LARGE-SCALE INTEGRATION OF BIOENERGY WITH PETROCHEMICAL COMPLEXES

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OVERVIEW

Modern bioenergy is expected to make a significant contribution to the world's sustainable development. It will be used mainly in the heating/cooling, co-generation and transport sector. The EC aims at increasing biomass supply from the current level of 45 MTOE/y to 130 MTOE/y by year 2010.

Bio-fuels such as bio-ethanol, bio-methanol, bio-syngas and bio-hydrogen can make considerable contribution to the improvement of environmental conditions in congested urban areas. Furthermore, such fuels can help improve the quality of conventional fuels for the strategic transport sector by means of blending, reformulation and substitution. This paper is to summarise the main characteristics of a large-scale bio-energy project, which could be integrated with petrochemical complex. Data on the economic performance of the project is also presented.

In 1997, EUBIA initiated an extensive study to identify large-scale integrated energy complexes that are able to provide a wide range of products and that are economically feasible and sound. The study result indicated that a large-scale bio-energy complex based on sweet sorghum could represent an attractive investment opportunity. The study showed that the sale of grains could recoup a large proportion of the initial investments. Even if the selling prices of by-products such as sugar and lignocellulosic bagasse are very low, such a complex could still bring farmers considerable income.

Given low costs of sugar and lignocellulosic feedstock, the complex could also produce commodities with high value added, such as power, heat and paper, as well as strategic fuels like bio-ethanol, bio-methanol, bio-hydrogen and bio-syngas. Relevant commercial technologies are already available in EU and only modest adaptation is necessary.

Large-scale plantation of sweet sorghum in an area of 80,000 ha, located in the Pearl River Delta of Guangdong province, China, as proposed in the framework for EU-China industrial cooperation, could provide sufficient feedstock for

1. Co-generation: 50 MWe using 270,000 tons of bagasse pellets per year
2. Bio-ethanol (de-hydrated): 660,000 m^3 per year from sugar juice
3. CO_2 recovery (high purity): 510,000 tons per year, used for bio-methanol synthesis
4. Bio-hydrogen: 71,000 tons per year, by means of steam reforming of charcoal pellets and CO shifting from 1.4 million tons of pellets per year
5. Activated coal: 36,000 t/y from charcoal pellets obtained from 300,000 t/y of pellets
6. Bio-methanol: 460,000 m^3 /y from catalytic synthesis of CO_2 and H_2
7. Animal feed pellets (mixture of sweet sorghum grains + 30% of bagasse): 1,160,000 t/y

LARGE-SCALE INTEGRATED INDUSTRIAL COMPLEX

Sweet sorghum is a very promising energy crop with high yields of grains, sugar and bagasse. Sweet sorghum is preferable because it could be a very competitive energy crop. With some special varieties, it is estimated that the sale of grains alone (yield of 5-8 t/ha) can cover nearly all the cost of crop production ($400/ha in China and $800/ha in EU). The other products of the complex, sugar and lignocellulosic bagasse could bring in surplus income of around $200/ha to farmers, given modest estimation of selling prices of there two commodities ($30-50/t for sugar and $10-15/dry t for the bagasse).

To produce bio-ethanol from sweet sorghum seems to be most profitable and promising and the justification is as follows:

- Sweet sorghum can be grown almost anywhere, in temperate and tropical regions as well as on low-quality soils, hence, it can be a valuable crop for all continents.
- Sweet sorghum is a C-4, with short growing period (4-5 months) and high yield, multi-component crop (starch, sugar and lignocellulosics).
- Sweet sorghum demands little inputs of water and fertilizer. For the whole growing period, it requires 1/3 of the water necessary for sugar cane and half of that for corn.
- Plantation of sweet sorghum requires small amount of seeds. The seeds needed for sweet sorghum is 10 kg/ha, while those for corn are 40 kg/ha and for wheat, 150 kg/ha.
- An integrated complex based on sweet sorghum could produce a number of valuable products in the fields of food, animal feed and energy, for instance, grains-sugar, grains-leaves-bagasse, power-heat-bioethanol-charcoal, etc.
- The ratios of energy output to input are positive (2-4), for the production process to obtain bio-ethanol, DDG, co-generation fuels and biofuels.

According to preliminary estimation, the integrated bioenergy complex based on exploiting sweet sorghum to produce bio-ethanol and other energy and industrial commodities, could be economically viable. This could be a new path to sustainable production of bio-ethanol, which is considered to be strategic fuels for transport sector. The success of such a bioenergy project in China could be replicated worldwide. Previous studies and trials have shown that such a project could be economically sound in regions with different climate.

Such an integrated complex, if implemented on a large-scale (or broken into series of small-scale complexes) could keep the production costs of ethanol as a by-product at a reasonable level of $200-250/t. It is particularly advisable to utilise some special varieties of sweet sorghum to get the optimal results. Almost all parts of sweet sorghum can be commercially processed, for example, starch, sugar and lignocellulosic. This distinguish sweet sorghum from other crops that are currently utilised for producing bio-ethanol.

Sweet sorghum has its origin in China. Today there exists many varieties of this crop. By utilising sweet sorghum of different varieties, an integrated bioenergy complex could obtain various yields of grains, sugars and bagasse. In tropical regions, sweet sorghum could be planted twice a year, which would further increase the economic performance of such an integrated complex.

One point worth attention in ethanol production is that harvesting and juice extraction and fermentation should be done as quickly as possible, to reduce sugar losses. The maximum harvest time for sweet sorghum is two months. The total running time of a bioethanol plant can be maximised (8-10 months) by means of selecting particular varieties of sweet sorghum and delaying and alternating the seeding process in tropical regions, which could also reduce operating costs considerably. For the Chinese integrated complex examined in this paper, two plantations are planned for each year.

The general scheme of the integrated industrial complex to be built in Guangdong province, China is illustrated in Figure I and the sites for sweet sorghum plantation and for the integrated bioenergy complex are shown in Figure II.

The preliminary estimation of the economic performance of the integrated complex in Guangdong province is as follows:

Investment (EU tech)	**Operating Costs**	**Income**
Cane crushing: 40 Bioethanol plant: $460 mio CO2 recovery: $20 mio Pelletisation: $80 mio Power plant: $71 mio Activated coal: $55 mio Biomethanol: $360 mio Total: $1,086 mio	Financial costs: $103 mio/y (i = 5%, no. of years = 15) Operating cost: $43 mio/y (4% of investment) Maintenance: $22 mio/y (2% of investment) Plantation: $98 mio/y Total: $266 mio/y	Bioethanol: $198 mio/y Biomethanol: $77 mio/y Animal feed: $116 mio/y Activated coal: $47 mio/y Sale of pellets: $23 mio/y Total: $461 mio/y

Profit
Income: $461 mio/y Expenses: $266 mio/y Revenue: $195 mio/y ROI: 18%

The estimated ROI of such a project is 18%, which is based on the assumption of adopting EU technology. All the amounts of investment and expenses are comparable at EU level. Given China's less expensive manufacturing facilities and cheap labour, the investment for a Chinese project could be considerably reduced. Accordingly, the ROI could be increased to about 25%.

CONCLUSION

Sweet sorghum of special varieties is very promising energy crop. It can be used to produce large amounts of liquid biofuels such as bioethanol, biomethanol and biohydrogen. An integrated complex based on sweet sorghum in tropical regions could be very profitable.

In Guangdong province, China, sweet sorghum can be planted twice a year and by selecting specific varieties, delaying the seeding process and intercropping, a long operating period for the complex can be achieved. The production costs of bioethanol and biomethanol are estimated to be $250/t and $210/t respectively. The yield of biofuel there is expected to be 13.8 m^3 /ha per year.

Figure I
Concept of Biofuels Industrial Complex in Guangdong Province
(BIOETHANOL-BIOMETHANOL)

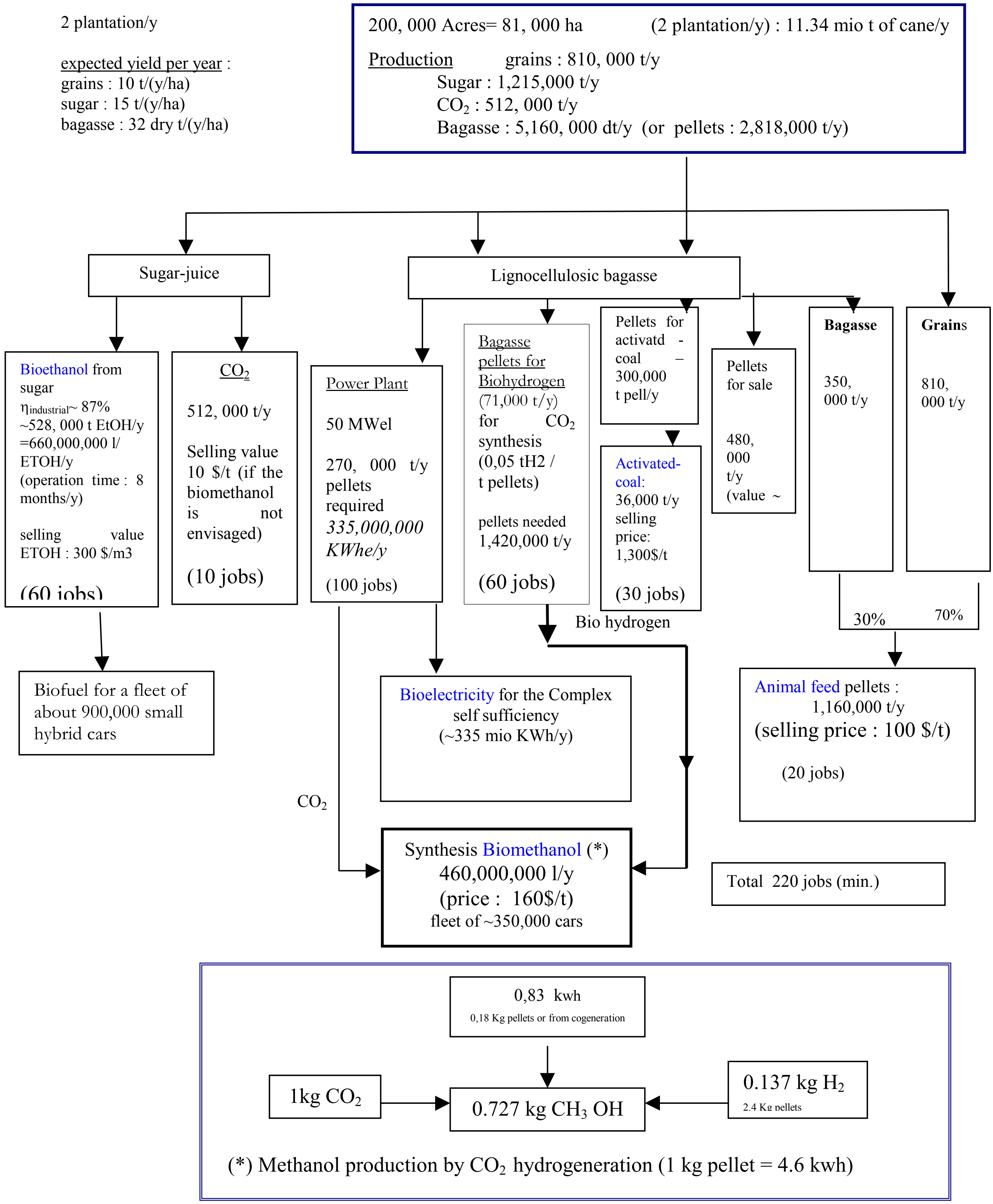

Figure II
Sites for plantation and integrated complex

Figure III

Bioenergy competitiveness against conventional Energy