STEP-Bio Themes and Project Clusters

- **Theme 1: Risk-mitigation**

  These are projects that will mitigate risks associated with increased production of bioethanol and cogeneration that could have environmental and sustainability impacts if not addressed. They will also consider how so-called “waste” streams could be turned into revenue generating opportunities.

  - **Project Cluster 1.1: Minimisation and beneficiation of effluent (vinasse) from bioethanol production – PRIORITY 1**

    With the drive towards bioethanol production for biofuels, the problem of how to dispose of increasing quantities of the waste stream (vinasse) from the ethanol process after ethanol separation in a cost-effective and environmentally responsible manner will become increasingly important. It should be noted that the amount of vinasse produced is between 8 and 15 times the volume of ethanol produced. Typical properties of vinasse resulting from fermentation of South African sugarcane molasses are shown in Table 1. Such vinasse contains additional potential energy if converted to biogas (methane) by anaerobic digestion and also contains significant quantities of potassium that has substantial value as a fertiliser, most of which is currently imported.

**Table 1. Typical properties of vinasse from South African sugarcane molasses**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>4.66</td>
</tr>
<tr>
<td>COD</td>
<td>mg/ℓ</td>
<td>126 000</td>
</tr>
<tr>
<td>(\text{BOD}_5)</td>
<td>mg/ℓ</td>
<td>43 000</td>
</tr>
<tr>
<td>Total Solids</td>
<td>mg/ℓ</td>
<td>3 160</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>mg/ℓ</td>
<td>1 940</td>
</tr>
<tr>
<td>Phosphate</td>
<td>mg/ℓ</td>
<td>355 (as P)</td>
</tr>
</tbody>
</table>

However, there are considerable technical challenges with vinasse treatment, as the solution applied in many other cane-growing countries that produce bioethanol from sugarcane is to distribute the vinasse back to the cane fields with irrigation. For various technical and economic reasons, this is not a viable option in many parts of the South
African sugarcane growing region, and alternative solutions must be urgently sought. Although a number of technology vendors supply vinasse treatment equipment, the general view of the local industry is that none of these provide a satisfactory solution for various technical and economic reasons and that design of the vinasse management system is the bottleneck in design of new bioethanol-from-sugar-factory-streams production facilities. Furthermore, there may be opportunities for reducing the quantities of vinasse produced by removal of certain components from the fermentation feedstock. Such technologies may permit recovery of valuable components such as potassium at an earlier stage in the process and may also enhance the efficiency of the fermentation process.

NOTE: this is an existing SMRI research area and while the SMRI will take a lead role, collaboration and innovative approaches will be valued.

○ Project Cluster 1.2: Disposal or beneficiation of boiler ash – PRIORITY 3

At present, sugar factories burn mostly bagasse (the fibre residue left after extraction of sucrose from the sugarcane) and some coal to generate steam and electricity to power the process. The flue gases from the boilers are scrubbed to remove particulate emissions (soot and fly ash) and sulphur dioxide if coal is used to ensure emission regulations are adhered to. The water from the scrubbers is led mostly to settling dams where the soot and ash settle out, with the clean water being recovered for re-use. These dams gradually fill up with solid material and either they have to be dug out periodically and the solid material sent to land-fill, or new dams must be constructed. In either case, a more sustainable long-term solution to disposal needs to be found, particularly as the situation is likely to be exacerbated with the potential increase in power generation for co-generation by means of increasing biomass availability from leaf matter previously burnt or left in the field. Ideas are sought to either reduce the quantity of material that needs to be dealt with or to beneficiate the ash to generate additional revenue.

Although this issue may not be as urgent or of high a risk as the vinasse project, it will need to be addressed at some time in the future, as at least one South African factory has already had to take urgent action to address capacity shortage in its ash dam.

• Theme 2: Enabling of Opportunities

Within this theme opportunities will be researched that have the potential to boost industry profitability, but which, if not addressed, do not pose a clear risk, other than the omnipresent issue of economic sustainability.

○ Project Cluster 2.1: Options for biomass off-crop storage – PRIORITY 1

The return on investment for new capital equipment for co-generation or bio-ethanol is significantly improved when the plant can run throughout the year; the average sugarcane processing facility produces fuel for energy in the form of bagasse during the
crushing season (typically nine months), but not during the off-crop. However, excess bagasse or fibre that may be produced in excess of immediate requirements throughout the season is bulky, liable to decay and may be prone to spontaneous combustion. Hence, storage of such biomass in its natural form in the substantial quantities that would be required to sustain the plant through the off-crop presents a number of significant challenges.

To fully realise the potential benefits of year-round operation that can be made possible by improved energy efficiency and supply of additional biomass from the fields and also to deliver against agreed monthly supply targets it will be necessary to develop appropriate technologies for effective storage and recovery of the biomass. This could be in the form of pelletised compressed fibre or torrefied biochar or bio-oil, for example, but the materials handling issues and costs associated with such technologies would need to be properly investigated.


Although this project is listed under the “Opportunity” Theme, it may well be a risk area if the cogeneration power purchase agreement requires year-round power generation.

- **Project Cluster 2.2: Value addition to sucrose – PRIORITY 2**

  The South African sugar industry currently produces more sugar annually than is required to satisfy the domestic requirements; the remainder is exported either through long-term agreements or at world market prices. The volatility of the world market prices and the occasional flooding of the world market with imported cheap sugar at below production cost mean that the export revenue earned per ton of sugar is distinctly less than that earned from domestic sales. However, opportunities exist for the use of sucrose as a feedstock for the production of higher value chemicals/products (over and above fermentation to ethanol) that would earn more revenue than from exporting the sugar. Examples include production of intermediates for the manufacture of biopolymers and bulk pharmaceuticals. Raw sugar is a relatively pure source of sucrose and the use of such may lead to relatively simple and cheap processing routes. Alternatively, sucrose solutions from within the sugar factory could be used, avoiding the need for energy-intensive evaporation and crystallisation steps, reducing the potential feedstock cost.

  Part of the initial work required would be to investigate what opportunities exist for value addition in the South African context, including assessing opportunities that exist with regards to import replacements, and explore possible processing routes, such as biocatalysis, fermentations or chemical catalysis to higher value products. Such a study, which would form an initial phase of Project Cluster 3.3 (see below), would include, at an early stage, engaging with potential industrial buyers of such intermediate chemicals to understand the markets and value chains.
o  Project Cluster 2.3: Value addition to ethanol – PRIORITY 2

Although there is much current interest in the developing bioethanol market in South Africa, the main focus is clearly on the biofuel market. However, the market dynamics and pricing structure have not yet been fully resolved, despite the implementation of mandatory fuel blending being scheduled for October 2015. There are, in addition, a number of different feedstock sources other than sugarcane in the race for the biofuel market. Irrespective, ethanol for biofuel can be considered as an additional commodity, and there exists greater revenue potential in the conversion of ethanol to higher value chemical intermediates for use in biopolymer production, for example.

Similarly to Project Cluster 2.2, a study, which would form an initial phase of Project Cluster 3.3 (see below), should be undertaken to investigate what potential opportunities exist for conversion of ethanol to higher value chemicals in the South African context and explore possible processing routes, such as biocatalysis or chemical catalysis to higher value products. Such a study would include, at an early stage, engaging with potential industrial buyers of such intermediate chemicals to understand the markets and value chains.

•  Theme 3: Strategic and decision-support projects

The projects within this theme are intended to assist with providing information for decision-making purposes primarily to provide direction for further research efforts so as to be able to maximise the opportunities available in the medium term. A considerable amount of work in the directions outlined in Project Clusters 3.1 and 3.2 has been undertaken already, but much of this is not co-ordinated and not readily accessible by researchers and factory personnel. It is foreseen that the development of widely available decision support tools would be a desired outcome of these projects.

o  Project Cluster 3.1: The techno-economics of sugar, ethanol and cogeneration in South Africa – PRIORITY 1

Although mass and energy balance models with some economic data are available for sugar, and work has been undertaken by the industry in terms of developing economic models for bioethanol production and for cogeneration, it is believed that the need exists for an integrated model that can be used to assess the optimum combination of these products and new products to be developed under a range of likely scenarios, including sensitivity analyses for various key indicators. This project would seek to integrate the available data and modelling work done to date in a common platform that could be further developed into appropriate decision support tools that could be used by researchers to identify future opportunities for improving the viability of the sugarcane biorefinery when further products based on ethanol and/or sugar are developed, as these could alter the factories’ energy balances.

NOTE: this is an existing SMRI project and while the SMRI will take a lead role, collaboration and innovative approaches will be valued.
**Project Cluster 3.2: Optimising energy efficiency and integration in South African sugar mills – PRIORITY 1**

Until fairly recently, sugar factories have needed to be “energy sufficient”, that is, they are set up to achieve a balance between the energy available in the sugarcane bagasse and the energy required to run the factory. However, with the greater likelihood of being able to generate additional revenue initially through electricity cogeneration, there will be an increasing focus on improving the energy efficiency of sugar factories so as to maximise the amount of energy available for sale.

This project could consider a number of related aspects, including:

1. development of a benchmarking protocol so as to allow factories to identify best practice and where opportunities might exist for improving energy efficiency;
2. development of mass and energy balance models that are flexible enough to be able to explore the economic effects of different process configurations (including the addition of ethanol distilleries and cogeneration facilities) and the installation of new equipment to enhance energy efficiency, and;
3. exploration of the potential for radical change in the approach to energy transfer and management in sugar factories, such as using different heat transfer fluids (other than water and steam) and refrigeration cycles.

NOTE: this is an existing SMRI research area and while the SMRI is likely to take a lead role, collaboration and innovative approaches will be valued.

**Project Cluster 3.3: Study of local market opportunities for bio-based chemicals from sugarcane – PRIORITY 2**

It is clearly evident from interactions with experts in the field of biorefining and bio-based chemical development both within South Africa and internationally that when considering the development of new value-added bio-based products, there needs to be a clear focus on market demand, rather than looking at what can be made from the biomass, i.e. market pull rather than technology push. It is also clear that industrial buyers of intermediate chemicals from bio-based sources are unlikely to pay higher prices for such chemicals and that these chemicals would preferably have to be of higher quality than, and ready substitutes for, existing chemical feedstocks. This is particularly the case in the biopolymer market, where polymer processors would be unwilling to source alternative feedstocks that have different functional characteristics to those they currently use as this would mean expensive changes to their processes and equipment.

Accordingly, there is a clear need to undertake a number of focussed market studies with large multinational companies, preferably with a South African presence, to identify what bio-based chemicals they would be interested in sourcing from the local sugarcane industry if such chemicals were to be made, what the market size and economics might be and what key physical and chemical characteristics would be
desired. Based on such information, research projects could then be funded to develop the technical pathways and processing routes for manufacturing such chemicals from sugarcane feedstocks in a cost-competitive and economically-viable means. This Project Cluster should initially consider value-addition opportunities for sugar and ethanol so as to provide insight and direction to Project Clusters 2.2 and 2.3.

A survey of opportunities for value-addition in the South African sugarcane industry was undertaken by Walford and Morel du Boil in 2006 (http://www.sasta.co.za/wp-content/uploads/Proceedings/2000s/2006_Walford_a%20survey%20of%20value%20addition.pdf), but this is a rapidly developing area worldwide and some of the technologies then being researched are now being commercialised.