energy from invasive alien plants

Invasive alien plants (IAPs) are the single biggest threat to plant and animal biodiversity in South Africa and have become established in over 10 million hectares of land. IAPs waste 7% of the water resources; reduce the ability to farm; intensify flooding and fires; cause erosion, destruction of rivers, siltation of dams and estuaries; reduce water quality; and can cause a mass extinction of indigenous biodiversity. The cost of controlling IAPs in South Africa is currently estimated at R600 million a year over 20 years [26]. The eradication of IAP represents a burden to society and the Working for Water programme has initiated a sister organisation, Working for Energy, whose aim is the eradication of IAP with the provision of energy as an additional benefit. IAP biomass can be burned directly or converted to intermediate solid, liquid or gaseous fuels to generate heat and electricity. The qualifying criteria for an IAP bioenergy project are that it should utilise all available biomass and not incentivise the farming of IAPs. This presents a new challenge, since IAPs are a non-renewable resource so that sustainability can only be attained in the short-term or there needs to be a strategy to de-commission or re-locate the bioenergy plant, or switch to a different biomass feedstock, once the local IAP biomass has been depleted.

The Agulhas Biodiversity Initiative (ABI) is an implementation agency under the Cape Action plan for People and the Environment (CAPE) that wishes to stimulate a green economy on the Agulhas plains, and has begun exploring options for bioenergy from IAPs. The CSIR team has engaged with the relevant stakeholders- Working for Water, Working for Energy, ABI, Landcare and farmers- to apply BIOSSAM for the assessment, management and monitoring of IAP to bioenergy interventions. The sustainability framework established the common vision of IAP eradication and beneficiation with the goals of increasing biodiversity, water availability, and job creation, while generating a valuable energy product from IAPs. Based upon available technology and processes, scenarios were developed that represented the various possibilities that can generate a range of bioenergy products such as electricity, heat, biogas, bioethanol, charcoal, syngas and synfuels. The application of the STBS identified combustion, slow pyrolysis and gasification as the most feasible technologies. The SURE-DSS was applied to explore if these options will make best use of the physical, financial, social, natural and human capitals of the area. The MCDA is planned for October 2010 where the final decision of the preferred IAP to bioenergy option for a defined locality will be made in participatory fashion. The preferred option will be modelled using System Dynamics to aid forecasting and policy-making that can improve the IAP to energy interventions.

4. CONCLUSIONS AND FUTURE DEVELOPMENTS

BIOSSAM is a portal that provides a strategic framework and associated tools for the assessment, monitoring and management of bioenergy interventions. BIOSSAM integrates systems thinking and a life cycle approach into a framework with associated tools to ensure that bioenergy interventions (policies, programmes, projects) are sustainable.

BIOSSAM can be effectively used to:

- Establish sustainability indicators that are used to ensure that the bioenergy policy, project or programme achieves defined sustainability goals.
- Screen bioenergy options for sustainability based on technical, economic, social, environmental and governance criteria.
- Implement the appropriate bioenergy interventions in an integrated manner.
- Monitor the bioenergy policies, projects or programmes to ensure sustainable adoption, operation and management.

BIOSSAM offers a participatory and transparent process to decision-making that involves multi-stakeholder engagement coupled with expert and public opinion. This helps to ensure stakeholder buy-in as well as general trust brokering which facilitates the process of technology transfer and increases the long-term success of the bioenergy intervention.

BIOSSAM is currently being tested with a number of case studies in order to add rigour to the BIOSSAM approach and the web-portal is in active development. Current case studies include energy from invasive alien plants (IAPs), biodiesel from canola, bioethanol from soya and improving the access of rural communities to modern energy carriers.

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Presenter

The paper is presented by William Stafford.