ECHI-T

Large Bio-ethanol Project from Sweet Sorghum in P.R.China and Italy

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Foreword

The European Biomass Industry Association (EUBIA) in 1998 started the development of new concepts for a diversified industrial strategy on bio-energy. This strategy, focused on viable economic perspectives, aims at addressing problems typical of modern societies and communities, like:

- **poverty** and socio-economic exclusion of rural population living in remote areas;
- **quality of the environment and air pollution**, especially in congested urban districts;
- **green-house** effect;
- **unemployment**, especially in rural areas;
- **security and diversification** of energy supply and promotion of industrial competitiveness;
- insufficient technological / business oriented **co-operation**.

So far, some very challenging industrial bio-energy projects have been identified, which fit well inside this EUBIA mission: the ECHI-T project represents a simplified version of likely future large industrial complexes.

The novelty introduced by these integrated bioenergy complexes, as the ECHI-T, is represented by

- The future utilisation of specific high-yield dedicated energy-crops (such as Sweet Sorghum) rather then well-known food crops (corn, sugar beet, wheat)
- The adoption, if possible, of inter-cropping and crop rotation to improve the economic and environmental results
- The complete utilisation of the crop in its various components (sugar, starch, lignocellulosic, etc) to produce simultaneously several biofuels and industrial commodities. In this way the Integrated Complex will be more sustainable from the economic point of view and less sensitive to fluctuation of markets. In the case of Sweet Sorghum crop 10 or more products could be obtained.

This type of projects will be needed in the future, both in Developed as well as in Developing Countries. In fact,

- Targets on greenhouse gas emission reduction have been defined for Europe in the Kyoto Protocol: these targets are becoming commitments after the World Summit on Sustainable Development in Johannesburg. It is expected that a large scale deployment of bioenergy will take place, especially in the strategic sector of transport fuel. The industrial community should be aware and ready to deal with these ambitious targets and the long-term learning period.
- Developing Countries are facing a very fast industrialisation and urbanisation, as well as transition (in most cases) to market economies, which generates social stresses and serious impacts on the quality of life, and affects the environment. However, the issue of sustainable development of these countries having lack of technology and, at the same time, abundant biomass resources, offers an unique opportunity to adopt modern bio-energy systems at large scale. This should be a goal of the industrial developed world and a main interest of the Developing Countries.

Based on these considerations, and taking into account the large biomass potential available all over the world, EUBIA, in collaboration with its Members, is making a wide effort focused on:

- bio-energy activities at small, medium and large scale, in collaboration with National Governments and Local Authorities, agricultural organisation, local partners and industries.
- modern, efficient, sustainable and commercial bio-energy schemes adapted at specific local situations.
- international co-operation and education in bio-energy

In this framework, several sectors of industrial activities were identified, such as bio-energy and commercial technologies for rural development, industrial bio-energy plants (for power/heat, bio-ethanol/bio-methanol, syngas/hydrogen production), and integrated Biomass Complexes at small and very large-scale. A strategy to use bio-ethanol and bio-methanol in secondary/niche market transport applications has also been developed, which considers the production of small ecological hybrid-cars fed with these bio-fuels.

All these schemes are eligible for financial support measures, such as carbon trading mechanisms (Joint Implementation and Clean Development Mechanism), in Europe and in the frame of co-operation programmes between Europe and Third Countries, as P.R.China.

At present, EUBIA is planning - in collaboration with the P.R.China Central Government and with 3 autonomous Province Authorities - very advanced large scale project based on Sweet-Sorghum plantations for the production of bio-hydrogen (70,000 t/y) and 1 billion litre/year of liquid bio-fuel for a fleet of small hybrid-cars. This project could constitute a model to be replicated in other Regions of the P.R.China. Potential partners for Joint-Ventures are under identification, among which the Brazilian bio-ethanol industry could play an important role for bioethanol.

Promotion by EUBIA of similar bioenergy activities is being carried out for 3 of the 5 Central Asia Countries.

EUBIA and its members, promoting this type of integrated projects in Europe and abroad, will contribute to the effort of demonstrating that bio-energy can provide a significant contribution to a more sustainable energy-mix and better environmental conditions for the future generations.

Giuliano Grassi
EUBIA

David Chiaramonti
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ECHI-T - LARGE BIO-ETHANOL PROJECT FROM SWEET SORGHUM IN P.R.CHINA AND ITALY

1. Introduction: the ECHI-T project

Renewable energy from biomass (bio-energy) is regarded as a key element for the future sustainable energy mix. It is widely agreed that bio-energy could provide a significant contribution to the Kyoto Protocol commitments that the Europe is determined to fulfil: currently its potential is estimated at ~200 MTOE/year (maybe ~400 MTOE/year in the longer run).

Today, the heat-market is probably the most developed one, mainly in Northern and Central Europe. The prospect is bright for biomass resources (in particular energy crops) to penetrate the power generation and the transport markets.
Nevertheless, it is necessary to demonstrate the economic viability of such projects before large-scale deployment: in this respect, ECHI-T can serve as an example.

The ECHI-T project aims at demonstrating the feasibility of Sweet Sorghum cultivation for the renewable and sustainable production of transport fuels (bio-ethanol, and even hydrogen and methanol), energy (electricity and heat) and other products (such as animal feed, pulp for paper, charcoal, activated coal, etc.) in Europe and abroad. Integrated Sweet Sorghum complexes can actually contribute to the achievements of the following European Member States policies and goals:

- **Renewable energy production at competitive cost.** Sweet Sorghum can be used to produce various competitive products for the transport (bio-ethanol from Sweet Sorghum sugar juice and grains), electricity and heat markets (from Sweet Sorghum bagasse), which can support European Member States in achieving its Kyoto Protocol commitment in terms of reducing greenhouse gas emissions.
- **Diversification of energy supply.** As a non-fossil energy source, the comprehensive utilisation of Sweet Sorghum can help Europe to reduce its dependency on fossil fuels.
- **Vegetal protein production.** Sweet Sorghum can possibly be useful for large-scale production of vegetal proteins Distillers' Dried Grains (DDGs), which is of great interest to Europe today due to the BSE problem.
- **New permanent job creation.** The plantation and processing of Sweet Sorghum can create new employment opportunities in both agricultural and industrial sectors.
- **Innovation and development of advanced technologies**. Processing of Sweet Sorghum can be done with existing commercial technologies, but the application of these technologies to Sweet Sorghum crop is very innovative. Furthermore, the integrated processing of an energy crop into several products with high added value (e.g. chemicals) has never been implemented so far. Should a Sweet Sorghum complex be put into operation, it would be the first one of that kind.

The project contributes to meet both the European and Chinese policy targets that aim at increasing the share of bio-ethanol fuel in the transport sector:

- The European Union aims at replacing 20% of the fossil energy in the transport sector by 2020 with renewable fuels.
- The proposal for a Directive of the European Parliament and of the Council on the promotion of the use of biofuels for transport. The proposal, currently under discussion, recommends that 2% of the gasoline and diesel fuels used in the transport sector should be replaced with biofuels by 2005. This amount should increase with 0.75% each year and reach 5.75% in 2010.
- China has recently (May 2001) set up a national standard for bio-ethanol fuel, aiming at the widespread use of bio-ethanol in the transport sector in 3 provinces (Henan, Heilongjiang, Jilin) in a pilot-project phase. The final goal is to achieve a share of 25-30% of bio-ethanol cars in 2-3 years. The two Chinese oil companies involved in the project (Kenli Oil Company in Dongying and PetroChina in Huhhot) indicated that their interest in bio-ethanol from Sweet Sorghum stems from this national policy.


by Tommaso Guicciardini

Finally, the ECHI-T project also aims at establishing more active co-operation between Europe and P.R.China since it could be of mutual benefit:

- Sweet Sorghum is a well known crop in P.R.China: in fact, P.R.China has extensive experience in the development, cultivation and use of Sweet Sorghum. During the start-up phase P.R.China could transfer know-how and supply seeds to Europe.
- Europe has suitable and valuable commercial technologies for processing Sweet Sorghum, potential financial resources (if the project is economically viable) and potential interest in the implementation of Sweet Sorghum based complexes. European technologies could be exported to the Chinese market.

The establishment of a large industrial bio-energy complex in P.R.China, as the one under assessment in the ECHI-T project, could be beneficial for Europe to verify the viability of such schemes in a different context. Moreover, financial mechanisms on carbon trading (for example, the Joint Implementation) could be implemented in a joint Europe-P.R.China project.

2. The three sites

2.1 Pisticci, Basilicata region (Italy)

The Basilicata region, located in the Southern part of Italy, is characterised by hilly areas of up to 2000 meters above the sea level, with access to the Ionio sea and the Tirreno Sea. The population density in the region is very low: 609,596 persons in 1995 on a total area of 9,992 km^2, i.e. 61 inhabitant per km^2, which is less than 1/3 of the national average. From the socio-economic point of view, although the agricultural sector is still the driving force of the regional economy, the urbanisation process is moving forward: towns and villages in the rural areas are facing sever migration problems. The per capita income in Basilicata is approximately 2/3 of the national average.

Various possible locations suitable for Sweet Sorghum cultivation have been examined by the project partners in consultation with local players. In particular, after several site visits and project missions, the Consorzio di Bonifica di Bradano e Metaponto (CBBM) has been identified as one of the most appropriate candidates for the ECHI-T project.

The district managed by CBBM is situated on the Ionian side of the Basilicata region: it includes the most productive agricultural land of the region, i.e. the valleys of the rivers Bradano, Basento, Calandrella-Cavone, Agri and Sinni as well as the hilly areas and plateaux amongst those valleys. It covers 260,777 ha, which have been divided into four main areas: Alto Bradano, Collina Materana, Basso Sinni, Arco Ionico. Most of the territory lies at less then 600 m above sea level.
The soils of the district fall into the following four main categories, according to the texture :

1. calcareous clay and calcareous silt
2. clay and clay silt
3. sandy clay and sandy clay silt
4. sandy, sandy silt and sandy calcareous

The type 1 soil represents 5% of the total surface managed by CBBM, type 2 and type 3, 25% each, and type 4 covers the remaining 45% of the total surface. Calcareous clay and calcareous silt soils are mainly concentrated in the inner regions (Alto Bradano and Collina Materana), while the clay and clay silt type are located in the areas of Collina Materana, Basso Sinni and Arco Ionico. The other types of soil are typical of any flat area in the district.

The soils fall into two categories according to their fertility: good fertility (soil type 2 and 3 - clay, clay silt, sandy clay and sandy clay silt) and medium-low fertility (soil type 1 and 4 - calcareous clay, calcareous silt, sandy, sandy silt and sandy calcareous).

The irrigated valley floor areas, where Sweet Sorghum cultivation can be introduced, are located on alluvial soils which contain a great amount of fine elements, and which can be categorised as type 3 and 4.
The total currently irrigated surface in the district is 55,372 ha: other additional 29,628 ha are planned to be irrigated in the short term.

Site	*Total farm area (ha)*	*Area that could be irrigated (ha)*	*Currently irrigated areas (ha)*	*Other areas planned for irrigation (ha)*
Alto Bradano	40,532	22,650	0	13,181
Collina Materana	107,776	21,200	6,729	13,483
Basso Sinni	36,251	16,280	8,035	2,344
Arco Ionico	66,600	44,300	40,608	620
TOTAL	251,159	104,430	55,372	29,628

Table 2.1 Status of irrigation in the areas managed by CBBM (source: CBBM)

Site	Cereal	Olive	Grapevine	Citrus	Fruit orchards	Leguminosae, Industrial crops and other crop	Vegetable	Fodder
Alto Bradano	32,810	516	677	0	12	769	145	962
Collina Materana	65,397	3,202	1,791	17	380	3,928	367	165,182
Basso Sinni	14,200	1,465	654	1,190	1,432	1,873	225	219,912
Arco Ionico	26,962	5,568	2,878	2,713	2,482	3,826	3,630	46,186
TOTAL	139,369	10,751	6,000	3,920	4,306	10,396	4,367	5,273

Table 2.2 Main products (source: CBBM)

The current use of the agricultural area controlled by CBBM is the following:

agricultural area	ha
forestry	29,364
suitable for sowing	159,405
fields and pastures	27,957
permanent cultivation (arboreal)	24,932
others (uncultivated, forestry, etc.)	9,279
TOTAL agricultural area	250,939

The Bradano-Metaponto region which has been studied for the project consists of 5 separate zones situated in the valleys between the two rivers. The total area of the region is approximately 22,250 ha.

Areas	Total surface (ha)
1 - Salandrella - Cavone	6,520
2 - Val Basento - Trincinaro	4,130
3 - Val Basento - Grassano	1,930
4 - San Giuliano	3,160
5 - Basentello	6,510
TOTAL	22,250

Table 2.3 Agricultural land studied for the project (source: CBBM)

From an administrative point of view, the region covers the territory of the 12 towns of the Matera Province: Bernalda, Ferrandina, Grassano, Grottole, Irsina, Matera, Miglionico, Montescaglioso, Pisticci, Pomarico, Calandra, San Mauro Forte.

As far as the climate in the region is concerned, two main zones can be distinguished within the CBBM district: an internal "Bradanica" (Alto Bradano and Colline Materane) zone and a coastal "Ionica" one (Basso Sinni and Arco Ionico). Climatic data are given in table 2.4.

Within this region, an area of 7,000 ha was selected for the project, located near the Municipality of Pisticci, where the industrial complex could be located (industrial area of Val Basento). These fields mainly lies in the valley floor areas with alluvial soil, have a good or high degree of fertility and are well equipped with irrigation infrastructure (a pipeline for pressure irrigation system is available). The water flow in the irrigation network varies from 1,300 to 3,700 l/sec, depending on the specific district under consideration.

The industrial area near Pisticci (Val Basento district) is managed by the "Consorzio per lo Sviluppo Industriale della Provincia di Matera" (Syndicate for the industrial development of the province of Matera, CSIPM), which is also known as ASI (Area Sviluppo Industriale - Industrial Development Area). The district covers a total of area of 300 ha: 150 ha are currently in use, 50 ha are already equipped and available, and an additional zone of 100 ha is to be equipped with infrastructure.

Within this industrial estate, "CSIPM" runs a 50 MWel multi-fuelled thermal electric co-generation unit (which will be increased to 70 MWel), currently fuelled by methane: its annual production is approximately 250,000,000 kWhel/y. A sewage disposal plant (serving 200,000 standard inhabitants), an air compression unit (300,000,000 m^3/year), a nitrogen production unit (10,000,000 m^3/year), a water production unit for industrial use (2,000,000 m^3/year), a 180 t/year unit for the production of superheated steam are also available. The district infrastructure is completed by a 6 km long inner railway system: additional services are provided by a specialized company (called TVB - Tecnoparco Val Basento spa). Companies in the area mainly belong to the chemical industry and to the biotechnological sector (SNIA, DOW).

Table 2.4 Climatic data (source: CBBM)

Area	Annual Precipitation (mm)	Temperature Range (°C)	Total water deficiency (mm)	Climate
Bradanica	671	5.7 - 24.1	Moderate (380)	Marine continental
Ionica	600	7.8 - 25.6	Elevated (470)	Mild semi-arid

Finally, it has to be mentioned that as a result of the initial screening analysis of the Basilicata region another possible location (Alto Bradano) of 22,070 has been identified. These will be irrigated in 5-10 years. This second area, located nearby the industrial area of Irsina which is under rapid development, is extremely promising from both the agronomic and the economic point of view, thanks to its favourable geographical position (inner areas with scarce alternatives for crop production).

The Municipality of Pisticci

2.2 Dongying, Shandong Province (P.R.China)

The Dongying city of Shandong Province is located on the coast of Bohai Sea (118° 07'-110° 10' East longitude; 37°20'-38°10' north latitude) with 350 kilometers long coastal line: it is the bridge linking the northeastern and mid-China economic regions. It is 400, 300 and 250 kilometers away from Beijing, Tianjin, and Qingdao respectively. Dongying is well equipped with infrastructure, such as highways, electric grids, power stations, etc.

Dongying covers an area of 790,000 hectare. Only 55.8% of the land is in use: 350,000 hectare of land resources are to be exploited. The Yellow River passes through the Shandong Province, flowing into the sea from Dongying, with a cross-section of approximately 128 kilometers. The annual runoff volume is 30 billion cubic meters. Such powerful reserve provides Dongying with sufficient fresh water resource.

As far as regards the climate, Dongying lies in a semi-humid, northern temperate zone with continental climate. It has four distinct seasons, with moderate temperature, rainfall and sunshine, which are suitable for cultivation and growth of various crops.

The average elevation is 7-8 meters above sea level. Humid and salty soil accounts for 95% of the total area. The number of hours with sunshine is 2,692 hours per year. The total radiation is 124-128 kcal/cm^2. The annual average temperature is 12.2 °C, while the accumulated temperature is 4,300 degrees. The annual rainfall is 601 mm. Frost-proof period is 211 days.

The State Planning Commission recently announced that the Government established two plants for producing bio-ethanol in the north-eastern P.R.China to promote bio-ethanol as fuel. What's more, the Commission has started the market trial in Henan Province, allowing fuel mixed with bio-ethanol to show up at gas stations.

Dongying is the production base for the second largest oil field in P.R.China with annual outputs of 30 million tons of crude oil and 23 billion cubic meters of natural gas. The total annual yield of C4-C8 distillation fraction reaches 2.4 million tons: at present, C4-C8 products are mainly used in catalytic cracking and liquid gas production.

The P.R.China Oil University is also located in Dongying City: it has become the advanced research and education base for highly qualified personnel in the oil and petrochemistry industry.

The Kenli Petrol Chemical Plant has been selected as the target factory for large-scale production of bio-ethanol from Sweet Sorghum. It is a large state-owned enterprise with revenue reaching RMB 646 million and profit before tax of RMB 52.57 million in year 2000.

The refinery plant covers an area of 60 hectare. The total assets of Kenli is worth RMB 590 million and it has a total work force of 1,784 people. It owns an oil refinery factory with production capability of 1 million tons. It also has a thermal power plant with a capacity of 70 tons of steam per hour. Kenli is only two kilometers away from the Dongying-Qingdao Highway.

The Municipalities of Dongying and Huhhot

Since 1999, Kenli has carried out the feasibility study and planning on the production of 30,000 tons of bio-ethanol and 10,000 tons of ethyl acetate. The engineering process passed the professional verification not long ago, and the project has been listed in the Provincial-Plan.
At present, the Kenli target for bio-ethanol production is 100,000 t/year. According to Kenli's original plan, corn and dried sweet potato would be used as raw materials to produce bio-ethanol: however, as Sweet Sorghum is proved to be more convenient and efficient than conventional crops, Kenli is interested in the ECHI-T project. The industrial processing of Sweet Sorghum could be done on their industrial site.

The land in Dongying, Shandong Province, is suitable for Sweet Sorghum cultivation. Today, a total area of 800 ha already grows this crop, which is mainly used as forage for cow and cattle. The potential plantation area reaches 60,000 ha. Several cultivar (as "M81-e", "Tianza No.2" and "Tianza No.3") have already been tested in Dongying, and the results are very promising in terms of adaptability and productivity of these hybrids. Even though irrigation system is not available, when necessary a huge amount of water can be obtained from the Yellow River. In dry years, an area of 150,000 hectare can be effectively irrigated.

2.3 Huhhot, Inner Mongolia (P.R.China)

Huhhot (also called Hueahote or Hohhot) is the capital of the Inner Mongolia region, which is close to the border of Mongolia. It is at approximately 40° North Latitude, W-NW from Beijing. It belongs to a middle-warm semi-dry zone. The average elevation is around 800-1100 meters above the sea level. The annual average rainfall is approximately 400 mm with frost-proof period by 160 days.

The solar energy resource is abundant, with annual sunshine hours above 3,000 hours and sunshine percentage by 60-75%. The annual solar radiation in Inner Mongolia as well as the accumulated temperature are suitable for Sweet Sorghum cultivation.

The low temperature typical of winter time offers unique on-field storage conditions for Sweet Sorghum stems (stalks) in Inner Mongolia. In fact, since the temperature fall below zero during the harvesting season (end of October), stems left in the fields will not deteriorate, and the stem-processing phase can therefore be extended to the subsequent April. Harvested stems can be stored in the fields for a period of 5 months.

Table 2.5 Meteo data in Huhhot: monthly reference

Meteostation: Huhhot Coordinates: 40.49 North 111.41 East
Altitude: 1063 m. Country: P.R.China

Month	Min. Temperature °C	Max. Temperature °C	Humidity %	Wind m/s	Sunshine Hours	Radiation MJ/m/day
January	-19.6	-4.7	60	1.2	6.6	8.8
February	-15.7	-0.4	58	1.3	7.5	12.1
March	-6.7	7.9	46	1.5	8.1	16.1
April	-0.2	15.6	51	1.8	8.7	20.1
May	6.5	22.7	50	1.7	9.5	23.1
June	12.6	28.0	55	1.4	9.6	24.0
July	16.6	28.9	65	0.9	8.8	22.5
August	14.4	27.4	72	1.8	8.4	20.4
September	8.3	22.3	64	1.0	8.5	17.8
October	-0.6	14.8	68	1.0	7.8	13.5
November	-9.5	4.4	64	1.2	6.9	9.7
December	-16.7	-2.2	60	1.0	6.2	7.8
Year	-0.9	13.7	59	107	8.1	16.3

Climate station: Huhhot Eff. rain method: USDA S.C. Method

	Rainfall (mm/month)	Effective Rainfall (mm/month)
January	2.0	2.0
February	6.0	5.9
March	10.0	9.8
April	20.0	19.4
May	28.0	26.7
June	46.0	42.6
July	104.0	86.7
August	137.0	107.0
September	40.0	37.4
October	24.0	23.1
November	6.0	5.9
December	1.0	1.0
Total	424.0	367.6

Eff rain form: Peff = (Pmon * (125 - 0.2 * Pmon)) l 125 for Pmon <= 250 mm
Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

CROPWAT 7.0

Table 2.6 Monthly rainfall data in Huhhot

The soils in this region are very fertile. Inner Mongolia has already developed Sweet Sorghum cultivation for food-ethanol (wine) production. The Sweet Sorghum wine is distilled and produced in Tuoketuo County. Tuoketuo locates to the west of Huhhot City, 70 km away from the urban area of Huhhot. The terrain is wide and even with convenient transportation systems and sufficient water and power supply. Besides the land occupied by the existing "wine" production plant, the remaining area is large enough to be considered for a possible industrial extension to fuel-ethanol production.

Inner Mongolia Autonomous Region is the main livestock husbandry zone in the P.R.China, with high demands for grass-feeds. The quantities of cattle and buffaloes, horses, donkeys, mules and sheep and goats in 2000 reached 3 million, 4 million, 1.5 million heads, 1 million, 800,000 and 30 million respectively.

Feed shortage caused by critical meteorological events has already occurred in recent years, and represents a serious problem for the regional government to deal with.
Furthermore, in this region specific regulations have been issued regarding environmental protection: the risk of desertification due to cattle breeding forced the government to restrict the use of natural vegetation as feed or fuel. Therefore, market demands for animal feed products and for domestic heating are strong.

The fermentative sludge from bio-ethanol-production based on Sweet Sorghum are the favourite food for cattle and buffaloes, sheep and goats, rabbits, gooses, camels, horses and donkeys. Today, low-compacted pellets (2-2.5 cm, 15% moisture content) are produced from a mix of chopped corn stalks and Sweet Sorghum bagasse after fermentation, and are sold as animal feed.

The current plantation area of Sweet Sorghum is over 1,000 ha.
The production capacity of the factory in Tuoketuo is approximately 4,000 t/y of drinking ethanol: it takes four days to ferment Sweet Sorghum juice into ethanol.

As far as the electric network is concerned, the national grid covers Inner Mongolia. P.R.China is investing to build a thermal power station in Tuoketuo County, which will be the largest one in Inner Mongolia. Renewable energy generation is encouraged by the State.

by Tommaso Guicciardini

An oil refinery has been selected for the ECHI-T project in Inner Mongolia. The industrial plant, belonging to the PetroChina Company Limited, is located 9 km away from Huhhot City and covers an area of 1,950 mu (130 ha). The initial investment for processing 1,000,000 t crude oil per year was 690 MYuan, and covered production machinery, oil storage and transportation, supplementary workshops, environmental measuring systems, etc. Today the PetroChina refinery processes 1,500,000 tonnes of crude oil per year to produce gasoline, diesel, LPG and bitumen, all satisfying or even exceeding Ministry and National Standards.

The PetroChina Company is very much interested in bio-ethanol for fuel reformulation or blending. In the past few years, PetroChina intended to produce MTBE from methanol for gasoline reformulation, but now for environmental reasons they would prefer to produce ETBE from ethanol. The target production of ethanol for PetroChina Company is 100,000 t /y. The main driving factor for implementing the project will be the bio-ethanol cost.

ECHI-T - CONCEPT OF LARGE INDUSTRIAL BIO-ENERGY COMPLEXES

3. Sweet Sorghum cultivation

In general, cropping practices for Sweet Sorghum do not change significantly among different locations despite large variations in climate, soil, thermal units, rainfall, etc., because the response of Sweet Sorghum is relatively constant to various environments. Nevertheless, the specific differences in the climate, among sites, allow the use of different cropping strategies to maximise both the farmer and the industrial incomes.

Seed bed preparation

Ploughing done immediately after harvest of previous crops at a depth of 15-20 cm is suggested for successful sowing in terms of water accumulation and drainage. All other complementary cultivation practices have to be carried out for water conservation in the soil and to obtain a very fine seed bed to facilitate sowing and emergence of the crop. The sowing in June and July, after the harvest of barley, wheat, frozen peas, etc. as double cropping, may be done in sodseeding or minimum tillage in Dongying.

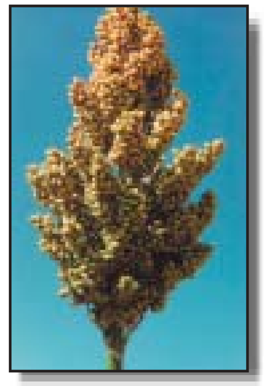
Plant density

Tests demonstrated that Sweet Sorghum performs well with a row space of 70 cm. Narrower rows cause extensive lodging, whereas wider rows cause stalk yield reduction. A plant density of 8-15 plants per m^2 are a good compromise between yield and lodging. In absence of single stalk hybrids, control of the final stand (main culm plus tillers) is a problem. To avoid or reduce lodging, a plant density not exceeding 10 plants per m^2 should be adopted.

Seed treatments

Dressing of seeds are used against diseases and insects to assure emergence of the crop. At present, TMTD+Captano or Carbossina+Thiram are used: however, many other systemic products are available when necessary.

Theis variety



Sweet Sorghum varieties

Varieties that performed well in all the locations under study are (GDD means Growing Degree Days):

- Keller, 1700 GDD (140-150 days);
- Mn 1500, 1600-1700 GDD (140-150 days);
- Dale, 1500 GDD (120-130 days);
- Theis, 1500 GDD (120-130 days);
- M81-E, 1600 GDD (130-140 days);
- Chinese1, 1400 GDD (110-120 days);
- AT623 x Roma, 1600 GDD (130-140 days);
- Experiment-1, 1600 GDD (130-140 days);

by Tommaso Guicciardini

Varieties of Sorghum grains

Harvesting tractor

Fertilisation

A reasonable fertilisation of Sweet Sorghum requires 90 to 120 kg/ha of nitrogen depending on the soil availability and whether or not leaves are removed from the field at harvesting (Final Report FAIR CT 96-1913).

Weed control

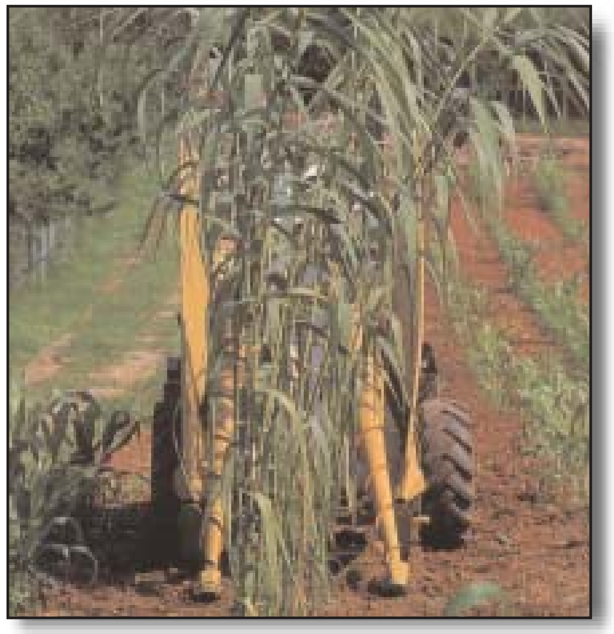
In Italy only Terbutilazina, Propaclor, and Aclonifen are allowed for pre-emergence use, whereas Dicamba, Terbutilazina plus 2.4D and MCPA, or the last only two of them, are allowed for post-emergence Sorghum. Rotation would help to reduce the pressure of Sorghum weeds. In P.R.China weeding machines and hand cultivation are usually adopted.

Irrigation strategies

Sweet Sorghum is a drought crop in the sense that it requires very little water per unit of organic dry matter (192 g per g of dry matter) accumulated. Moreover, Sweet Sorghum is considered to be a "Camel" crop because it resists water shortage until the wilting point and recovers without problems. With limited water supply, Sweet Sorghum yield is reduced nearly proportionally to the water shortage, so in Basilicata farmers are advised to irrigate fully to restore the crop evapotranspiration (ETc). Good water supply is important to achieve good stalk yield and seed yield. The threshold for separating stressed and non-stressed crops has been calculated to be -0.4 MPa in the crop leaf that is reached when the soil water passes the wilting point. In Basilicata, the total water stored in the soil for 1 m depth is very close to 120 mm/ha and consequently the irrigation volume could be considered very close to this value. Reducing irrigation by about 40%, the final yield decreases to nearly 30%. Consequently, if the amount of irrigation water is limited, it is better to crop less areas instead of sacrificing unitary yield, since at this time all other inputs have been used. If porometers are not available, and leaf water status can not be measured, the amount of water for each irrigation can be determined by applying, to reference Evapotranspiration (ETo), appropriate crop coefficients (Kc) that, according to FAIR CT 96-1913, are: 0.25 from emergence to 5-6th leaf; 0.7 during jointing; 1.15 during full development; 0.8 later. Watering is done any time when the sum of daily ETc (ETo*Kc) reaches 100-120 mm. In case of water shortage, the impact on the plant growth due to lack of irrigation during stem elongation is worse than in the later stages. Moreover, it could rain later in the season! In the areas under study, rainfall patterns are very different. In Basilicata rainfall is more frequent in September-October, even though there is a good probability that it will rain only in November, whereas in P.R.China rainfall is frequent during July and August when the irrigation need of the crop is at a maximum. The needed water, as a consequence, is very different among locations and among seeding time. For example, on the basis of last decade climatic data, there is no need for irrigation in Dongying, if planting is done after the 21st of May, whereas earlier planting required up to 250 mm/ha of water. In Huhhot, 120 mm are sufficient to irrigate the Sorghum crop without deficit, whereas in Basilicata the required amount is estimated, depending on the year, to around 5,000 - 6,000 m^3 ha-1.

An estimate of the amount of water required, based on the seeding time and lateness of the used cultivar has been calculated by means of the FAO database and software model CROPWAT. Results are given in the following paragraphs.

Harvesting machine



by Tommaso Guicciardini

Planning sowing and two months of harvesting

Sowing and harvesting were planned with the aim of obtaining the maximum yield and extending the harvest season as long as possible. In order to reach the most profitable yields, varieties with many GDD should be chosen: on the contrary, cultivar with low GDD should be selected to obtain an early harvest. Moreover, the planning of the first sowing in the three locations, Basilicata (Italy), Huhhot and Dongying (P.R.China), was based on the assumption that the cultivation will start when the average air temperature is above 9°C. In Basilicata and Shandong the crop could then be harvested, after physiological maturity, during a period of ten days (some cultivar may maintain a good level of sugar content longer than

Sowing	*Harvesting*					
	1,300 GDD		*1,500 GDD*		*1,700 GDD*	
Date	**date**	**lack**	**date**	**lack**	**date**	**lack**
21st March	22nd August	435	8th September	500	28th September	512
28th March	23rd August	436	8th September	475	29th September	510
4th April	23rd August	409	9th September	458	30th September	491
11th April	24th August	396	10th September	465	2nd October	509
18th April	25th August	410	12th September	476	4th October	515
25th April	26th August	384	13th September	448	6th October	487

Remark: in case a 1,200 Growing Degree Days variety (not in the table) is planted the 21st of March, it will mature the 15 August (requiring 435 mm of irrigation)

Table 3.1 Harvesting, sowing, GDD and lack of rainfall (mm) for each harvesting in Basilicata (using local climatic data)

others). sowing has to be done relatively early in Basilicata to avoid the lack of rainfall, which is very frequent in late spring. The same situation occurs in Huhhot, due to the very short season (low thermal units) suitable for crop growth. In Dongying, two different strategies are instead possible: the Sweet Sorghum cultivation could be planned to achieve a harvesting period of four months (this option requires irrigation), or to obtain a two months harvesting period (crop cultivated without irrigation).

Seeding and harvesting in Basilicata

In this location it is possible to use cultivar that require 1,300-1,700 GDD, and to start the sowing on the 21st of March, based on the average air temperature data of the last decade. With this sowing strategy, if we use a 1,300 GDD cultivar, harvesting time would be on the 22nd of August. To have a harvest ten days later with the same cultivar of it would be necessary to plant on the 9th of May or with another cultivar of 1,500 GDD, on the 10th of April. The last option would be preferable because late varieties are more productive, and sowing in April is more successful in terms of emergence rate, since rainfall is more likely to occur during this period of the year. With the second sowing, the harvest would be on the 1st of September. A third planting could be done on the 23rd of April and harvesting on the 10th of September with a 1,500 GDD cultivar and so on Table 3.1.

As it is evident from Table 3.1, except for the first sowing, the whole harvesting period could be covered by planting in April using cultivar requiring different GDDs.

Seeding and harvesting in Huhhot-Touketuo

Huhhot climatic data suggests using early or medium-early varieties with additional irrigation to fully compensate evapotranspiration.

Rainfall in fact restores only 70-80% of the evapotranspiration (Table 3.2).

Among the sites analysed in the project, Huhhot has the lowest number of Growing Degree Days because the average air temperature is low. If we consider a 1,300 GDD variety sowed when the mean air temperature reaches 9 °C (on 21st of April), the crop will be mature on the 30th of August; this is the beginning of harvesting in Huhhot. A cultivar requiring 1,400 GDD would ripen on the 15th of

Planting Date	*Harvesting*	*ETm*	*rainfall*	*lack of rainfall*
	1,300 GDD			
21st April	29th Aug	374	264	111
28th April	30th Aug	322	250	121
5th May	2nd Sept	302	240	100
	1,400 GDD			
21st April	13th Sept	365	286	98
28th April	14th Sept	374	271	121
5th May	18th Sept	350	270	99
	1,500 GDD			
21st April	29th Sept	403	306	115
28th April	30th Sept	400	290	128
5th May	8th Oct	380	290	113

Table 3.2 sowing and harvestings of Sweet Sorghum in function of GDD for Huhhot (using FAO CROPWAT/CLIMWAT data)

GDD	Sowing Date	Harvesting Date	GDD	ET_0 mm	Effective rainfall mm	ET_m mm	*Lack of Water mm
1,300	21st March	8th July	1,291	616	160	466	306
	28th March	9th July	1,306	601	163	441	278
1,500	21st March	19th July	1,501	672	207	465	258
	28th March	20th July	1,497	682	215	475	244
	22nd May	13th August	1,505	447	247	302	55
1,700	21st March	29th July	1,693	723	250	516	265
	27th March	30th July	1,708	708	253	506	253
	8th April	1st August	1,704	624	241	508	267
	22nd May	24th August	1,699	477	284	347	63
	27th May	29th August	1,692	449	287	318	31
	5th June	6th September	1,695	430	289	312	23
	12th June	16th September	1,702	418	288	308	20
	19th June	25th September	1,696	401	285	300	15
	26th June	9th October	1,698	405	304	274	30
	3rd July	28th October	1,697	422	328	264	64

Lack of rainfall = ETm – Effective rainfall

Table 3.3 Sowing, harvesting, GDD and water balance in Dongying (using FAO climatic data of Huimin)

September, whereas another cultivar of 1500 GDD would ripen on the 2nd of October. So the harvesting season could start at the end of August. If storage of the ripe cane is not a problem in the area (due to the very low temperatures in autumn), and physiological maturity must be attained to have ripened seed, it would be better to use the longest GDD cultivar at the beginning and the shorter GDD varieties later, in order to reach maturity before frost. This scheme would maximise the yield in the selected location. The use of earlier varieties is an important measure to compensate the delay of sowing required by the time necessary to do this work.

Seeding and harvesting in Dongying

Meteorological data suggest that Sweet Sorghum sowing can be organised for two months or four months of harvesting in Dongying. In fact, Growing Degree Days in Dongying allow a very long Sweet Sorghum cropping season, nearly double than in Italy. However, a very long harvesting season, longer than two months, would require irrigation in the first part of the cropping cycle (Table 3.3), whereas for a harvest in the middle of the summer, rainfall is sufficient to fully restore crop ET, even for medium-late varieties (1,700 GDD).

If we consider a cycle of 125 days and the previously reported crop coefficients (Kc), the sowing done from the end of May until the end of June do not require irrigation, because natural rainfall can restore the ETc. We did not assume the presence of a water table (because this information was not available): nevertheless, given that the land under evaluation is located at the river mouth (8 m above the sea level), the presence of a water table is highly probable. By beginning the plantation on the 22nd of May, it should not be necessary, based on FAO data, to irrigate the crop. This is true until the July 3rd planting, in fact, the lack of water is so low that it can be compensated by the water stored in the soil.

Two months of harvesting would instead not require irrigation. If an earlier cultivar (1,500 GDD) is used, it will be possible to avoid irrigation and start harvesting a little bit earlier (on 13 August).

Energy demand and associated cost for irrigation

Based on FAO meteorological data, in Dongying, the early planting would require irrigation, in order to harvest from the beginning of July to mid-August. The amount of water needed is 250-300 mm/ha, whereas in Huhhot 120 mm/ha are required. Watering can be done in both locations by furrow irrigation, supplying as much water as the soil can hold.

This could be done, for example, with a 12 HP engine (water-scooping machine) that pumps 5,500 liter/m (5.5 m^3/m) using 2.4 kg/h of fuel for a total of 9 kg of fuel/ha (equivalent to 91,800 kcal or 0.38 MJ) for 1,200 m^3 of water/ha.The energy used for irrigation in Basilicata, by high pressure, is 500 kg of fuel equivalent to 5,100,000 kcal or 21MJ, whereas the manpower is one hour per watering

for five watering times. With furrow irrigation, where possible, fuel consumption for water pumping would be reduced to zero, assuming that the water in the pipe is at the proper pressure for this kind of irrigation. In this case, the manpower required is 24 hours/ha taking into account that for each watering of 120 mm of water would be applied in 4 watering cycles. Labour cost for furrow irrigation is quite high and can reach 8 hours/ha per watering cycle.

Harvesting time

In order to maximise the manufacturing season of the industry, harvesting must be performed between the soft dough stage and physiological maturity. A combination of Sweet Sorghum varieties and different sowing times could be adopted to extend the harvesting season without compromising the preparation of the soil for the subsequent crop.

Sweet Sorghum rotation

Like most crops, Sweet Sorghum also produces a higher yield with crop rotation. In general, higher yields are obtained following the cultivation of a leguminous crop (soybean, peas, fababean, etc).

The EU project AIR-3-CT-96-1913 demonstrated that the best precession is wheat: the reason is that wheat is removed from the field early enough to allow a good seed bed preparation for the Sorghum. Emergence is, in fact, the principal bottle neck of the crop. In contrast, wheat yield may be less (5%) following the plantation of Sweet Sorghum than that after a leguminous crop, but wheat after Sweet Sorghum yields better than in a mono cropping, which indicates the positive effect of the rotation.

Even with the slightly lower yield of the wheat after Sweet Sorghum, a two-year rotation is realistic, given the economic importance of wheat crop in southern Italy and world wide. In Basilicata, durum wheat is the most important crop because it provides the best income among the open extensive field crops. Moreover, the slightly lower yield of wheat after Sweet Sorghum could be caused by the low level of nitrogen left in the soil after the cultivation of Sweet Sorghum, which could affect the wheat tillering and consequently the amount of spikes per surface unit.

Another reason for the lack of nitrogen in the soil after Sweet Sorghum plantation could be related to the bacteria involved in wheat straw decomposition. If the bacteria do not find nitrogen in the straw, it will take it from the soil. If this is true, the slightly lower yield of wheat after Sweet Sorghum could be improved just by fertilising the wheat a little bit more at the planting stage or within the third leaf stage.

The sustainability of this kind of rotation was demonstrated with grain Sorghum at the Perugia University. Biennial rotation allows a reduced area around the plant minimising the cost for transporting Sweet Sorghum cane to the plant.

The biennial rotation is already carried out in P.R.China in Tuoketuo County, Huhhot City of Inner Mongolia, and in Dongying City, Shangdong Province.

Seed supply

At present, the only Sweet Sorghum seed available in Italy is a fodder open-pollinated type and the price is 1.5-2.0 US$/kg.

The amount of seed yielded by a Sweet Sorghum variety is very small compared to a true fodder type (Sweet Sorghum for syrup could also be used as fodder) or to the HES (High Energy Sorghum), which is normally only 0.8 t/ha.

HE Sorghum, according to Texas AM University, have a dual purpose, i.e. grain and sugar. The ideal HES type assumes that with particular growing condition a full grain crop can mature on a non senescent plant. The green leaves not only accumulate starch and other sugars, but also use the stalk as a reservoir for soluble sugars after the photosynthate flow to the panicle has ceased (Miller and Creelman, 1980).

The presence of an heavy panicle induces in these hybrids a strong tendency to lodge. Nevertheless if we assume that the amount of seed necessary to plant a hectare of Sweet Sorghum is ~1:10 kg/ha, the multiplication rate for this type will be 1:1,000, sinificantly greater than wheat. The price for HES hybrids could be higher but due to a large-scale production the Italian SIS Company (Bologna) is willing to supply it at 3 US$/kg. Currently the Italian seed companies with certified Sweet Sorghum seed are: SIS (San Lazzaro di Savena-Bologna), Dekalb Italia (Chiarano Treviso), Pioneer (Borgo Ronchini, Parma), KWS (Bologna) and others. The use of HES, which can yield up to 5 t/ha of seeds, could improve the multiplication rate and as a result lower the cost of the seed.

To commercialise a Sweet Sorghum variety in Italy, it must be registered in the national catalogue or in a catalogue of another European country (then it is automatically registered in the European catalogue). Afterwards, the National Seed Board regulates all the processes related to yield and supply of such a seed variety. Seed imported from the USA costs US$ 10-12/kg.

In P.R.China many locally bred open pollinated cultivar may be used together with new hybrids.

The production cost of seeds in P.R.China is US$ 6/kg. The cost of exported seeds is US$ 10/kg (excluding transportation cost).

The Species Resource Institute of the Chinese Academy of Agricultural Science (CAAS) issues authorisation and seed quality certification. Then, the application to the Seed Division of the Department of Planting of the Ministry of Agriculture (MOA) has to be submitted for ratification. It is then possible to apply for an exporting license from the Ministry of Foreign Economic & Trade (Certificate of Exporting Allowance). Certified, licensed seeds are then exported through the P.R.China Seed Company.

Conclusions on Sweet Sorghum cultivation in the three sites

In addition to yielding a large amount of biomass resources and being a very water-efficient crop, Sweet Sorghum has several other advantages:

- it requires common soil and is also adapted to salty areas;
- it needs a small amount of seed compared to seed yield;
- it is adapted to limited soil preparation, fertilisation and weed control inputs;
- many varieties are available to fit the environmental conditions;
- yield can reach 5-6 t/ha of seed yield, 7-10 t/ha of sugar, 17 t/ha of bagasse;
- seed can be supplied by Chinese, American, European and Italian seed companies;
- it can be watered a few times with heavy volumes;
- it can be cropped in a two-years rotation with wheat.

4. Configuration of the three complexes

Sweet Sorghum complexes and their configuration have been defined, with the possible products identified and their amounts estimated. The preliminary assessment of their economic performance has also been done.

The complex owes its promising prospects to the use of Sweet Sorghum, which is perhaps the best C4 industrial energy crop, and to integrated simultaneous processing of this crop into several high-value products, such as bio-ethanol, grains, sugar juice, and bagasse, "green" electricity and heat, charcoal, activated coal, hydrogen, methanol and pulp for paper.

A broader concept study has been developed, based on the extensive analysis of the energy context (as far as the technological, market and environmental aspects are concerned), the main objective being to identify a large integrated energy-industrial activity addressing several strategic issues.

The integrated complex is based on the integration of two main conversion processes: the biological and the thermochemical conversion routes. The wide range of possible industrial energy products reduces the sensitivity of this complex to the fluctuating biofuel market. Different levels of integration, with significant different consequences on the bio-energy complex economics, should be considered.

The configuration of the integrated complex in the three sites has been drawn, describing the possible yields of Sweet Sorghum (grains, sugar juice and bagasse) and the technological options for the industrial activities.

Grains could be processed to obtain bio-ethanol and DDGs which are of great interest for cattle breeding (meat/milk production) thanks to their high proteins content. Sugar juice could be fermented and distilled to obtain alcohol and CO_2. Lignocellulosic bagasse, after being squeezed and pelletised, could be directly utilised for:

- heat production
- co-generation

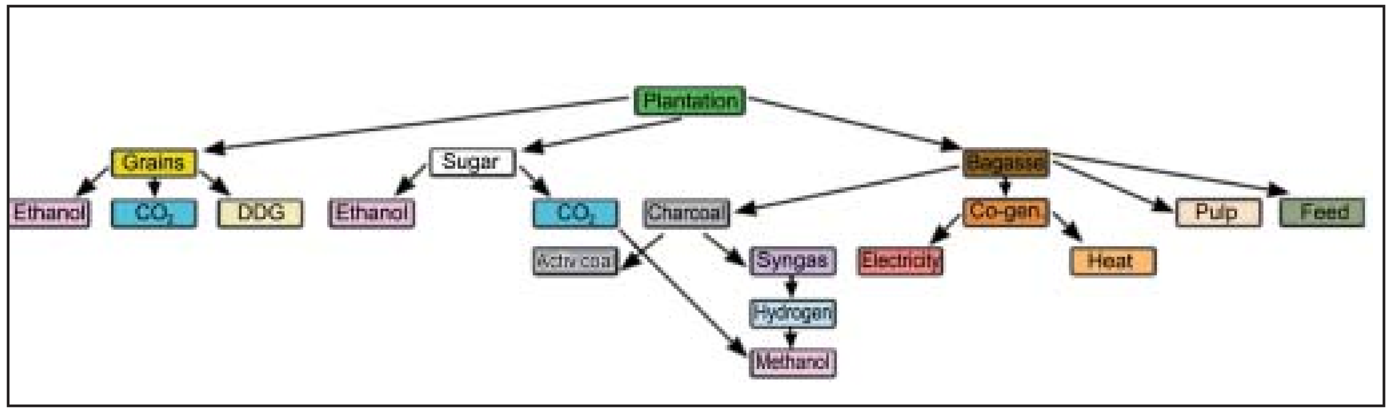
or processed into higher quality bio-products, such as:

- charcoal pellets
- syngas/hydrogen

Other interesting industrial co-products are possible from Sweet Sorghum, for instance:

- pulp for paper
- bio-methanol (synthesis of H_2 with CO_2 produced during sugar fermentation), bio-Fischer-Tropsch gasoil etc.
- organic fertilisers (compost)
- bagasse fibres composite board and panels
- liquid or dry ("dry ice") CO_2 for beverages and various food-industrial processes

Possible conversion paths for the integrated complex



The following degrees of integration are therefore possible:

1st level of integration: bio-ethanol / DDGs / CO_2 / bagasse pellets for sale

2nd level of integration: bio-ethanol / DDGs / CO_2 / heat&power / bagasse pellets for sale

3rd level of integration: bio-ethanol / DDGs / CO_2 / heat&power / pulp for paper

4th level of integration: bio-ethanol / DDGs / CO_2 / heat&power / pulp for paper, activated coal

5th level of integration: bio-ethanol / DDGs / CO_2 / heat&power / pulp for paper, activated coal / syngas (hydrogen) / bio-methanol (or bio- Fisher-Tropsch gasoil)

In the previous schemes the process paths and the large scale industrial Sweet Sorghum complex is sketched, showing all possible Sweet Sorghum processing steps (5th level of integration). The actual project may then contain all or part of these steps.

Following the development of this broad concept, the analysis of strategic, economic, social, environmental, technological, industrial and agricultural issues in the three sites is necessary.
This "exploratory phase" has been carried out by collecting data on industrial processing of Sweet Sorghum from different industries, SME, research institutes, universities and governmental organisations. Furthermore, the project team visited the Basilicata region as well as the two Chinese locations under evaluation to collect local data. Contacts with interested oil companies (Kenli Oil Company in Dongying and PetroChina in Huhhot) were also established.
The analysis of the possible schemes, by comparing local conditions and markets, led to the conclusions that the 2nd level of the integration is the most appropriate approach for the three selected sites.

Description of each complex

In this section, the results of the adaptation of the general scheme to the three sites is presented. The definition of the plant configuration (from the reception of the biomass at the plant gate to the supply of products) has been evaluated.
Two basic configuration models have been designed:

1. a centralised Model (Dongying, Basilicata);
2. a decentralised Model (Huhhot).

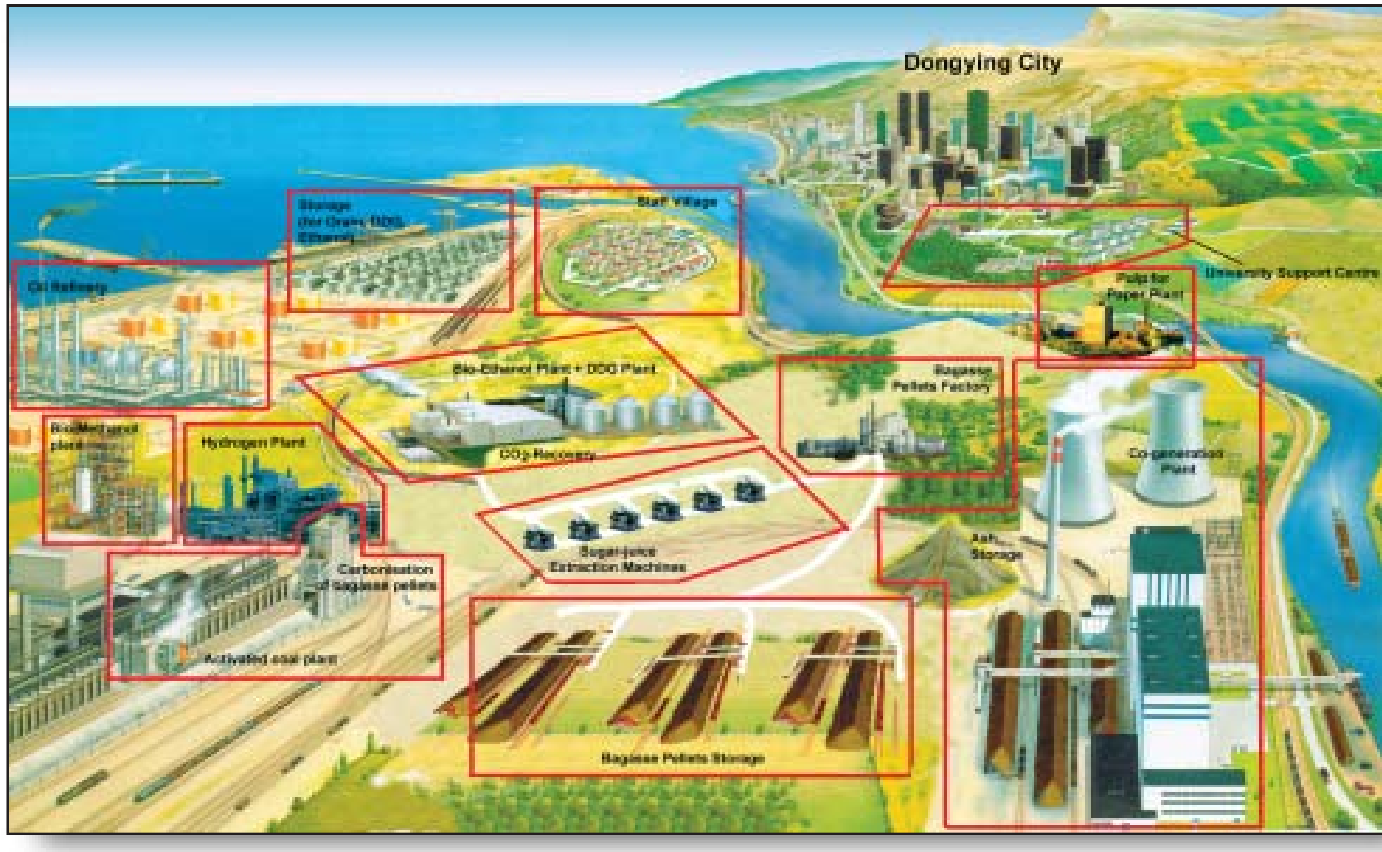
In fact, differently from the Basilicata and the Dongying sites, (similar centralised complexes), in the case of the Huhhot complex the existing rural structure and the logistic prerequisites suggested the analysis of a decentralised structure based on 10 similar clusters. This basic difference in configurations has also important impacts on the logistics, especially in terms of harvesting and transportation of the raw material. The selection of processing technologies depends on the type of model chosen for each specific site.

The mass, energy and products flows have been calculated, thus obtaining :

- the amount of biomass produced, in terms of grains, sugar, bagasse
- the amount of Sweet Sorghum derived
- the energy used for Sweet Sorghum processing (both electricity and heat / steam).

The previously described area of 7,000 ha has been proposed for Sweet Sorghum plantation in Italy: the expected total bio-ethanol production is approximately 42,000 ton / y. Bagasse is primarily used for co-generation, with surplus electricity sold to the grid as 'green' electricity, given its high value (Green Certificates system). The remaining bagasse can be sold as animal feed, that is expected to have a good market in Europe. The plantation is not as large as the one in Dongying, but it is large enough to demonstrate the feasibility of Sweet Sorghum complexes in Southern Europe. The integrated complex will be situated in the Pisticci industrial area, which is located in the centre of the five plantation areas.
The plantation area of 19,000 ha in Dongying has been chosen with the aim of providing sufficient

ECHI-T - CONCEPT OF LARGE INDUSTRIAL BIO-ENERGY COMPLEXES



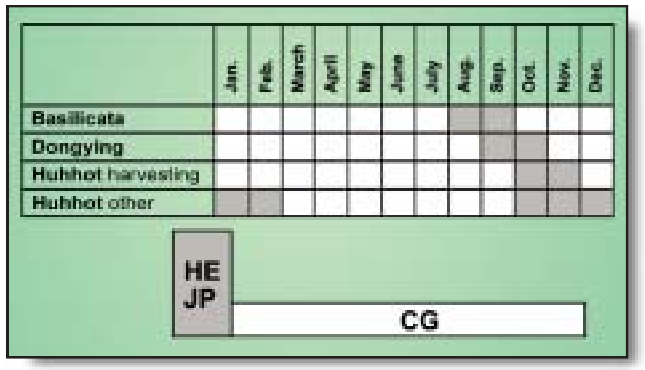
The Sweet Sorghum integrated Complex

feedstock to produce 100,000 t bio-ethanol per year, since the local oil company (Kenli Oil Company) indicated that its demand for bioefuel would be of this level. The Sweet Sorghum complex will be located at the premises of the Kenli Oil Company, which intends to establish an industrial consortium to implement this Sweet Sorghum processing unit. Approximately 60% of the bagasse pellets available is used for co-generation. In addition to providing electricity and heat (steam) to the Sweet Sorghum processing plants, the co-generation unit will also replace an existing coal-fired power station with a capacity of 6 MWe. The remaining bagasse pellets will be sold as animal feed.
In summary, in Dongying, just like in Italy - but on a larger scale, the cultivation and processing of Sweet Sorghum will take place in a single large scale integrated complex.

In Huhhot, the PetroChina oil refinery is ready for processing 100,000 t / y of bio-ethanol into reformulated / blended transport fuels: the production of such quantity of biofuel will require a total plantation area of approximately 20,000 ha. However, as already mentioned, the authorities in Inner Mongolia pay more attention to the rural development issue: therefore, at first a configuration based on smaller clusters have been examined for the Huhhot site. It has been decided that the total area of 20,000 ha will be divided into 10 small scale cultivation clusters of 2,000 ha each: in each cluster, sugar juice and grain are converted into bio-ethanol and DDG. Bagasse is used to provide heat (steam) to the Sweet Sorghum processing in each cluster.
It is proposed that only heat will be produced (with a relatively simple boiler) instead of co-generation, since co-generation is not economically justified for such small scale clusters. The remaining bagasse is used as animal feed, for which there is substantial demand in the Huhhot region, Inner Mongolia, which is well known for its cattle and other animals herds.

Planning of the activities

Plans on Sweet Sorghum cultivation and processing have been developed for each site. Sweet Sorghum harvesting and juice processing (i.e. sugar juice extraction, conversion of sugar juice to bio-ethanol, pelletisation of bagasse) should be done as quickly as possible to avoid various types of losses, reduction of sugar in the stem, sugar losses through spontaneous fermentation, dry matter losses in the bagasse (due to the high moisture content that enhances natural decay). Processing of the grain, however, does not have to take place immediately since grains (dried below 12% moisture content) can be stored for a longer period of time without material losses.



Crop harvesting and processing schedule

As already mentioned, in Huhhot the temperature during the harvesting season is so low that spontaneous fermentation of sugars does not occur, and therefore the stems can be stored in the field for a rather long period (5 months). Based on these technical considerations, the following planning schemes have been proposed for the three sites:

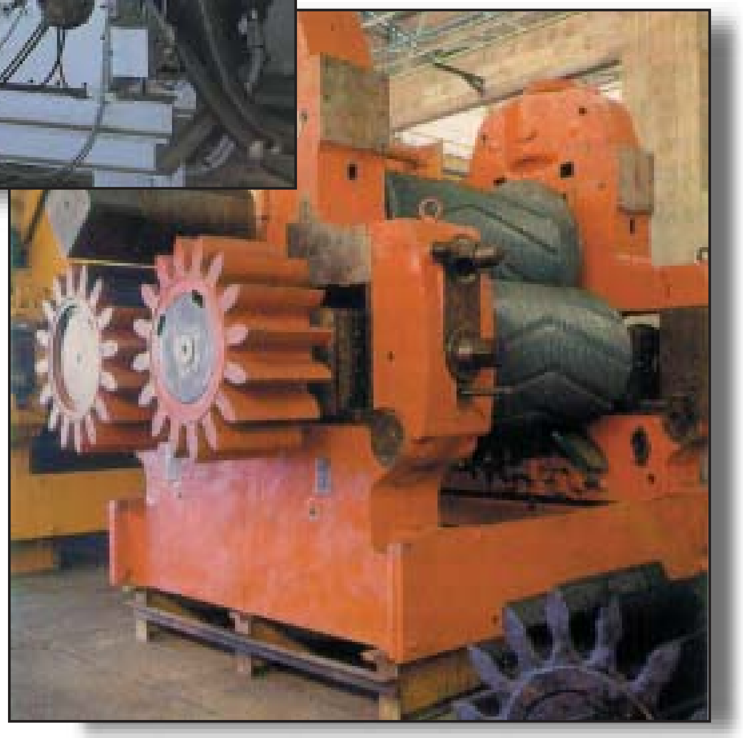
- The period of time allocated to harvesting, extraction, (sugar) juice to bio-ethanol and pelletisation (HEJP) is 2 months for Dongying and Basilicata, while it is 4 months in Huhhot.
- The remaining period is dedicated to the cultivation of Sweet Sorghum and processing grains into bio-ethanol and DDG (CG).

Technologies

The main technologies used in the integrated Sweet Sorghum industrial complex are the following:

- Cane crushing/sugar juice extraction
- Drying and pelletisation of bagasse
- Co-generation plant
- Ethanol from juice and ethanol/DDGs from grains

Pelletisation machine ETS® (ECOTRE System)



Juice extraction machine

A brief description of each of the main technologies is given below.

Cane crushing/sugar juice extraction

Grains and leaves are separated from the stem when Sweet Sorghum is harvested. Stems are cut into pieces, crushed, and the sugar juice is extracted from the billets through mechanical extraction. Intermediate products are raw juice and bagasse. Extraction machines are widely utilised in the sugar cane processing industry: here, it is assumed that they can be adapted without any further modification to process the Sweet Sorghum stems, without loosing their extraction efficiency. These machines usually consist of a tandem of single units based on three rollers - a top roller, a bagasse roller and a feed roller. The cane is crushed between the top roller and the bagasse roller. This step breaks the cane fibres, producing fine bagasse and juice. These standard machines operate 24 hours per day, and require a very limited maintenance. The typical capacity range in the Brasilian industry is about 50 ton/hour of fresh cane processed, however, the largest crushing machine can process up to 650 t/hr.
Concentration of the sugar juice (to enable long term storage of the sugar juice without sugar losses by spontaneous fermentation) is not recommended for the project, on the basis of the experience in Brasil, where fast processing of the cane and the sugar juice into bio-ethanol is usually preferred to avoid the high energy demand typical of juice concentration.

Drying and pelletisation of bagasse

To improve the logistic aspects and enable long term storage, drying and compaction-pelletisation of bagasse are necessary. This process step transforms the bulky bagasse (about 100 kg/m^3, 50% moisture content) into pellets (about 900 kg/m^3, 8-10% moisture content). Pellets can be used as fuel, as raw material for products or as animal feed. There are several suppliers of compaction technology active on the market. Pellet size ranges from 15 to 40 mm diameter and length 30 to 80 mm.
Most technologies consist of a separate drying step followed by compaction. For the integrated complex, however, a novel technology has been proposed that dries and compacts the bagasse simultaneously, thereby saving significant amounts of energy. The production capacity considered for the ECHI-T project is around to 5 t bagasse/hr (assuming an initial moisture content of 50%); power consumption is around 60-100 Wh/t of pellets produced.

Co-generation (production of electricity and heat from bagasse-pellets)

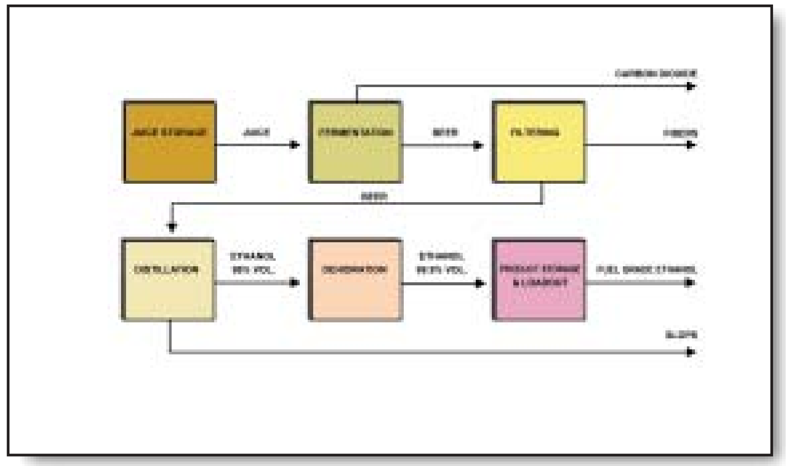
The technology chosen for co-generation is the traditional steam cycle, a well developed and reliable technology for heat and power generation from biomass. Sweet Sorghum processing requires both electricity and heat (steam). Co-generation plant parameters (electricity/heat ratio) are adapted to the demand for heat (process steam) by Sweet Sorghum processing.
Main design parameters of the co-generation plant are the fuel availability (amount of Sweet Sorghum bagasse pellets) and the energy demand for Sweet Sorghum processing. The travelling grate technology often used by Siemens AG was selected for the project.

Co-generation plant (Siemens AG)

A major result of the study is that Sweet Sorghum cultivation will provide sufficient bagasse input to supply the required process energy for each of the three sites.
It should be mentioned that the uneven distribution of energy use with time (high demand during HEJP, relatively low demand during CG) made the design of the co-generation plant rather complex, both from the technical and an economical point of view. This fact shows once more how carefully the planning of the Sweet Sorghum cultivation and processing should be determined and integrated.

Bio-ethanol from sugar juice and grains/DDGs

After extraction, sugar juice can be converted by fermentation into a "beer" with alcohol content of about 7%, which is consequently distilled to low-grade bio-ethanol with 95-96% alcohol and finally upgraded to high-grade bio-ethanol (alcohol percentage 99.8-99.9%).



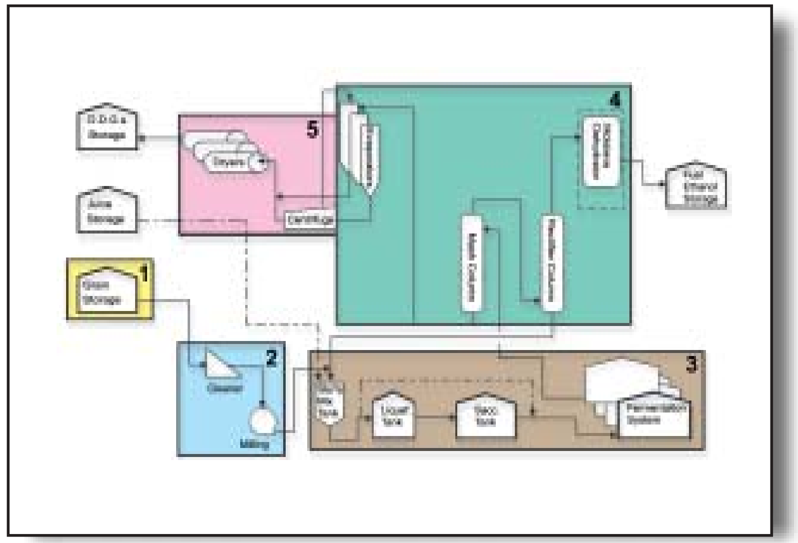
Ethanol from Sweet Sorghum juice

Grains can be converted into bio-ethanol as well. Since sugars in grains are only available as complex sugars/starches, grains have to be mashed and saccharified in a first processing step to convert these complex sugars/starches into simple fermentable sugars (mach separation and saccharification).
The subsequent process steps are similar to those adopted to ferment sugar juice into bio-ethanol (followed by distillation). However, when converting grains to bio-ethanol, a non-fermentable residue remains, i.e. DDG, a high-value protein rich animal feed. This so called stillage is processed separately from the fermentation and distillation processes.

For economic reasons (upgrading bio-ethanol to a high degree requires costly technology and preferably scale-up), in case of Huhhot - Inner Mongolia - it is proposed to produce only low-grade bio-ethanol in each cluster, and to process the bio-ethanol further into high grade bio-ethanol (99.8-99.9% alcohol) centrally in the PetroChina refinery.

The processing steps are described in more details as follows :

- Grain treatment, mash preparation and conversion (only for grains)
- Fermentation (both for grains and sugar juice): conversion of sugar into alcohol by using enzymes produced by living micro-organisms (yeast). For the ECHI-T project the continuous fermentation process is selected.
- Distillation and dehydration: fermentation results in a 'beer' with low alcohol content (7%). In the distillation section the alcohol is stripped and concentrated in preparation for dehydration. The dehydration technology selected for the Basilicata and Dongying is the molecular sieve (a molecular sieve functions as a sponge removing water from the beer).



Grain and Juice conversion routes to bio-ethanol and DDG (Delta-T)

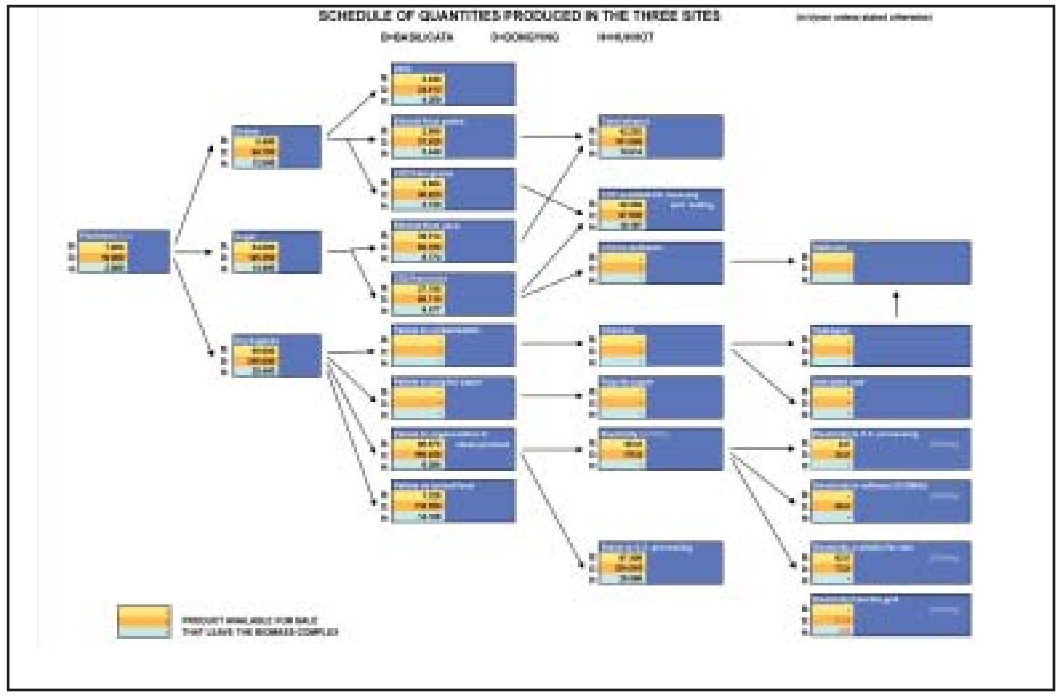
Grains to bio-ethanol and DDGs:

After the process steps described above are carried out, the stillage from grain fermentation is processed further into DDG.

Process steps are:

- Stillage separation: solids contained in the stillage water are separated from the water. A dekanter reduces the water content of the solids to 70%. A continuous evaporation plant increases the solid content in the waste water to 35%.
- Stillage evaporation: the evaporation method selected for this project is multi-effect evaporation, that can make use of waste heat for evaporation.
- DDG's drying: Selected drying technology for the project is the rotary drying system, which utilise natural gas as heating medium.

The bio-ethanol and DDG plants have been jointly designed by Delta-T to guarantee low initial investment and running costs. Delta-T has supplied numerous successfully functioning plants all over the world.
The plants can be easily adjusted to different sizes. The Delta-T's well proven technology (already used for other sugar/starch crops like cereals, fruit, molasses) has been adopted for the three different plants.
A summary of the overall scheme indicating the amount of products for each site is given in the figure below.



Feedstock, mass flows and products in the three sites (including DDG production)

by Tommaso Guicciardini

5. Logistics

A two-year crop rotation is proposed for all sites. The biennial rotation (Sweet Sorghum and wheat) is already well demonstrated and justified from both the economic and agronomic point of view in China (Huhhot and Dongying). The use of traditional crops guaranties acceptance and sustainability too.

As far as regards raw material production and farmworks costs, these are reported in the following table. Raw material production include seeds, fertilizers, pesticide and irrigation, and the farm works comprise of ploughing, soil dressing, sowing, spreading and harrowing.

	Basilicata (7,000 ha)	*Shangdong (19,000 ha)*	*Huhhot (10 * 2,000 ha)*
Raw material production	455 €/ha	211 €/ha	127 €/ha
Farm works	260 €/ha	666 €/ha	615 €/ha
Total per ha	715 €/ha	878 €/ha	740 €/ha
Total per year	5,005,000 €/y	16,689,410 €/y	14,802,600 €/y

Table 5.1 Summary of raw material production and farmworks

Mechanical harvesting is envisaged in the three regions (Basilicata, Dongying and Huhhot). The CLAAS harvester model VENTOR has a designed harvesting capacity of 84 t/hr. Harvesting techniques of Sweet Sorghum depends on the use of the crop. The ensilage machinery for corn is not appropriate: actually, the mincing due to the ensilage causes too much sugar juices loss.

Transportation costs include transport capacity, speed average (loaded/unloaded truck), distances from fields to plants, fuel and labour cost.

5.1 Basilicata

5.1.1 Harvesting

We consider a 24 working hours/day for the whole harvesting period which should not exceed 60 working days. A cost of 50 € for manpower is foreseen for one person who works 8 hours per day: 3 shifts of 8 hours each are considered. Assuming a 50% higher salary for the Claas Ventor driver, the total labour cost reaches approximately 225 €/day. 4 harvesters are required to cover the 7,000 ha. Depreciation and operation and maintenance costs on the harvesters are considered, the annual costs for mechanical harvesting are estimated at 50,000 €/y.

Assuming that 3 shifts of 4 drivers are necessary during the 60 days harvesting period (i.e. 54,000 €/y), a total cost of 104,000 €/y (equal to 14.9 €/ha/y) is estimated.

5.1.2 Transport

A total mass of 420,000 tons of chopped canes has to be moved from the 7,000 ha fields to the plant after harvesting. The calculated distance between fields to plant is ~25 km. When the raw material density is accounted for, the total calculated volume of chopped stems is 2,800,000 m^3.

If properly equipped, one truck can transport ~100 m^3 and can make one round trip within 2 hours (loading and unloading included). 78 trucks are required every day (6 trips) for a period of 60 working days. The total price per truck per day reaches 304 €/d: therefore, total transport costs are estimated at 1,423,000 €/y.

5.2 Shandong

5.2.1 Harvesting

Assuming a harvesting period of no more than 60 working days, and 24 working hours per day, 12 harvesters are required. The average labour cost for the 12 drivers is 50.22 €/day/driver (3 shifts), which corresponds to 9,039.6 €/year; added to the annual costs for 12 harvesters (150,800 €/year), a total of 160,000 €/y is estimated (8.4 €/ha/y).

5.2.2 Transport

A total estimated mass of 1,425,000 ton of Sweet Sorghum canes has to be transported from the 19,000 ha fields to plant: 440 trucks (9 t per trip, 6 trips/day) are required every day throughout the whole season.

The average distance from plantations to plant is less than 15 km (30 km round trip).
The total cost is ~58,91 €/day or, for the 60 days harvesting season, the total price for one truck reaches
3,534.6 €/year. For 440 trucks, a total estimated cost is consequently 1,555,000 €/y.

5.3 Huhhot

5.3.1 Harvesting

The harvesting period in Huhhot is longer than in Basilicata and Dongying: at a first estimation, 120 working days have been considered. 10 clusters of 2,000 ha each have to be harvested. Assuming 24 working hours per day, a total of 5 harvesters are required.
Therefore, a total cost of 113,000 €/year is estimated.

5.3.2 Transport

The total mass (referred to 10 units of 2,000 ha each, i.e. 20,000 ha) to be transported reaches 1,200,000 tons of canes per year. The scheme is the same as for Shandong. 10.000 ton have to be transported to the plants everyday. 185 trucks are required every day for the entire season. The average distance from plantations to plant is less than 10 km.

As for truck transportation in Huhhot, one truck costs 39.27 €/day or 2,356.2 €/year. For 185 trucks, the total cost for the season is 872,000 €/year.

Table 5.2 Summary of harvesting and transportation costs

	Basilicata (7,000 ha)	*Shangdong (19,000 ha)*	*Huhhot (10 * 2,000 ha)*
Harvesting	104,000 €/y	160,000 €/y	113,000 €/y
Transport	1,423,000 €/y	1,555,000 €/y	872,000 €/y
Total per year	1,527,000 €/y	1,715,000 €/y	985,000 €/y

ECHI-T - CONCEPT OF LARGE INDUSTRIAL BIO-ENERGY COMPLEXES

6. Economic analysis

The economic analysis of the ECHI-T project is a rather complex task: in fact, a wide range of options and conditions have to be considered for each site, such as the large number of products, the very different local market conditions in the three sites as well as the world market prices, the possibility of implementing international mechanisms in support of such projects (for instance, the Joint Implementation and the Clean Development Mechanisms for CO_2 trading), etc.

A site specific evaluation has been carried out for each of the three locations under investigation. The methodology included feedstock production (mainly based on the analysis of logistics), investment and operation costs of the integrated complex, analysis of possible revenues from CO_2 trading.

Local data have been collected for electricity (bought from the grid or sold as "green" electricity), bio-ethanol, animal feed, DDG. If local figures were not available, or their preliminary estimation is too different from general world market prices, a further verification has been carried out and, in some cases, world market values have been used, as a conservative approach.

It has been assumed that Sweet Sorghum, separated into grains and fresh cane, is harvested and transported to the Industry Battery Limits. The feedstock is then processed inside the integrated complex, according to the scheme described in the previous chapters (squeezing, pelletting, etc.). Mechanical harvesting has been considered, and this cost taken into account when considering the feedstock selling price to the integrated complex.

The following initial investment and operation and maintenance costs have been considered for each site: cogeneration system, bio-ethanol production and DDG unit, extraction plants, pellettisation machines, storage of grain, juice and bio-ethanol.

As far the financial aspects are concerned, we have assumed an investment horizon of 20 years, a discount rate equal to 8%, a loan interest rate of 5.5% on a 12-year loan.

Finally, it has to be mentioned that the scheme proposed for Basilicata and Shandong is very different from the one for Inner Mongolia, which has a smaller size and is more focused on addressing the rural development issue. Nevertheless, according to the results of the site visits and inspections, a single large integrated complex could be established in Inner Mongolia as well.

6.1 Pisticci, Basilicata (Italy)

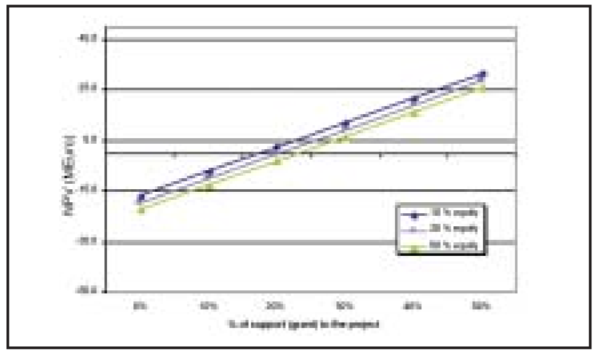
Italy is a very interesting market for the ECHI-T project. It offers several favourable conditions to the implementation of a Sweet Sorghum project, the most important of which are the following:

- Basilicata is an "Objective 1" region, i.e. funds are available for supporting sustainable energy projects.
- Italy has, in the past years, established a set of regulations promoting renewable energy (electricity) by means of the so-called Green Certificates, as well as energy efficiency.
- EU is promoting biofuels, therefore the project in Basilicata would fit perfectly into this strategy in terms of biofuel production and end use.

The following assumptions have been made.

The gross income for the farmers has been considered to be approximately 1,033 €/ha. This figure, which includes the income for the farmer (100 €/ha), corresponds to approximately 13.00 €/t of fresh bagasse and 125.00 €/ton of grain.

NPV vs support to the project in Basilicata (without DDG production, without CO_2 trading)

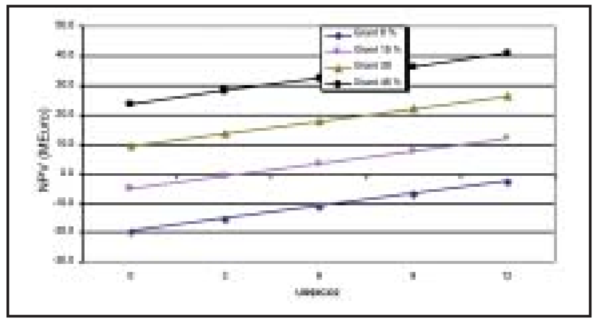


Issues on storage of the whole amount of grains have been considered. Sugar juice storage time has been assumed equal to one day (60 days processing time), while bio-ethanol storage capacity has been designed to satisfy 1 month production during the first two months.

Electricity has been valued according to the current Green Electricity tariff in Italy, i.e. it has been distinguished between the first 8 years of operation and the following years. Income from bio-ethanol has been valued at 250.00 €/m^3, DDG at 110.00 US$/t and that from pellets as animal feed at 41.32 €/t.
The total investment has been estimated equal to 143.6 M€.

The main results of the economic analysis for the project in Basilicata indicate that sponsorship (around 40% of the total investment cost) is needed to make the project economically feasible without CO_2 trading.

CO_2 trading improves the results, but at least 30% support to the investment is necessary even considering CO_2 selling values of 6 US$/t$CO_2$. Of course 9-12 US$/tCO_2 would produce better economic returns for the investor. The analysis on the cost of the feedstock (in the range –20%, +20% of the predicted production cost) showed that the scheme is not very sensitive to it, unless it is decreased to figures as low as –40% of the reference values.



NPV vs CO_2 trading in Basilicata depending on project support (grant), without DDG production

However, the study on the techno-economic aspects in Basilicata indicated that, according to the given Sweet Sorghum yields, the production of DDG is not recommended, as the amounts of grains produced per year are very low. A second simulation has therefore been performed excluding production. The result, in this second case, is more positive: 20% grant, without CO_2 trading, already gives a feasible scheme (*top of page*). Valued at ~6 US$/t$CO_2$, CO_2 trading is sufficient to make the scheme feasible with only 15% support. The project in Basilicata, without DDG production, is also more sensitive to variation on the feedstock costs.

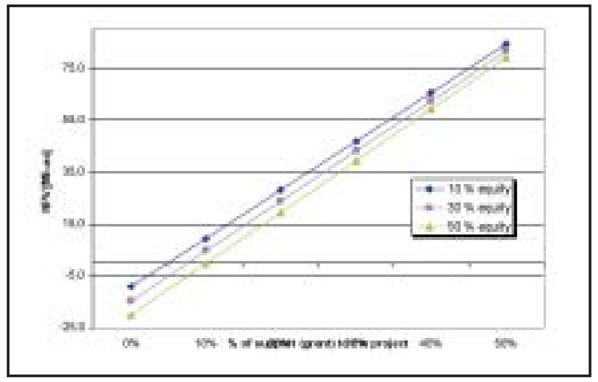
6.2 Dongying city, Shandong Province (P.R.China)

Given the basic assumptions and constraints considered for the three sites, the ECHI-T project probably finds in Dongying the most favourable conditions for its implementation.
The gross income estimated for the farmers is higher than that in Basilicata, i.e. 1,070 €/ha (including 100 €/ha income), but the crop management strategy and the specific costs for storage are instead similar.

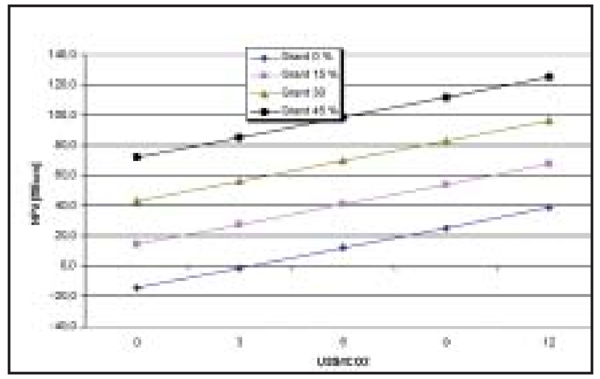
The electricity price from the grid is equal to 7.1 c€/kWh, the selling price of the electricity the grid is 9.1 c€/kWh and the electricity sold to the refinery (90 GWh/y) has been valued at 6.3 c€/kWh. As in the case of Basilicata, bio-ethanol has been valued at 250.00 €/m^3, while DDG at 151.00 US$/t and pellets as animal feed at 20.50 €/t. The total investment is estimated at 236.0 M€.

The economics of the project are such that a certain amount of support is still needed: depending on the equity, around 15-20 % of the total investment cost as grant would be necessary to reach positive results for the project. However, a proper combination of support with CO_2 trading mechanisms would be very attractive for the investor.

The sensitivity of the scheme to variations in the feedstock costs is very similar to that in CO_2 trading. The output of grains from crop cultivation is sufficiently high to justify the production of DDG. Nevertheless, as in the other locations, currently DDG production seems less economically interesting than direct selling of grains. In case of bio-ethanol production without DDG, 10% grant (with 10% equity) or a CO_2 selling price of 4 US$/t$CO_2$ is sufficient to obtain a positive NPV value.



NPV vs support to the project in Dongying (without DDG production, no CO_2 trading)



NPV vs CO_2 trading in Dongying depending on project support (grant), without DDG prodution

6.3 Huhhot, Inner Mongolia (P.R.China)

	with DDG	without DDG
NPV [Meuro]	40.5	43.1
IRR	15.0%	15.1%
PBP [years]	8.1	7.8

Table 6.1 Comparison of the two schemes in Dongying with/without DDG production (30% grant, 30% equity)

As already mentioned, the Inner Mongolia case offers similar conditions as those in Shandong, i.e. a project based on a single industrial complex of approximately 20,000 ha and 100,000 t of bio-ethanol production could be developed. It also has an important advantage over the other two sites: harvesting and cane processing can be performed on a longer time, thanks to the cold winter temperature.

However, in order to broaden the scope of the project, it has been decided to investigate if a cluster-based system, composed of 10 clusters of 2,000 ha each, would be possible. This approach would be very suitable for rural areas, such as western regions of P.R.China.

As far the assumptions on the economic analysis are concerned, the gross income for the farmers is the highest in Huhhot, reaching 1,230.00 €/ha. This figure, based on available information and survey in the Inner Mongolia region, seems excessive: it is probably due to the existing farm structure supplying Sweet Sorghum for wine production. However, industrial production of crops for bio-ethanol should lead to significantly lower figures.

The juice processing time is longer than in the other two sites, and therefore the storage parameters is adjusted accordingly.

Due to the smaller size of the scheme in Huhhot, cogeneration is not considered: electricity is bought from the grid (2.5 GWh/y) at a price of 7.1 c€/kWh.

Similarly to Dongying, bio-ethanol has been valued at 250.00 €/m^3, and pellets as animal feed at 20.00 €/t. It has to be remarked that bio-ethanol for wine production would have had a commercial value of approximately 464.00 €/t.

The total investment for each unit (2,00 ha) is 36.5 M€ with DDG and 25.7 M€ without DDG production.

The scheme in Huhhot never reaches a positive balance, even if huge support is taken into account. One of the main reasons for that is the high production cost of the Sweet Sorghum. Another element, which is not in favor of small systems, is that cogeneration is not used, while only process steam is produced from bagasse pellets: therefore, an important source of income (electricity selling) is not available. DDG has been first considered in the scheme, but excluded later on due to negative results.

Moreover, another calculation has been performed assuming the gross income of the farmer in Huhhot similar to that in Basilicata. Even in this case, a large public support (grant) of 60 % of the total initial investment combined with CO_2 trading (at 4 US$/t$CO_2$) is necessary to make the overall economic results positive.

Finally, if a large integrated complex is established in Huhhot, the expected results are very favourable. In fact, in contrast to the already positive balance of the scheme in Dongying, Huhhot offers the advantage of reducing the overall investment cost (mainly cogeneration, bio-ethanol production, pelletisation and storage) thanks to the longer processing period for Sweet Sorghum stems and bio-ethanol produced from juice.

6.4 Conclusions on economic aspects

TThe ECHI-T scheme has been evaluated based on local conditions and on data provided by the project partners. The following main conclusions can be reached:

- The scheme is economically feasible with public support, the amount of which is determined by site elements. The implementation of CO_2 trading schemes will greatly reduce the grant needed.
- Larger complexes are preferable. Dongying is the most successful case among the three studied, while Huhhot is the worst case. However, on the basis of the analysis carried out in Dongying and local climatic data in Huhhot, a single large integrated complex in Huhhot should have the best economic returns.
- Given the present technology costs, the ECHI-T scheme seems not suitable for small rural development schemes, unless major adaptations are implemented.
- DDG production is not necessarily the most convenient economic option, depending on the market price of this product.
- The adoption of a four-months harvesting strategy, or the implementation, when possible, of two crop cycles per year could also make a significant contribution to the improvement of the project results.
- The investments in bio-ethanol technologies is significant, due to the short processing time available for bio-ethanol-from-juice production (2 months in Basilicata and Dongying, 5 months in Huhhot). The combination of Sweet Sorghum with other ethanol crops could extend the use of these plants and therefore improve the economics of the project.

7. Project financing

The Chinese government has been making continuous effort to develop renewable energy resources. Starting with the Eighth Five-Year Plan, renewable energy development and utilisation have been an important part of the national development strategy. However, many factors that have hampered the progress still remain. Issues such as the need for an integrated renewable energy policy, insufficient investment, and lack of necessary non-technical infrastructure, continue to limit the development and commercialisation of renewable energy technologies.

7.1 Administrative bodies and/or energy agencies in P.R.China

The main institutions dealing with energy and/or investment related issues are described in the chapter on Legal Issues. They can be summarised as follows:

- The State Development and Planning Commission (SDPC), which emerged from the merge of the State Planning Commission (SPC), and the local Development Planning Commission in May 1998.
- The Ministry of Science and Technology (MOST), which plays an active part in the formulation and implementation of energy policy regarding research and demonstration projects, together with the Academy of Science and the Academy of Social Sciences, which have a number of research institutes under their wings.
- The State Economic and Trade Commission (SETC), whose Resources Conservation and Comprehensive Utilization Department takes on a major role in developing a national supply of technologies in the field of renewable energy.
- The Energy Division of the Ministry of Agriculture, which is also involved in rural energy supplies, although it concentrates on the use of biomass for electrical and/or non-electrical purposes.
- The Ministry of Foreign Trade and Economic Co-operation (MOFTEC), with respect to foreign investments and joint-ventures.

7.2 Renewable Energy Sources Incentives

The central government has taken the following measures to promote renewable energy:

(a) In 1995 the Chinese Government promulgated the Electric Power Act. In the first chapter (Introduction) it clearly states that P.R.China encourages the use of renewable and clean energy sources. The deployment of renewable energy resources will be encouraged and supported by the government.

(b) The Guidelines of the Ninth Five-Year Plan and 2010 Long-Term Objectives on Economic and Social Development in P.R.China, approved by the Eight National People's Congress, have become the primary guidelines for the Chinese government in energy development. The guidelines call for actively developing new and renewable energy resources, and improving energy infrastructure. For rural electric development, the guidelines emphasize the importance of e.g. biomass resources and that the development strategies should adapt to local conditions.

(c) The 1998 Energy Conservation Act again recognises and emphasises the importance and strategic role of using renewable energy to replace fossil fuels, reduce emissions and to protect the environment.

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In parallel with national laws and programmes 'Economic Incentive Policies' have been implemented, as i.e.:

(a) Import Duty Reduction Some renewable energy technologies enjoy special low rates.
(b) Reduction in Value Added Tax Although not all renewable energy technologies enjoy reduced VAT rate, the VAT for biogas is only 13%.
(c) Reduction in Income Tax Governments of several provincial and autonomous regions have initiated special low or even "zero" income tax rates to encourage the development of renewable energy technologies.
(d) Low Interest Loans The amount of low interest loan for specific renewable energy projects was increased to 120 million RMB in 1996.

Government supported R&D

Central Government supports renewable energy by establishing R&D strategy and plans for the renewable energy industry and is funding many R&D projects directly. R&D initiatives cover the following three major areas:

(a) To support various renewable energy research institutes and research projects.
(b) To subsidise renewable energy demonstration projects.
(c) To target specific technologies for improvement and provide necessary training.

7.3 Financing opportunities

7.3.1 Project financing techniques (Italy and P.R.China)

In project financing (i.e. limited recourse financing), lenders take collateral from a borrower so that if the loan cannot be repaid the collateral may be sold and the proceeds used for loan repayment. Recourse against the sponsors of the project is possible only in very restricted circumstances.

Project financing has been technically feasible under Chinese law since the promulgation of the so-called guarantee law which was adopted on the 1st October 1995 at the 14th Meeting of the Standing Committee of the 8th National People's Congress on 30 June 1995 (« the Guarantee Law »). The Guarantee Law provides for a legal framework for guarantees, mortgages and pledges. It should be noted that Chinese mortgages are rather weak as a mortgage may not be enforced without a prior judgment of a Chinese court.

In other words, the debt raised to finance the ECHI-T project might be secured, fully or partly, by the assets of the said project, namely:

(i) the cash flow generated by the project ; this can be done through pledging a tender-established cash collateral account into which the purchasers deposits all revenue; the lenders then apply the money to debt service, after the payment of the operating expenses of the project;
(ii) real property (land and the buildings);
(iii) industrial equipment, vehicles, etc. ;
(iv) intangible assets (technology rights, technology licenses, trademarks, patents, etc.) ;
(v) permits, licenses and concessions (provided that Chinese law allows it) ;
(vi) contracts ;
(vii) insurance proceeds ;
(viii) surety bonds, if any, provided by contractors ;
(ix) guarantees ;

(x) liquidated damages ;
(xi) political risk insurance ;
(xii) bank accounts ;
(xiii) carbon emission credits.

Of course, in Italy, project financing is technically feasible.

7.3.2 Carbon Emission Credits (Italy and P.R.China)

Non-Chinese (or non-Italian) investors, facing a relatively high cost to meet carbon reduction targets (i.e. US$ 100 per ton of carbon), might prefer to invest in the ECHI-T project in P.R.China and/or Italy at a cost of, say, US$ 10 per ton of carbon. Any amount paid for the carbon emission reduction above the price of US$ 10 per ton of carbon will be net income for the ECHI-T project and may enhance its financial viability.

It should be noted that to the International Finance Corporation (IFC), the resources to be spent by companies from OECD countries to acquire carbon emission certificates may be considered as a new source of co-financing for projects that result in lower greenhouse gas emissions than the «business-as-usual» situation. Any biomass project is therefore particularly appealing to the IFC.

7.3.3 Non-private sources of funding

7.3.3.1 Grants and subsidies

The European Structural Funds - Objective 1 (Italy)

In order to improve the transparency of Community legislation, the European Council found it desirable to combine all the provisions concerning the Structural Funds into a single regulation and to repeal the Regulation (EEC) No. 2052/88 and the Council Regulation (EEC) No. 4253/88 of 19 December 1988, which lay down provisions for implementing Regulation (EEC) No 2052/88 regarding the coordination of activities of different Structural Funds, on one hand, between themselves and with the operations of the European Investment Bank and the other existing financial instruments, on the other hand. This was done in the Council Regulation (EEC) No. 1260/1999 of 21 June 1999 which lays down general provisions on the Structural Funds (the "Regulation No. 1260/1999"). This Regulation, in its Article 29, was amended by the Council Regulation (EEC) No. 1447/2001 of 28 June 2001.

At the end of the programming period provided for in the Regulation No. 1260/1999, which took more time than expected, the European Commission issued, on 5 July 2001, a Communication on the results of the programming of the Structural Funds for 2000-2006, but restricted to Objective 1 (COM52001) 378 final.

Each of the Structural Funds, the EIB and the other financial instruments contribute in appropriate fashion to the attainment of the following three priority objectives:

(i) promoting the development and structural adjustment of regions whose development is lagging behind (hereinafter referred to as "Objective 1");
(ii) supporting the economic and social development of areas facing structural difficulties ("Objective 2");
(iii) supporting the adaptation and modernisation of policies and systems of education, training and employment ("Objective 3"); Objective 3 provides financial assistance outside the areas covered by Objective 1 and provides a policy frame of reference for all measures to promote human resources in a national territory without prejudice to the specific features of each region.

On 1st July 1999, the list of the regions covered by Objective 1 of the Structural Funds for the period from 2000 to 2006 (published in EC-O.J. of 27 July 1999, L 194, pp. 53 et seq.) was established. Basilicata is mentioned on the list of the regions concerned by Objective 1 for the period from 1st January 2000 to 31 December 2006.

Structural Funds may finance expenditure for major projects, i.e. those:

(i) which comprise an economically indivisible series of works fulfilling a precise technical function and which have clearly identified aims; and
(ii) of which the total cost that should be contributed by the Structural Funds exceeds EUR 50 million.

As for investment in infrastructure which generate substantial net revenue, the contribution of the Structural Funds may not exceed 40% of the total eligible cost in the regions covered by Objective 1. This rate may be increased for financing forms other than direct assistance, provided that this increase does not exceed 10% of the total eligible cost.

Operating expenditure is eligible for support from the Structural Funds only if these activities are essential for the implementation of the project. Expenditure may not be considered eligible if it has actually been paid by the final beneficiary before the date when the application for assistance reaches the European Commission. That date shall constitute the starting point for the eligibility of expenditure. It appears that Structural Funds budget for the Basilicata is not yet exhausted.

With the Global Environmental Facility (GEF), grants of less than US$1 million are available through expedited procedures that speed up processing and implementation. To the best of our knowledge, the GEF is more or less the only institution to give grants for this type of projects. The GEF funds projects in four focal areas: biodiversity, climate change, international waters, and ozone. Projects to address land degradation, as it relates to the four focal areas, are also eligible for funding.

GEF climate change projects are organized in four areas:
1) removing barriers to energy efficiency and energy conservation;
2) promoting the adoption of renewable energy by removing barriers and reducing implementation costs;
3) reducing the long-term costs of low greenhouse gas emitting energy technologies; and
4) supporting the development of sustainable transport.

From 1991 to 1999, the GEF allocated US$884 million to 227 climate change projects and related activities, which was matched by more than US$4.7 billion in co-financing.

To be eligible, any individual or group who proposes a project must meet two key criteria:

(i) it must reflect national or regional priorities and have the support of the country or countries involved and
(ii) it must improve the global environment or advance the prospect of reducing risks to it. GEF project ideas may be proposed directly to UNDP, UNEP, or the World Bank.

Country eligibility for funding is determined in two ways. Developing countries that have ratified the relevant treaty are eligible for biodiversity and climate change projects. The PRC ratified the United Nations Framework Convention on Climate Change in December 1992. Other countries, primarily those with economies in transition, are eligible if the country is a party to the appropriate treaty and is eligible for borrowing from the World Bank or receiving technical assistance grants from UNDP.

Let's look at an example a renewable energy project financed by GEF: the Capacity Building for the Rapid Commercialisation of Renewable Energy (CCRE) which was authorised by the Global Environmental Facility (GEF) in 1998 and launched in March 1999, for an initial term of 5 years. This project promotes the generation of electricity from bagasse in CHP plant. It aims at making a contribution to institutional capacity building and the implementation of demonstration projects. The CCRE Project has obtained financial support by the Australian and Dutch governments.

It should be noted that P.R.China is a world leader in the use of anaerobic biomass gasification plants. Along with millions of small and micro-scale plants, which mainly deal with liquid manure on farms,

there are about 150 larger plants in which the organic content of industrial effluent (from the paper, sugar and pharmaceutical industries and from alcohol and food production) is decomposed. If only 50% of the industrial effluent were treated, the quantity of biogas obtained would be equivalent to the present level of natural gas production in P.R.China.

As a first step to implement of the CCRE Project, the Chinese Renewable Energy Industries Association (CREIA) was founded. The CREIA sees itself as an intermediary between the industry and the authorities and aims at bringing national and international project developers and investors together. One of the services that the CREIA offers is a database of the most important national and international projects in the field of renewable energy. It should be noted, however, that these arrangements are a directive from central government. Implementation is therefore crucially dependent on the political will of the provincial government concerned.

7.3.3.2 International or Regional Development Banks

For P.R.China the International Finance Corporation (IFC) promotes sustainable private sector investment in developing countries as a way to alleviate poverty and improve people's living standards.
The IFC is a member of the World Bank Group and is headquartered in Washington, DC. It provides:

(i) loans for IFC's own account: A-loans ;
(ii) equity finance;
(iii) quasi-equity finance: C-loans;
(iv) syndicated loans: B-loans;
(v) risk management products; and
(vi) intermediary finance.

The IFC operates on a commercial basis. It invests exclusively in for-profit projects and charges market rates for its products and services. As a rule, the enterprises that the IFC finances must be majority private sector owned and controlled. Exceptions can be made for state-owned enterprises that are in the process of being privatized. Although the IFC does not demand any government guarantees for its financing, IFC's projects often require close cooperation with government agencies in developing countries.

In order to be eligible for IFC funding, a project must meet a number of IFC criteria:

(i) the project must be located in a developing country, which is a member of IFC (which is the case for P.R.China);
(ii) it must be in the private sector;
(iii) it must be technically sound;
(iv) it must have good prospects of being profitable;
(v) it must benefit the local economy; and
(vi) it must be environmentally and socially sound, satisfying IFC environmental and social standards as well as those of the host country.

A company or entrepreneur, foreign or domestic, seeking to establish a new venture or expand an existing enterprise can approach IFC directly by submitting an investment proposal. After this initial contact and a preliminary review, IFC may proceed by requesting a detailed feasibility study or business plan to determine whether or not to appraise the project.

To ensure the participation of investors and lenders from the private sector, IFC limits the total amount of own-account debt and equity financing it will provide for any single project. For new projects the maximum is 25% of the total estimated project costs, or, on an exceptional basis, up to 35% in small projects. For expansion projects IFC may provide up to 50% of the project cost, provided its investments do not exceed 25% of the total capitalization of the project company.

The ECHI-T project falls, within the IFC's classification, under the competence of the Power Department.

The Asian Development Bank (ADB) can mobilize commercial cofinancing of ADB-assisted private sector projects, using the following methods:

(i) uncovered parallel loans;
(ii) complementary financing schemes;
(iii) guarantees covering commercial and / or political risks; and
(iv) co-financing with export credit agencies

The ADB offers its borrowers LIBOR-based loan (LBL) carrying a floating lending rate that consists of a six-month LIBOR and a spread fixed over the life of the loan. Borrowers will have a high degree of flexibility under the new LBL lending facility, such as:

(i) choice of currency and interest rate basis;
(ii) options to link repayment schedules to actual disbursement for financial intermediary borrowers;
(iii) change the original loan terms (currency and interest rate basis) any time during the life of the loans; and
(iv) options to cap or collar the floating lending rate at any time during the life of the loans.

At the end of 2000 the Asian Development Bank (ADB) launched a programme to promote clean and renewable energy sources. The project has a total volume of US$ 98 million and a credit volume of US$ 58 million. Up 2003 it will support the construction of three grid-coupled wind farms with a total generating capacity of 78 MW. This is the first ADB-financed environmental project in P.R.China. It has been co-financed by the Global Environment Facility (GEF) with a grant of US$ 6 million and an interest-free loan for the same amount. The GEF loan only has to be paid back in full if the project is economically successful.

ADB is also introducing its latest technical assistance project to P.R.China to help tackle rising environmental problems. According to the new plan "PREGA," 10 to 15 energy projects will be selected in the coming months, and each will be financed by ADB or other international financial institutions to promote energy efficiency, greenhouse gas abatement and the use of renewable energy. PREGA is part of ADB's Renewable Energy, Energy and Climate Change (REACH) Programme, established early this year. REACH, which coordinates renewable energy and energy efficiency and monitors climate change activities, is supported by the Netherlands, Canada and Denmark. Apart from ADB, the project - which is starting in 2002 and will end in 2004 - will be funded by commercial, multilateral, and bilateral sources. The sources include the GEF and the Clean Development Mechanism (CDM). The State Environmental Protection Administration (SEPA) will oversee the study for P.R.China and generate project proposals up to the pre-feasibility stage.

The European Investment Bank (EIB) is authorized to grant loans for projects in P.R.China and Italy and has already financed an infrastructure project in the PRC for at least once. Outside the European Union, the EIB participates in implementing the European Union's development aid and cooperation policies through long-term loans from own resources or subordinated loans and risk capital from EU or Member States' budgetary funds.

Promoters in both the public and private sectors may enter into individual loans with the EIB. The loan may be made directly with the EIB if capital investment project exceeds EUR 25 million and up to 50% of the investment costs. In the industrial sector, the project horizons are up to 12 years and, for infrastructure projects, up to 20 years, or more in exceptional cases. The interest rates are at a commercial level. Nevertheless, they are attractive given the AAA rating of the EIB.

7.3.3.3 Export Credit Agencies (ECAs)-Credits and Insurances (China and Italy)

Direct export credit usually comes in the form of a buyer credit, whereby credit is provided directly to the importer or buyer to fund the procurement of exported goods or services primarily from the country in which the ECA is located.

Export credit can also be extended through a supplier credit, whereby a supplier makes a sale based on deferred payment terms, with export credit insurance protecting the supplier or its commercial bank against the buyer's failure to make payments when they become due.

Export credit is often part of a project finance package. The mandate of most ECAs is to fill a financing gap and cover the risks that the commercial market is not willing to take.

We assume for the time being that the European partners will be mainly Italian, German, Swedish and Belgian. Those European partners export equipment to the PRC for the ECHI-T Project, the involvement of the export credit agencies from the exporters-based countries can be envisaged.
The relevant export credit agencies are as follows:

(i) Hermes in Germany;
(ii) EKN in Sweden;
(iii) SACE in Italy; and
(iv) Ducroire in Belgium.

It should be verified, on a case-by-case basis, whether or not those agencies are willing to deal with PRC projects.

7.3.3.4 The Multilateral Investment Guarantee Agency (MIGA)

The MIGA is a member of the World Bank Group and is based in Washington, D.C.
MIGA provides non-commercial guarantees (insurance) for investments in developing countries. MIGA's guarantees protect investors against the risks of transfer restriction (including inconvertibility), expropriation, war and civil disturbance, and breach of contract. MIGA issues guarantees for up to 15 years and, occasionally, 20 years. In guarantees that cover loans, MIGA usually issues coverage to match the length of such loans.

MIGA currently has a limit of $420 million per country on a net basis. However, MIGA works closely with public and private insurers, using, for example, treaty and facultative reinsurance as well as coinsurance to augment its capacity limits.

There is no minimum size limit for a project. At present, MIGA can cover up to $200 million per project, which may be supplemented through MIGA's coinsurance and reinsurance programs.

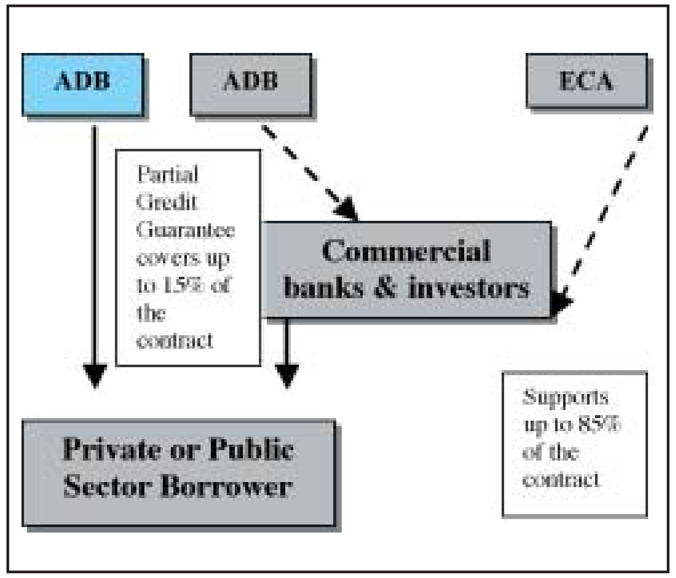
It should be noted that the MIGA has signed a protocol of Agreement with the People's Insurance Company of P.R.China.

7.3.4 Co-financing

Official co-financing is an arrangement under which official funding agencies finance a single project. These official funding agencies may provide funds on a parallel or joint basis.

In a parallel co-financing, each of the co-financiers finances separate components of the project, with each co-financier following its own procurement procedures for the components it finances. In a joint co-financing, the co-financiers together finance common goods and services for the project on a pro rata basis; this type of co-financing works well when a co-financier does not tie its assistance to procurement from its own country, and agrees to follow the procurement guidelines of a leader co-financier. Most official co-financing is arranged on a parallel basis.

An example of co-financing arrangement: co-financing at ADB. ADB promotes coordination with the other funding agencies as follows.



Example of co-financing arrangement.

When formulating ADB's operational strategy for each of its developing member countries (DMCs),

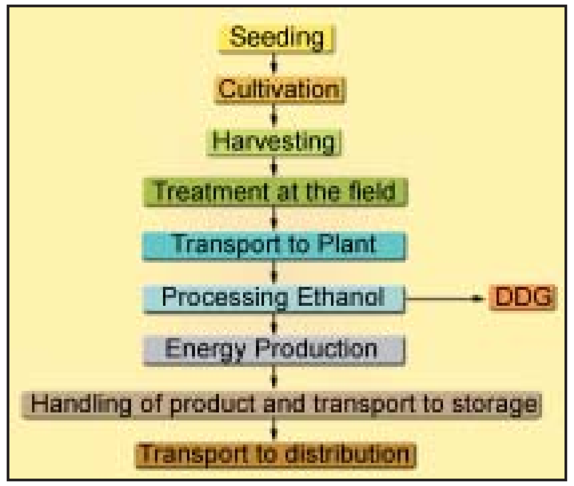
(i) ADB contacts the other major official funding agencies in the country, for collecting information on their aid strategies and operational objectives;
(ii) ADB identifies cofinancing opportunities related to specific projects when the Country Strategy and Programme in the DMC concerned is formulated, and later (if required), when project preparatory technical assistance is provided; and
(iii) ADB explores opportunities for cofinancing during all stages of the project cycle, and welcomes cofinancier participation in appraisal missions, subject to government concurrence, as well as in project implementation review missions. For instance, ADB develops co-financing with export credit agencies (ECAs), as described in the scheme.

8. Environmental analysis

This section aims at examining the environmental performances of the integrated complexes in the three sites, and to report about bio-ethanol from Sweet Sorghum as a transport fuel.

The energy consumption as well as the CO_2 emissions "from cultivation to vehicle" have been computed based on local conditions. Fossil and Renewable Energy were both examined: CO_2, CO, HC, NO_x, Particles and SO_x emissions were considered.

The effects from transport of fossil fuels on the oceans which causes spill and emissions during drilling and production have not been evaluated in this study.



Overview of the system under consideration

An overview (*above*) of the system which have been analysed is given.

A two year rotation scheme for crop cultivation has been chosen, since it was considered sustainable and compatible with the existing cultivation patterns.
Depending on the seeding strategy, and based on average figures for yields, climate and water demand, irrigation will only be needed in Huhhot and Basilicata (not in Dongying). The amount of annual average irrigation needed is estimated at approximately 475 mm for Basilicata and 120 mm for Huhhot. From an environmental point of view, it is very important that irrigation is performed as much as possible by surface water and with energy-efficient systems.

The specific amount of fossil energy use is around 0.4-0.5 kWh/litre of ethanol, since renewable energy is used for the production of the heat and the electricity needed by the integrated complex. This is a very low figure, as common figures for ethanol from corn in USA are around 0.9-1.0 kWh/litre of ethanol. The amount of fertilizers and pesticides in the case of bio-ethanol from Sweet Sorghum are also lower than in the case of ethanol from corn.

Activity	*Basilicata*	*Dongying*	*Huhhot*
Summary of cultivation of Sweet Sorghum	0.2876	0.1924	0.1182
Irrigation of land	0.0737	0.0000	0.0151
Total energy at fields processing	0.0019	0.0008	0.0008
Transport field to plant	0.0022	0.0424	0.0042
Total fossil heat for processing	0.0995	0.1440	0.0865
Fossil electricity	0.0001	0.0001	0.0912
Summary ethanol to the market	0.0593	0.0593	0.0780
Total fossil energy	0.5242	0.4389	0.3939
Fossil energy use in% of produced ethanol	8%	7%	6%

Table 8.1: Total fossil energy (kWh/litre ethanol)

Table 8.2: Fossil energy divided into share of activity

Activity	*Basilicata*	*Dongying*	*Huhhot*
Summary of cultivation of Sweet Sorghum	55%	44%	30%
Irrigation of land	14%	0%	4%
Total energy at fields processing	0%	0%	0%
Transport field to plant	0%	10%	1%
Total fossil heat for processing	19%	33%	22%
Fossil electricity	0%	0%	23%
Summary ethanol to the market	11%	14%	20%
Total fossil energy	100%	100%	100%

The total fossil energy demand per activity, in kWh/litre of ethanol and as% of total demand, is given in the following tables.

Table 8.3: Emissions kg/litre of ethanol

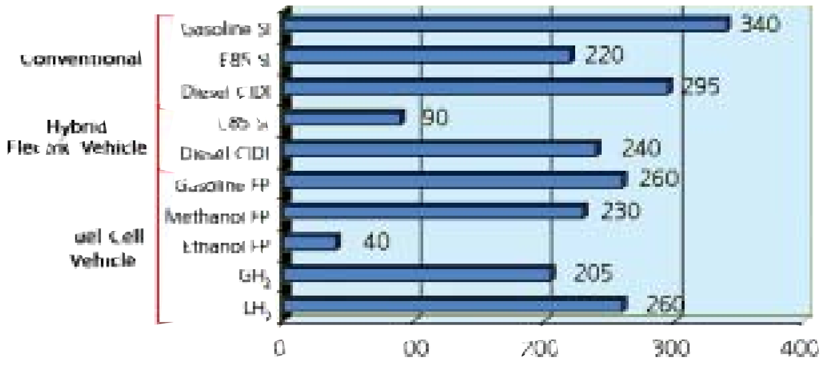
	CO_2	CO	HC	NO_x	PM	SO_x
Basilicata	0.1415	0.0007	0.0001	0.0027	0.0004	0.0002
Dongying	0.1185	0.0006	0.0001	0.0025	0.0004	0.0002
Huehot	0.1063	0.0006	0.0001	0.0023	0.0004	0.0002

Table 8.4 : Emissions (ton per year)

	CO_2	CO	HC	NO_x	PM	SO_x
Basilicata	7,467	38	5	142	22	9
Dongying	15,062	74	10	313	53	21
Huehot	14,109	85	10	308	55	21

The total energy demand including renewable energy is also low: comparable figures can be found in sugarcane-based ethanol production.

The emissions in the three sites have been calculated: they are summarised in the following tables.



Notes: Results are expressed in grams/kilometre

E85 = 85% ethanol, 15% petrol;
SI = spark ignition;
CIDI = compression ignition direct injection;
FP = fuel processor;
GH_2 = gaseous hydrogen from natural gas
LH_2 = liquid hydrogen from natural gas.

C_{O2} emissions estimated by Life Cycle Analysis: conventional and hybrid fuels/vehicles (Source: General Motors, Argonne National Laboratory, BP, Exxonmobil, and Shell, (2001). Well-to-wheel energy use and greenhouse gas emissions of advanced fuel/vehicle systems: North American analysis.)

As far as regards the final use of bio-ethanol, the levels of reduction in CO_2 emissions (shown in table 8.5) varies depending on how the ethanol is used. In this respect, an "exchange factor" is defined, which estimate the amount of fuel (biofuel or reformulated fuel) that gives the same driving range as the base-case fossil fuel.

If bio-ethanol substitutes gasoline in low-blending, 1 litre of ethanol is approximately equivalent to 1 litre of gasoline, as the oxygen in the ethanol improves the combustion of gasoline (for this reason ethanol is promoted in USA).

If instead ethanol is used in FlexiFuel Vehicles (like the Ford Focus flexifuel, that run either on E85 or on pure gasoline or on any blend in between), 25% more fuel is needed in case of E85 to maintain the same driving range as in case of gasoline In case of ethanol-buses, the factor is 60% more (i.e. 1,60).

Finally, if Fuel Cells are introduced on the market, the situation will change again, because ethanol is a better hydrogen carrier than gasoline and/or diesel. The exchange factor of 0.70 is an estimate commonly agreed for ethanol fed Fuel Cells.

As a general remark, it can be observed that flexifuel vehicles could work as a bridge, from today to the future re-fuelling system, as described in the market analysis.

A recent study published by Shell, BP, Exxon Mobil and General Motors confirms that bio-ethanol is environmentally superior to all other major fuels, especially if combined with hydrogen Fuel Cells.

CO_2 reduction when ethanol is used in different vehicles

		Basilicata	*Dongying*	*Huhhot*
Ethanol production ton/year		42,000	101,700	106,000
Fossil use: Seed to vehicle		8%	7%	5%
	Exchange factor	*CO_2 reduction ton/year*		
Low blending 5-10%	1.00	113,500	278,800	292,800
Reduction in kg/ha*a		16,300	14,700	14,800
Flexifuel vehicles E85	1.25	90,700	223,000	234,300
Fuel Cells with reformers	0.70	162,000	398,200	418,300
Diesel engines	1.60	81,100	199,300	209,400

1 liter gasoline: 2.36 kg CO_2
1 liter diesel: 2.70 kg CO_2

Table 8.5: Net CO_2 reduction in emissions for ECHI-T project depending on bio-ethanol use

Non-CO_2 emissions also depends on how the ethanol is used in engines. Low blending of ethanol in gasoline will reduce non-CO_2 emissions (as NO_x), but not as much as if diesel is substituted with ethanol.

It has to be remarked that emission tests on low-blending of ethanol in gasoline gave very different results depending on the type and the age of the tested vehicles. In general, all test showed that ethanol blending performs better: older cars gave higher reduction in emissions.
In summary, the production of fuel-ethanol from Sweet Sorghum is a successful step towards a more sustainable mobility.
The degree of benefits for the environment depends on:

- how the bio-ethanol production chain from seed to fuel will be implemented
- the level of engagement from the farmers to cultivate Sweet Sorghum in a sustainable way
- the yield in different parts of the chain
- the way bio-ethanol is used in different vehicles, and the type and age of these vehicles
- what is the kind of emission under investigation

As far as the bio-ethanol and DDGs production are concerned, no significant mass streams are expected from the plant, as water will evaporate at the DDGs-unit.

Water in the bio-ethanol plant will be re-circulated and the slop will go to the DDG plant for evaporation and fodder production.
The vent gases contains water and can produce some odours, but no other environmental problems are foreseen.

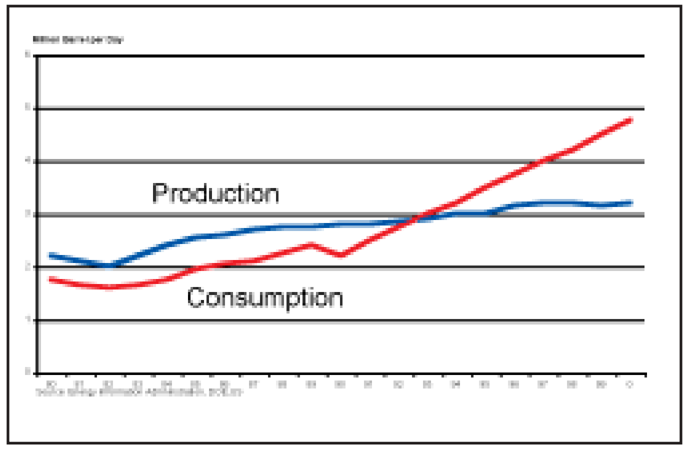
The use of bio-ethanol generates a long term positive impact on the local economy, the environment, the energy security, and on the development of the Sustainable World.

9. Market opportunities

The transport sector has an unbalanced use of oil that leads to an undesired dependency on fuel import. For example, Middle East represents 2/3 of the oil reserves in the world.
Through the local production and use of biofuels, not only the climate change can be reduced, but also the security of fuel provision is increased and regional development is created.
Large scale experiments and introduction in some countries like Brazil have shown that bio-ethanol is a good alternative to fossil fuels. Today ethanol is competing with gasoline in Brazil on market conditions without governmental support.

As far as P.R.China is concerned, it is easy to verify that the market for biofuels is almost insatiable there. Today the use of fossil based diesel and gasoline is nearly 100% in the transport sector. In P.R.China the demand for transport fuels increases annually with 15%, which means doubling in five years time.

The graph shows the development of production and use of oil in P.R.China.



Oil production and consumption in P.R.China

The two ECHI-T plants in P.R.China will only cover 0.8% of the transport need, equal to 5% of the annual increase. The production of ethanol in P.R.China has increased by 15% in the last five years: it was ~3.1 billion litres in 2001, mainly used in the chemical and food-alcohol market. The market for ethanol in the transport sector in P.R.China is under development, and a production capacity of 1.2 billion litres are planned in P.R.China.

The local or regional market of the ethanol for the two sites is rather large. However, the number of cars in the surrounding market is not sufficient for receiving all the produced ethanol. In the Shandong province there are approximately 0.6 million cars using about 600-million litre gasoline annually: considering 10% replacement in gasoline, the ethanol demand in the province will be around 50,000,000 litres of ethanol, compared to the production of 127,000,000 litres.

Neverheless, both Dongying and Huhhot are conveniently located for road transport to Beijing. Introduction of ethanol fuels in the Capital of the P.R.China will maximise the environmental advantages and the publicity. This acton should also include the development of the flexible infrastructure adjusted for today's and adopted for tomorrow's bio-fuels.

As far as Italy is concerned, during the last five years the Italian production of ethanol have decreased more than 20%, due to the reduction in excess of wine and the shutdown of a molasses based ethanol plant. In the year 2001, the Italian production was 190,000,000 litres.

In the case of Basilicata, the ethanol could be used in the Southern Italy transport sector. The ECHI-T plant would only cover 0.5% of the Italian gasoline market, which is approximately 10 billion litres annually.

Ethanol prices and customs

The "normal or medium price" of anhydrous bio-ethanol bought from Brazil or other countries could be around 30 c€/litre on the world market. The world's spot market price of anhydrous ethanol during the last five years has fluctuated between 19 c€/litre up to 43 c€/litre. This includes transport and handling costs but not custom duty. The custom duty on import of ethanol to EU from third countries is ~19 c€/litre.

Today ethanol is not a commodity traded like oil and chemicals. It is seen as an agricultural product with

regulations and customs duty in most countries, especially in the European Member States.
Production cost for ethanol in Brazil is, according to the sugarcane industry, around 22 c€/litre anhydrous ethanol. The production cost of ethanol from corn in US is slightly greater, with 25 c€/litre at the ethanol plant gate.

Production cost from wheat in Europe between 38-48 c€/litre anhydrous ethanol. The higher prices are from rather new plants with high capital cost, and it can be estimated that the cost will decrease during time. Due to the import taxes, they can still operate on the market without serious competition from third countries. The price of imported ethanol will be around 40-45 c€/litre after customs duty.

Liquid biofuels production will create opportunities for new and additional jobs, especially in marginal rural areas. The European Commission estimates that a biofuel contribution of around 1% to total European fossil consumption would create between 45,000 and 75,000 new jobs. The most of these jobs would be located in rural areas. The creation of an European market for biofuels will also offer an opportunity for the Accession Countries.

Bio-ethanol produced from grains converts the starch, but not the proteins and fibre, which are recovered and sold as Distillers' Dried Grains, a high value added animal feed that replaces in the market imported American transgenic Soya meal and animal feedstuff now forbidden in Europe due to "Mad Cow Disease".

Biofuel development offer an opportunity for trade to promote sustainable development: in particular, this new market could help developing countries like P.R.China which strongly dependend on agriculture.

Bio-ethanol as gasoline replacement

The easiest way to introduce bio-ethanol in the market is to blend 5-10% bio-ethanol in gasoline, or convert ethanol to ETBE and blend it in gasoline. Today, Otto engines cars can use both bio-ethanol and ETBE in gasoline. As MTBE now are going to be phased out in California due to ground water pollution and related cancer risks, ETBE can be seriously considered for gasoline reformulation in the future.
Following the trends of development in Sweden and US of flexifuel vehicle and Fuel Cells, it is recommended to consider the construction of a flexible alcohol compatible refilling infrastructure.

Ford is investing in Europe starting with Sweden by introducing small, ethanol/gasoline flexible fuel vehicles build in Europe and introduced as a world market car. Before the end of year 2003 about 10,000 Ford Focus flexifuel cars will be delivered to participants throughout Sweden.

Today the fuels pure ethanol, e85 and e5-25 are easily available at the refuelling stations in Sweden, US and Brazil. In Brazil and US large oil companies are involved in the distribution of ethanol, but also

Ford Focus
Flexifuel Vehicle

ECHI-T - LARGE BIO-ETHANOL PROJECT FROM SWEET SORGHUM IN P.R.CHINA AND ITALY

smaller companies owned by the Farmers in the area are involved in this activity.

Bio-ethanol as diesel fuel

Sweden has become the only country in the world having a heavy diesel vehicle fleet running on pure bio-ethanol. The main part of the fleet is composed by approximately 410 city buses.
During the last years Scania and Akzo Nobel in co-operation performed ethanol bus fleet tests in Denmark, Brazil, Mexico and Australia. Etamax D, or "The bus fuel" as it often called, is a diesel replacing fuel based on ethanol and standardised on the Swedish market.

From exhaust emission tests, it is confirmed that the bio-ethanol buses generate less nitrogen oxides and particulate emissions than standard diesel buses. Carbon monoxide, hydrocarbons and other organic compounds are also lower when reformulated ethanol is used as diesel fuel.

E-diesel is instead a blend of 10-15% anhydrous ethanol and 5 -10% solubilizer additive in diesel oil. The solubilizer additive makes ethanol and diesel oil "splash blended" which means there is no equipment or heating required getting a homogenous fuel.

Summarising, bio-ethanol gives a really good market opportunity to replace both gasoline and diesel in the transport sector. The market price of both produced and imported ethanol, the taxation levels in different countries and the possibilities to reduce taxation on biofuels create favourable conditions for a very large market penetration in Europe and P.R.China. The main limitation is given by the available land and biomass to cultivate crops for bio-ethanol and energy.

10. CO_2 trade-off

Biomass is a renewable energy source with approximately no net CO_2-emissions: therefore, when biomass energy generation systems instead of fossil fuel systems are installed, CO_2-emission reduction takes place. This environmental benefit can be converted into CO_2 emission reduction credits that can be traded. European industries and investors willing to reduce CO_2 emissions could do so by taking costly technical measures in Europe, or they might also achieve this goal by investing in CO_2 emission-reducing methods in the Third World. The investment costs per ton of CO_2 emission reduced in these countries are often lower than those in Europe: technologies in developing countries are usually less advanced than in Europe, i.e. with a lower efficiency and more serious environmental impact. This method is advantageous for both sides: European countries achieve their CO_2 emission reduction goals with relatively low costs and make profits by exporting technology or know-how, and third countries get access to advanced technologies.

What is described above is a brief explanation for the so-called "flexible mechanisms", born after the Kyoto Protocol, which allow countries to achieve CO_2 reductions where the cost is the lowest. Emission reduction from specific projects can be traded. Under the "Joint Implementation" mechanism, it is possible to earn revenues when the projects are located in countries where Kyoto Targets will be met (e.g. Europe). On the contrary, Clean Development Mechanisms are related to developing countries, and - provided that the project satisfies certain conditions - they might attract investments. Generally, both type of projects have to fulfil some "eligibility requirements", namely the "environmental additionality". This means that the reductions in emissions must be incremental to those that would occur in absence of the certified project activity. In some cases a proof of the "investment additionality" is also required, which means that project financial data must be provided for investors to assess whether the carbon value makes the project viable.

Currently, the main investors in carbon trading are a mix of governmental (for instance, the Dutch government) and private actors.

Different projects and programmes on Joint Implementation/Clean Development Mechanism (JI/CDM) have already been implemented in the last 2 years. However, so far the average price of CO_2 has not been fixed in the international market: in some cases the average price paid for CO_2 emissions reduction credits has been up to 8 €/t CO_2 (price set in the Dutch carbon purchasing programme "EruPT"), while the World Bank Prototype Carbon Fund (created in 1999) has set a price of US$ 3/t CO_2 (REFOCUS, Jan/Feb 2002).
Before the project is implemented, different steps have to be taken, first of which is the "carbon assessment". This consists of a study to assess whether the project is eligible under the CDM/JI, and to quantify the potential for carbon trading revenues. As far as the ECHI-T project is concerned, this latter is described in the section below.

Bio-ethanol production - ECHI-T project

From the environmental point of view, bio-ethanol can be a very promising CO_2-saving instrument.
The industrial bio-energy complexes, envisaged in the "ECHI-T" project, is a good example of projects which in principle could be eligible under JI (Basilicata Complex, Italy) and CDM (Dongying and Huhhot, P.R.China) mechanisms. This could further improve the competitiveness of such projects.

The life-cycle methodology can be a good and reliable instrument to determine precisely the amount of CO_2 saved. A life-cycle analysis is the comprehensive "cradle-to-grave" account method which describes a product's flow to and from the environment: and it concerns both air, water and solid waste emissions, as well as other primary resources extracted from the environment. Generally speaking, a life cycle analysis is very time-consuming work, and nowadays specific softwares have been developed to perform the calculations.

Currently various international and national bodies are developing international guidelines (ISO 14040, 14041, 14042 and 14043) and associated protocols to standardise CO_2 emissions calculations/estimations, with the aim of being consistent with guidelines and good practices issued by the IPCC. The guidelines should include general methodologies for data collections, calculations of greenhouse emissions, reporting conventions, definitions of boundary conditions, plus data quality control/assurance and treatment of uncertainties.

In the case of the ECHI-T project, the assessment of the CO_2-saving potential has been performed by means of general algorithms, which provide approximate but realistic figures without implementing a complete LCA study.

The tradable unit is likely to be 1 tonne of CO_2 equivalent. We have, however, only taken into account the potential CO_2 reduction from the envisaged "integrated process". One great advantage of this process in economic terms is that Sorghum provides also the lignocellulosic bagasse as fuel for power generation (thus the consumption of fossil fuels for ethanol production can be avoided), and generates power surplus as well, which can be sold to the grid. This is one of the most important characteristics distinguishing Sweet Sorghum from the other grain crops currently utilised for bio-ethanol production in other European areas, while similarities can be found between Sweet Sorghum and sugar cane in Brazil.

The total volume of CO_2 reduction (trade-off potential negotiation volume) in the ECHI-T project can be obtained evaluating the following issues:

1) substitution of gasoline with bio-ethanol +
2) saving of fossil fuel to provide steam/electricity [bagasse pellets providing the necessary energetic input for sugar/grain processing and surplus energy to be sold to the grid]

The estimation of energy related emissions CO_2 is usually based on the fuel consumption and CO_2 emission factors, that are fuel specific. In particular, as far as electricity generation is concerned, in most of the cases it is quite difficult to identify the exact source of generation that has been reduced or displaced. With the aim of estimating the range of fossil CO_2 emissions saved, different emission factors are considered. The emission factors quantifying the CO_2 saved when 1 kWhel of bio-electricity is produced have been fixed to 0.467 kgCO_2/kWhel for Italy (substitution of natural gas plants) and 0.946 kgCO_2/kWhel in the case of P.R.China (assuming the substitution of a coal power plant). In our calculations, we considered the total substitution of fossil fuels due to using bagasse as fuel for heat/electricity generation. A similar approach has been adopted for calculating the heat (steam) produced from biomass and supplied to the ethanol production process.

Finally, as the amount of CO_2 saved using bio-ethanol as transport fuel depends on several factors, an average figure of 2.06 tCO_2/tETOH has been used, as suggested by EUBIA. Given these assumptions, preliminary estimations have been provided for each of the "Sweet-Sorghum complexes" (Basilicata, Dongying, Huhhot), in terms of CO_2 saved/ha of Sweet Sorghum cultivated; they are reported in the table below.

	Basilicata	*Dongying*	*Huhhot (1 of 10 clusters)*
Tons of ethanol produced per year (sugar +grains)	42,202	101,688	10,614
Tons of ethanol/ha	6.03	5.35	5.31
CO_2 saved from (i) bio-electricity production + (ii) bio-heat (steam) production for Sweet Sorghum processing [tons/ha] (*)	9.42	12.29	4.47
CO_2 saved from substitution of gasoline with bio-ethanol ton/ha	12.42	11.03	10.93
Total saved CO_2 ton/ha	21.84	23.32	15.50
CO_2-Potential volume for negotiations (ton/year)	152,862	443,005	31,007
CO_2 credit amount (€)- price given: 5 €/ton CO_2	764,309	2,215,026	155,035

(*) based on the total number of kWh produced utilising bagasse as a fuel for co-generation

Table 10.1 CO_2 *avoided emissions*

11. Legal aspects

If all or part of the ECHI-T Project is judged to be economically viable in a certain site, those who will take direct part in the implementation will have to envisage a consortium agreement. They will also have to consider the legal aspects of their future investment.

Under a consortium agreement, the parties involved in the project would define the general framework for development, implementation and commercialisation of the ECHI-T Project, and their respective rights and obligations to one another.

A temporary partnership ("société momentanée" or "tijdelijke vennootschap") would be constituted according to the Article 47 of the Belgian Company Code. The sole and limited purposes of the temporary partnership will be twofold.

On one hand, it would aim at promoting, developing, implementing and commercialising the ECHI-T Project at three levels:

(i) negotiating and optimising the ECHI-T Project to satisfy the local needs based on local biomass resources, arranging and implementing all necessary financing actions for the ECHI-T Project, and signing all relevant agreements and documents;
(ii) advising on technological and scientific matters and providing assistance in the establishment of (incorporated) cooperative joint ventures, if any, and in defining the legal and financial structures of these (incorporated) cooperative joint ventures (including technical assistance for financing); and
(iii) providing the required technical assistance (maintenance, training etc.).

On the other hand, the consortium agreement would guarantee that a cooperative joint venture could be incorporated, when necessary, for implementing the ECHI-T Project.

Once the consortium agreement has been signed, as far as the Chinese part of the project is concerned, the participants will have to determine whether the ECHI-T Project is encouraged, allowed, restricted or prohibited in P.R.China. Three sets of regulations govern the categorization of foreign investments in P.R.China:

(i) the Regulations on Foreign Investment Orientation as enacted on 21 February 2002;
(ii) the Guidance Catalogue for Foreign Investments, as amended in March 2002 and
(iii) the Catalogue on Advantageous Industries for Foreign Investment in Central and West Regions.

Under the Regulations on Foreign Investment Orientation, "new technologies, new equipment, energy and raw material saving, integrated utilization of resources and renewable resources, and environmental pollution prevention" are encouraged projects. Thus, the ECHI-T project falls into the encouraged category.

The foreign investment projects falling within the encouraged category enjoy tax benefits (customs duties and V.A.T.) for imported equipment. Finally, further industries that are listed in the Catalogue on Advantageous Industries for Foreign Investment in Central and West Regions can enjoy additional preferential treatments.

In P.R.China, the administrative approval process is cumbersome although it has been greatly simplified in the recent years.

The State Development and Planning Commission (SDPC), which is responsible for drafting the national economic plan, the five-year plan and the national long-term programmes for economic development, is the main administrative body responsible for the approval of all major projects. After November 2001, the SDPC does not have to approve various types of projects any more. Nevertheless, a project still has to be approved by the SDPC if

(i) it requires financing from the central government,
(ii) though using non-governmental financial sources, it concerns strategic exploitation and utilization of resources or covers several water streams or provinces,
(iii) it affects the regional economic coordinated development, or
(iv) the central government considers it to be of strategic importance for the national industry or it is subject to restrictions under some specific regulations. The SDPC has mainly to approve the project proposal, but depending on the type of project and its financing, it may also have to approve the feasibility study, the primary design and even verify the project at the end of the construction phase. Finally, it is also responsible for prices supervision.

Any other project should be approved by the local Development Planning Commission (DPC) provided that it affects only one single province.

The Ministry of Foreign Trade and Economic Co-operation (MOFTEC) and its local bureau are responsible for examining the contractual terms of the foreign investment and will examine and approve the joint venture contract and articles of association. Authority to approve joint ventures is delegated to the provincial municipal and county levels, depending on the project size and its categorization under the Guidance Catalogue for Foreign Investments.

Generally, all technology licences, know-how transfer contracts, technical assistance contracts and other types of technology contracts obtained from a third party or the foreign joint venture party should be separately reviewed by the relevant division of MOFTEC or its local branch, and then filed for the records. The parties to a joint venture should determine the amounts of contributions in kind through joint assessment or by a third party that both parties agreed upon.

Moreover, all contributions in kind by the foreign partner have to be submitted to the approval of MOFTEC and the governments at provincial and municipal level, under the direct jurisdiction of the Central Government or the competent authorities under the State Council. Similarly, although there are no restrictions on the payment of royalties by a Chinese-foreign equity joint venture to the foreign partner for the use of technology, the terms and conditions for the payment of royalties and methodology for calculating royalties will be examined closely during the approval process.

With respect to the use of land, the Chinese legislation requires that the joint venture submit an application for approval to the land authorities at municipal (county) level where the joint venture is located. The site use fees are determined by the people's government at provincial, autonomous regional and municipal level where the joint venture is physically located.

12. Conclusions

The ECHI-T project examined a wide range of configurations in Italy and P.R.China. The basic scheme adopted in the three sites is composed of bio-ethanol/DDGs/CO_2/heat&power/bagasse pellets (2nd level of integration), which represent a compromise. More complex integrations are possible but a detailed infomation of local markets and conditions is needed.

A survey of the three sites has been carried out, and areas suitable for Sweet Sorghum cultivation and the related industrial processing activities have been identified in Italy and P.R.China. The possible economic benefits from combined cultivation of Sweet Sorghum and other crops have not been assessed in the present work.

Two different approaches have been chosen: the first one aimed at designing a large scale centralised scheme to be adopted in Basilicata (Italy) and Dongying (P.R.China), while the second one was based on small scale clustered units suitable for rural areas and probably lower quality soils, and was evaluated for Huhhot (P.R.China). However, the possibility of adopting a single large-scale integrated complex in Huhhot has also been discussed.

The study demonstrated that the ECHI-T scheme is technically feasible based on the existing commercial technologies, even if minor adaptations would be necessary. As for the crop cultivation, two months harvesting and processing have been considered in Basilicata and Dongying, while a five months period can be adopted in Huhhot thanks to the favourable climate at the harvesting time. However, a main result of the investigations on crop hybrids was that a careful selection of the cultivar in terms of Growing Degree Days could allow a 4 month harvesting period even in Basilicata and Dongying, thus reducing the investment costs of bio-ethanol-from-juice production and significantly improving the economic returns.

The economics of the projects are favourable in Basilicata and Dongying, even if some support (i.e. grant) is needed to make the returns positive. Nevertheless, project conditions have not been optimised (in terms of further extended seeding-harvesting time) as it would have required local experimental work, so that opportunities exist for achieving better economic results. Moreover, the scheme in Europe and abroad is eligible for several measures financially supporting renewable energy projects, as Structural Funds or CO_2 trading, which could significantly improve the returns on investment.

Larger complexes generate the most positive results (i.e. Dongying), while the proposed scheme (on the basis of the existing technologies) seems not suitable for small scale systems typical of rural development projects (i.e. Huhhot). However, in the case of small integrated complexes based on Sweet Sorghum at village level, other kinds of activities are possible, but not presented here because out of the scope of ECHI-T. Based on the results of the project, it can be concluded that a single large integrated complex in Huhhot should produce the highest economic returns among the three cases considered, although this option has not been investigated in the present work.

In addition, tropical and sub-tropical southern provinces of P.R.China, as Guangdong provinces, should generate more positive economic returns, as indicated by some preliminary project feasibility studies already carried out for these zones.

The production of DDGs should be carefully considered, as the related significant investments should be justified only by a considerably high market value of the product DDG or by a strategic interest in maximising the bio-ethanol production.

The possibility of combining the bio-ethanol-from-Sweet Sorghum production with bio-ethanol from other crops could extend the use of the ethanol production plant, and therefore improve the economics.

The ECHI-T integrated complex will have significant favourable impacts on the environment, from the production as well as from the end use point of view. The estimation of avoided CO_2 emissions during the bio-ethanol and bioelectricity production has been carried out, while the estimation of the benefits due to bio-ethanol use depends on how the biofuel is used.

Project financing and legal issues have been discussed, and possible routes to project implementation preliminarily identified.

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