

## SAN CARLOS ‘SUGAR CANE TO BIO-ENERGY—A SUCCESS STORY’

By

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### Abstract

THE FIRST commercial scale sugarcane to bio- energy (i.e. fuel ethanol and grid connected cogeneration) plant in Philippines commenced successful operation in January 2009. The integrated facility was set up by San Carlos Bio-energy Inc. (a joint venture of Bronzeoak Clean Energy Inc, United Kingdom) near San Carlos on Negros Occidental Island, Philippines. The technologies have been provided by Indian companies, ISGEC John Thompson (IJT) for the complete plant and KBK Chem-Engineering for ethanol. The facility comprises a raw syrup plant using state of the art energy efficient juice extraction, clarification and evaporation plant followed by fermentation, distillation and dehydration for production of fuel ethanol. After concentration of the vinasse, 75% is used for dilution of syrup and the balance 25%, along with the filter-cake, is used for bio-composting for organic fertiliser which results in zero effluent discharge. The Co-generation plant comprises an 8 MW extraction-cum-condensing turbo generating set and a 45 TPH, 67 kg/cm<sup>2</sup> (g) travelling grate single pass water tube IJT make boiler suitable for firing a wide variety of biomass, mainly bagasse, woodchips, eco-friendly cane trash and bio gas to facilitate year round cogeneration. The total process steam consumption for production of fuel ethanol is 350 kg/tonne of cane. The plant has achieved 110% capacity utilisation with all the efficiency parameters in the second month of the trial season. The plant is meeting World Bank standards of stack emissions through an electrostatic precipitator and zero effluent discharge through bio-composting of the vinasse. The plant is fully automated through a DCS-based control system with facility for remote operations. The surplus power export to grid is 60 kWh/tonne cane. This opens up a new avenue in the South East Asian region for profitable production of green energy.

### Introduction

These days with increasing demand for fuel, ethanol blended with gasoline is the most widely used alternative fuel.

Replacing some petroleum use with renewable biomass resources and electricity is appealing but the approach brings with it important questions:

1. What is the best use of limited biomass resources?
2. How to replace litres of gasoline use in a timely fashion, maximising the greenhouse gas emission reductions and accounting for energy security issues?
3. Can we achieve these goals without reaching technology limits?

Here is the answer and following benefits of converting sugarcane to bio-energy:

- Insulation from fluctuation of fossil fuel prices in the world market.
- Utilisation of alternative, clean and renewable fuels for energy without compromising food security.
- Promotion of countryside development and rural employment.
- Mitigation of toxic and greenhouse gas (GHG) emissions.

In view of examining ways to abate gasoline consumption by adopting alternative fuels and shifting of energy to the electricity grid, ISGEC John Thompson, INDIA, an EPC group has emerged with integrated sugarcane to ethanol plant including cogeneration of power.

Building on prior experience in the field of sugar machinery and ethanol, ISGEC John Thompson along with KBK were involved to design, develop, construct, erect and commission an integrated sugarcane to ethanol complex including power cogeneration at San Carlos Bioenergy Inc. in the Philippines near San Carlos on Negros Island (Figure 1.)

The plant is designed to produce 125 000 litres/day of anhydrous ethanol directly from cane juice with 8 MW power generation and it emits 50 tonnes per day carbon dioxide.

An anaerobic digestion plant with integrated waste treatment plant is installed to minimise the liquid and solid discharge from the plant.

The complete concept of design engineering, erection and commissioning of the plant is described in this paper.



Fig. 1—San Carlos Bio-energy Inc., Philippines ‘Powering the Future’.

## Concept of plant design

### Energy security

The plant is fueled entirely by indigenous biomass resources, particularly bagasse and eco-friendly cane trash and wood chips.

The ethanol plant is designed to produce 125 000 litres of anhydrous fuel grade ethanol per day and 30 million litres annually. 8 MW of energy will be produced through cogeneration, with approximately 4 MW available for export.

### Environment

The ethanol plant conforms to World Bank emission standards. No NO<sub>x</sub> and SO<sub>x</sub> will be emitted. All liquid discharge is reused for the plant’s cooling systems and irrigation. Solids on the other hand are recycled as organic fertiliser.

Biogas produced and captured per day is utilised as additional fuel to the boiler.

### Agro economy

Farmers cultivating biofuel feedstock, cane, will have a ready and viable market and will progressively increase their income. This facility provides numerous farm services and plant site employment opportunities. Stable energy supply in the area will encourage further agro-industrial development, resulting in improved socio-economic status of the local communities.

### Main components of the plant

To meet local and international environmental and technical standards, the following are the main components of the plant:

- Cane handling and milling.
- Juice clarification and evaporation.
- Fuel ethanol Plant.
- Cogeneration plant.
- Carbon dioxide recovery plant.
- Anaerobic digestion plant.
- Integrated waste treatment.
- Bio-composting.

### Flow processes

The flow processes and functions of the integrated bio-ethanol plant are described below.

Cane crushed through mills driven by energy efficient shaft mounted hydraulic drives (Figure 2).



Fig. 2—Juice extraction milling plant with shaft mounted hydraulic drive.

The juice is clarified through a defecation process.

Juice Evaporation to 40<sup>0</sup> Bx in a state of the art fully-automated multi-effect evaporator station with all waste heat recovery system, condensate flash recovery for minimum steam consumption which is only 180 – 200 kg/tonne cane for raw syrup production to facilitate more power export (Figure 3).



Fig.3—Five effect evaporator set.

### **Ethanol production from raw syrup.**

The ethanol plant comprises three distinct stages: fermentation, distillation and dehydration. Syrup received from the raw syrup plant is diluted and fed to the fermentor for continuous fermentation (Figure 4).

In addition to production of relatively low alcohol feed to the distilling stage, fermentation results in the generation of carbon dioxide. This is a potential saleable byproduct for use in food and beverage industries. A CO<sub>2</sub> capture plant is installed.



Fig.4—Ethanol plant.

The distillation plant is designed to operate under vacuum and use low-pressure steam from the cogeneration plant. Preheated fermented wash is fed at the top of the distillation columns. As the wash descends, vapours containing alcohol are separated.

Up to and about 75% of the spent wash is re-circulated to the fermentation plant in order to dilute the incoming cane syrup with the balance directed to the effluent treatment plant. This approach reduces both raw water requirement and the resulting less effluent produced. However, it does increase effluent COD/BOD (chemical oxygen demand / biological oxygen demand).

Leaving the distillation stage, the separated alcohol vapours are sent to the dehydration stage where desiccant beds are used to remove residual water. The plant will have two 100% beds with one bed operating while the other is regenerated by steam from the cogeneration plant. Dehydration will result in ethanol with a concentration of 99.85%. Before leaving the plant, ethanol will be denatured.

It's the responsibility of ethanol purchasers to blend the ethanol with gasoline to E5 or E10 grade before commercial sale at gasoline stations for common use in the Philippines.

The ethanol plant typically results in a high COD and BOD effluent. In view of modern practice, the first stage in treatment of effluent at SCBI is by anaerobic digestion. This substantially reduces COD/BOD with production of biogas, which is used as a supplementary fuel for the boiler.

Following anaerobic treatment, the effluent is directed to a membrane filtering system for separation into a permeate stream (low COD/BOD) and a concentrated stream (high COD/BOD) stream.

The SCBI design incorporates recycling of the permeate (relatively clean) stream within the facility. The main part of the concentrate stream will be used to aid bio-composting of the residual filter cake from the raw syrup plant to which boiler ash and anaerobic digestion solids are added. The resulting bio-compost will be returned to the fields for soil nourishment as organic fertiliser. In addition, any surplus liquid concentrate that is not used for composting will also be disposed by spraying onto cane fields.

### **Cogeneration**

The cogeneration boiler is sized at 45 tonne/h and produces steam at  $67 \text{ kg/cm}^2$  (g) and  $480 \pm 5^\circ\text{C}$ . This steam drives an extracting-cum-condensing steam turbine to produce electricity, for in house consumption and facility for exporting surplus power (Figure 5). From an energy perspective, the plant is designed to be self-sufficient using bagasse from the mill and biogas from the anaerobic digestion plant. For longer operation wood chips can also be used.



Fig. 5—Cogeneration plant.

Depending on the availability of sugarcane, SCBI's operations will fall into two distinct modes a) the on-season mode, the period when sugarcane is harvested and available for processing, b) the off-season mode, the period when no sugarcane is available. During on-season mode, the cane mill, raw syrup plant, ethanol plant and cogeneration plant with all associated services will be in operation. During the off-season mode, plant operations are limited to that of the cogeneration plant and associated services.

Over the course of a year, the plant will process over 450 000 tonnes of cane while producing 39 million litres/year of ethanol. The cogeneration plant will generate 7.5/8 MW during the on-season mode, allowing about 3.5/4 MW for export to grid. During the off-season, the cogeneration plant is predicted to increase export to 4 MW due to lower on-site consumption. Plant operation parameters are as follows:

Annual cane throughput (tonnes)	450	000.
Daily ethanol production (liters)		125 000.
Ethanol purity (% v/v) min		99.85%.
Annual ethanol production (liters)	39	million.
On season power generation	7.5/8	MW.
Off season power generation	5/5.5	MW.

Contract risks have been mitigated by the appointment of international consulting engineers, to manage the procurement and construction process during post-financial close project execution.

This company is registered as a CDM (Clean Development Mechanism) project and will earn additional revenue from the sale of CERs (carbon credits). These should accrue from four sources, a) displaced fossil generated electricity, b) displaced vehicle use of gasoline, c) methane captured by anaerobic digestion process, d) carbon dioxide captured and sold for commercial use. At the time of writing, the CDM process has received approval for source (a). The other sources are the subject of ongoing discussions and decisions by the UNFCCC (United Nations Framework Convention on Climate Change) methodology panel.

Since the cogeneration plant uses only biomass, only very low sulfur dioxide emissions will occur. The main control is for particulates using electrostatic precipitators. The design of the ethanol plant effluent treatment was both a technical and commercial challenge in terms of achieving the low standard for the final effluent quality and in terms of finding a cost optimised approach. The final solution results in zero effluent discharge to surface water by a combination of recycling, bio-composting and limited use of liquid effluent as a soil nutrient.

## L'UNITE DE SAN CARLOS AU PHILIPPINES 'DE LA CANNE À SUCRE À LA BIO-ÉNERGIE: UNE RÉUSSITE'

Par

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**MOTS-CLÉS: Bio-Énergie, Biocarburant Éthanol,  
Cogénération, Biomasse, Élimination de Rejet.**

### Résumé

LE PREMIER complex industriel commercial à succès de la canne à sucre à la bio-énergie (c'est-à-dire bioéthanol et cogénération de l'électricité à la grille nationale), au Philippines a été mis en opération en janvier 2009. Cet ensemble industriel intégrée a été instituée par la San Carlos Bio-energy Inc. (une subsidiaire de Bronzeoak Clean Energy Inc, Royaume-Uni) près de San Carlos sur l'île de Negros Occidental, aux Philippines. Les technologies ont été fournies par les sociétés indiennes ISGEC John Thompson (IJT) pour l'ensemble industriel et KBK Chem-Engineering pour l'éthanol. L'installation comprend une unité pour produire du sirop à l'état brut à l'aide des technologies les plus avancées en matière d'efficacité d'énergie pour l'extraction, la clarification et l'évaporation suivie de la fermentation, de la distillation et la déshydratation pour la production de bioéthanol. Après la concentration du effluents, 75% est utilisé pour la dilution de sirop et la balance de 25% en mélange avec les écumes, est utilisé pour produire des engrais organiques par bio-compostage, ce qui se traduit par une absence complète de production d'effluents. L'unité de co-génération comprend un turbo alternateur extraction-cum-condensation de 8 MW et une chaudière à grille simple IJT de 45 TPH, 67 kg/cm<sup>2</sup> (g) pouvant être utilisée pour une grande variété de types de biomasse, principalement la bagasse de canne à sucre, des copeaux de bois, la paille de canne écologique et du biogaz qui permettent la cogénération pendant toute l'année. La consommation totale de vapeur pour la production de bioéthanol est de 350 kg/tonne de canne à sucre. L'ensemble industriel a atteint 110% de sa capacité tenant compte de tous les paramètres d'efficacité, au cours du deuxième mois de la saison d'essai. Le complexe industriel satisfait les normes de la Banque Mondiale pour les émissions à travers l'utilisation d'un filtre électrostatique et l'élimination totale des effluents par bio-compostage. L'ensemble industriel est entièrement automatisé par le biais d'un système de contrôle digitalisé (DCS) avec facilité pour des opérations de contrôle à distance. L'exportation du surplus de électricité à la grille est de 60 kWh par tonne de canne. Cela ouvre une nouvelle avenue pour une production d'énergie verte rentable dans le Sud-est Asiatique.

## SAN CARLOS ‘CAÑA DE AZÚCAR A LA HISTORIA DE ÉXITO DE LA BIOENERGÍA’

Por

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**PALABRAS CLAVE: Bioenergía, Etanol Combustible, Cogeneración, Biomasa, Cero Descargas.**

### Resumen

LA PRIMERA planta a escala industrial en Filipinas para bioenergía (i.e. etanol combustible y cogeneración conectada a la red pública) comenzó su exitosa operación en Enero del 2009. La instalación integrada fue establecida por San Carlos Bio-energy Inc. (una inversión conjunta de Bronzeoak Clean Energy Inc., United Kingdom) cerca de San Carlos en la Isla Negros Occidentales, Filipinas. La tecnología fue suministrada por compañías indias, ISGEC John Thompson (IJT) para la planta completa y KBK Chemical-Engineering para etanol. La instalación comprende una planta de sirope azucarado crudo empleando tecnología de “Estado del Arte” en cuanto a eficiencia energética para la extracción del jugo, clarificación y evaporación, seguida de fermentación, destilación y deshidratación para la producción de etanol combustible. Posterior a la concentración del vinasse, 75% se emplea para la dilución del sirope y el balance del 25% restante con la torta de los filtros, se utiliza para el biocompostado para fertilizante orgánico, lo que resulta en una emisión cero de efluentes. La planta de cogeneración comprende un generador de extracción-condensación de 8 MW de capacidad y 45 TPH, 67 kg/cm<sup>2</sup> (g), parrilla móvil, tubos de agua IJT de un pase, hacen que la caldera sea capaz de combustionar una amplia variedad de biomasa, principalmente bagazo, astillas de madera, residuos cañeros ecoamigables y biogas, todo para facilitar la cogeneración todo el año. El consumo total de vapor para la producción de etanol combustible es de 350 kg/t de caña. La planta ha alcanzado una utilización de 110% de su capacidad, con todos los parámetros de eficiencia en su segundo mes de la campaña azucarera de prueba. La planta también satisface los estándares de emisión del Banco Mundial mediante un precipitador electrostático y cero descarga de efluentes por la biocompostación de las vinazas. La planta está totalmente automatizada mediante un sistema de control DCS con facilidades para la operación remota. La energía excedente exportada a la red pública, es 60 kWh/t de caña. Esto abre una nueva avenida en la región del sudeste de Asia para la producción rentable de energía verde.