Meeting the Demands of Food, Feed, and Energy by Sweet Sorghum

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How to make integrated food-energy systems work for both small-scale farmers and rural communities in a climate change-friendly way

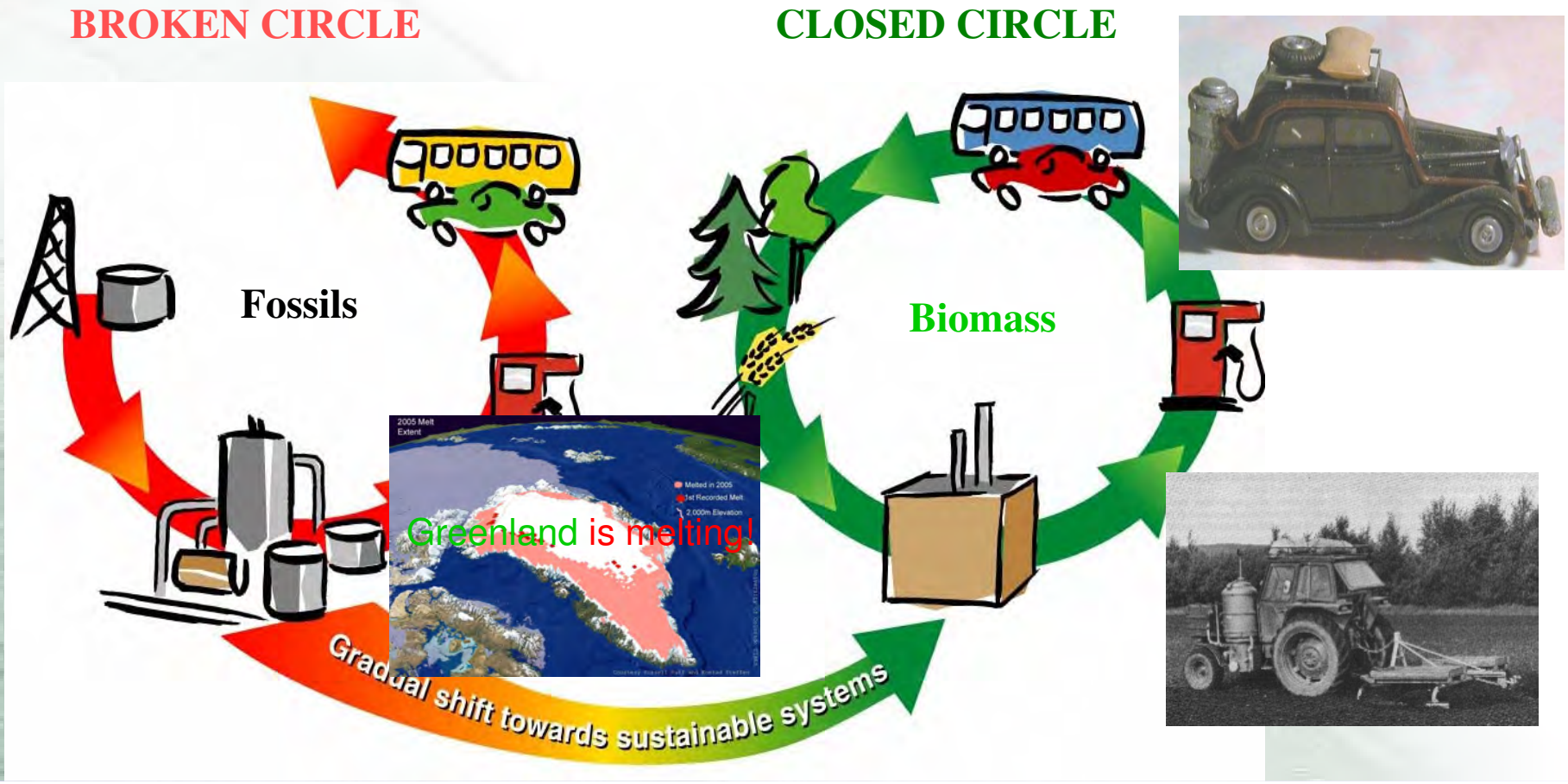
Food Crisis, Climate Change, and Energy Poverty

Political will needed to halt food price surge - FAO

Reuters, Saturday April 19, 2008

Why biofuels

Biofuels are today the only direct substitute for oil in transport that is available on a significant scale. 73.6 billion litters of bioethanol were produced in 2009, and is projected to replace 12-14% of global gasoline consumption by 2015.



Major concerns on biofuels

First generation bio-fuel feed stocks divert food crops to produce fuel, and can compete directly, or indirectly with food production resulting in:

- higher food prices
- food shortages
- De-forestation
- Expansion into environmentally sensitive ecosystems

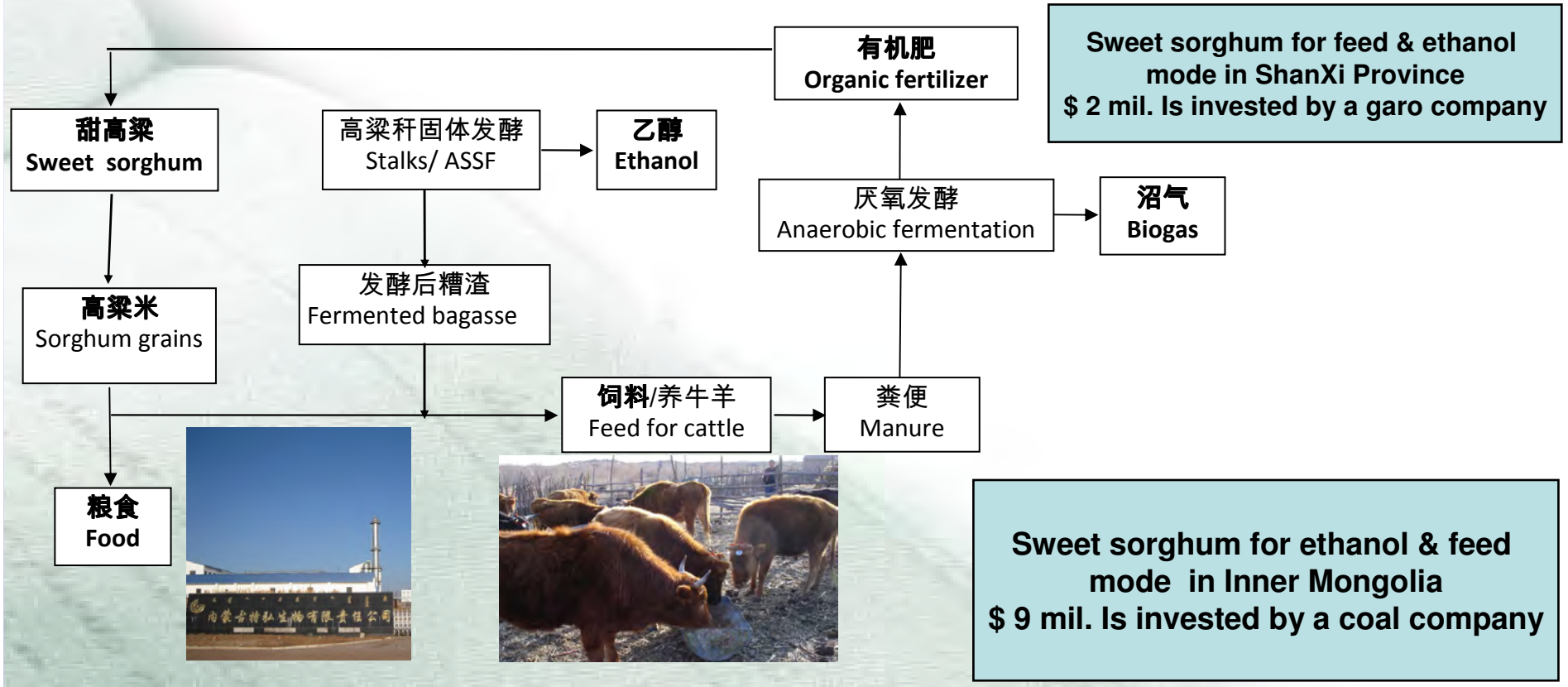
Food starch & sugar

Why IFES?

- Biofuel has to be non-competitive to feed, food & domestic energy
- A crop should combines energy and food on the same plot:
  - addresses food, fuel, fodder, fiber (FFF)
  - suits arid and semi -arid conditions
  - C4 - with efficient photosynthesis

IFES trials in China

A 'closed loop'/'zero waste' system is established in China



Sweet sorghum for feed & ethanol mode in ShanXi Province
$ 2 mil. Is invested by a garo company

Sweet sorghum for ethanol & feed mode in Inner Mongolia
$ 9 mil. Is invested by a coal company

Nov. 2007, Financial Incentive Policy for Bioenergy was issued by MOF and NDRC total five ministries, China- to support 20-40% investment of biofeul & bio-based product producers using non-food feedstocks; $400/hectare subsidies for farmers.

Why ASSF

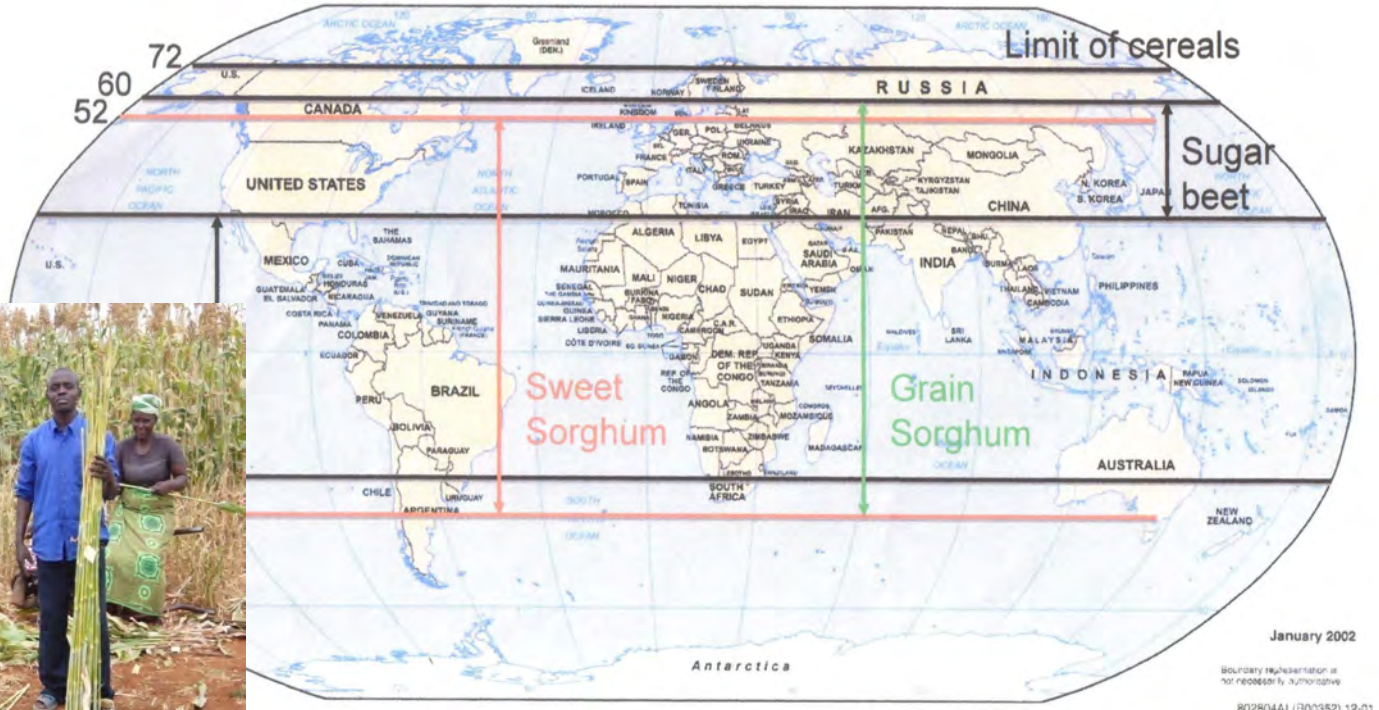
45 % of fibrous residues (1.18t) for boiler fuel, 55% (1.42t) to feed 1 cattle, and nutrition report is as the following

Raw material	Dry matter	Crude Protein content	Crude fiber	Neutral detergent fiber	Acid detergent fiber	Crude ash	Calcium	Phosphate	Total energy MJ/kg
Fermented bagasse (wet sample)	19.21	0.83	6.56	13.34	9.29	1.29	0.05	0.02	3.37
Corn silage	24	1.47	4.59	9.89	5.76	1.34	0.06	0.06	16.44
Fermented bagasse (dry sample)	94.22	7.26	30.12	63.75	40.62	22.5	0.32	0.13	11.91

Why Sweet Sorghum

Sweet sorghum is suitable in more areas

Potential adaptation of *S. bicolor*



Why Sweet Sorghum

- Sweet Sorghum may produce grain, sugar, ethanol, electricity, and feed without adversely impacting existing food crops or requiring the clearing of new land to grow fuels crops.

- Grown in drier areas (waste lands or sandy soils) with only limited water and fertiliser as compared to sugar cane and other crops:

  1 ton sorghum: 11 ton water

  1 ton sugarcane: 48 ton water (data from ICRIST)

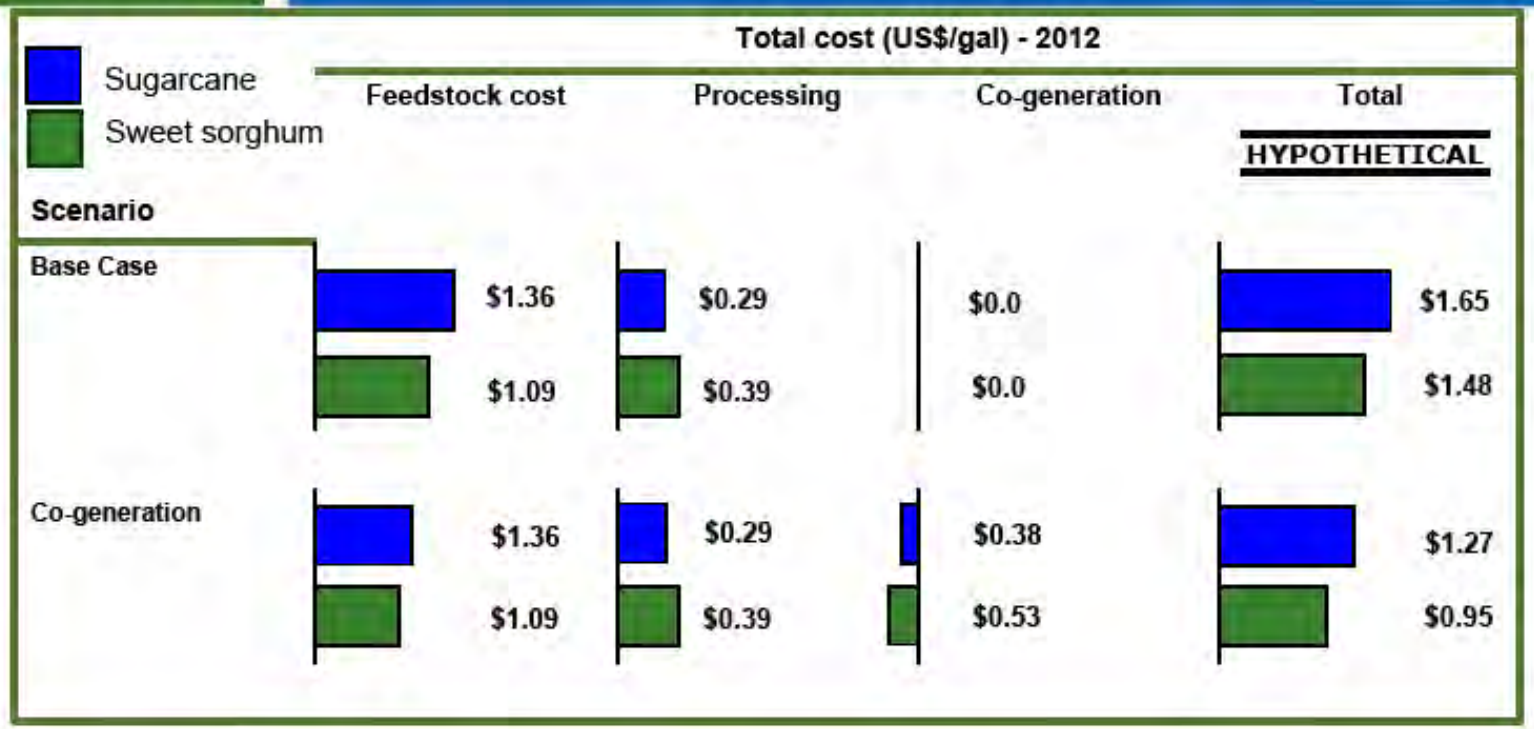
- sweet sorghum is significantly salt-tolerant, permitting it to be grown in high-salinity soils that are often unusable for other crops (e.g., in high salinity)

- High yield stalks: 70 ton/ha/harvest, 4 months per harvest

- Producing additional food (3 ton/ha/harvest) without the necessity to displace existing crops, such ad corn.

Why Sweet Sorghum

In certain situations sweet sorghum will have a lower feedstock cost than sugarcane



Lower inputs and higher biomass provide an advantage to sweet sorghum against sugarcane is some geographies

Note: Does not assume a ratoon crop. 10% TSR for sweet sorghum. Feedstock production costs based on U.S.

Sources: USDA ARS, LSU AgCenter, Cosan Quarterly Financial Letter, Ceres Analysis

Advantages of Advanced Solid State Fermentation (ASSF)

- Short process

  Directly ferment stalks to ethanol, 2/3 equipment compare to liquid state fermentation process (LSF)

- Less fermentation time

  24hr vs 36 hr for liquid process, and 55 hr for corn ethanol

- Less water consumption and less waste water

  1 ton water required vs 5+ ton for liquid process

- Less energy consumption

  About 300kwh/ton ethanol vs 800kwh/ton ethanol for liquid process

- Less total investment cost

  About 75% investment vs liquid process

- Simple operation

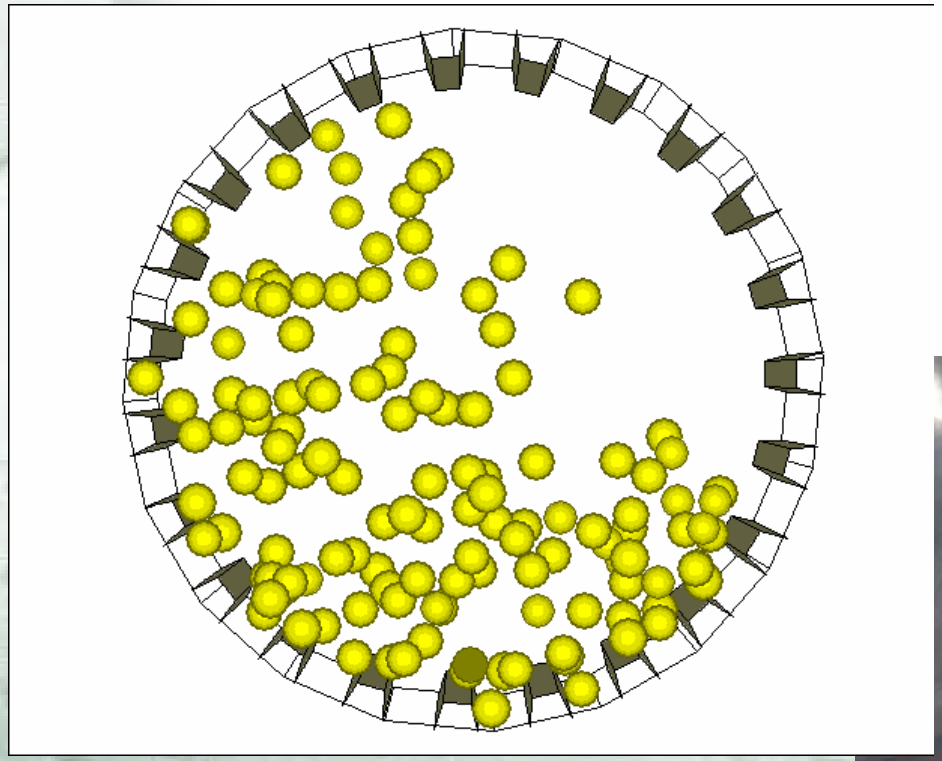
  Low educated labor for operation

Why ASSF

Solid State Fermentor with mass transfer and heat transfer from bench scale to pilot plant

Flask test

Moving particles in industrial fermentor



Energy balance of the whole process

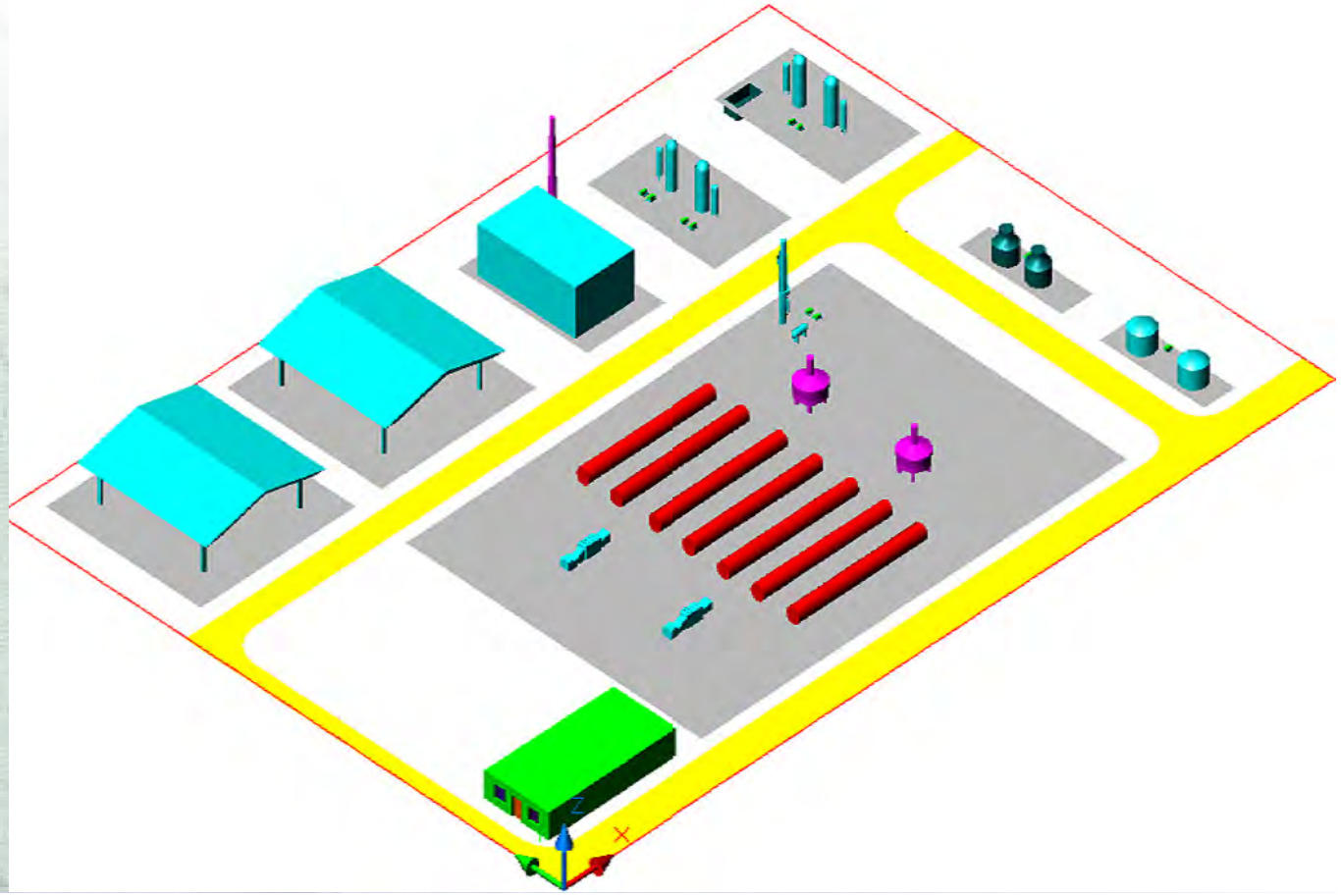
(based on 1 ton of fuel ethanol)

Energy input		Energy output	
Electricity: 373 Kwh (GJ) ethanol producing 230 Kwh (GJ) distiller pelletizing 143 Kwh (GJ)	1.343 0.828 0.515	1.18t pellets (GJ)	17.31
4.52 t steam for distillation (GJ)	11.92	1t ethanol (GJ)	29.30
5.0 t hot air for drying distiller (GJ)	0.50		
Total (GJ)	13.85	Total (GJ)	46.61

The energy input/output ratio during ethanol production process is 1 : 22, hence ethanol produced from sugar crops by ASSF can be regarded as ADVANCED BIOFUEL defined by U.S.A.“ Energy Independence and Security Act of 2007”

Layout for a 10,000t/a Sorganol Plant based on the successful pilot plant in Inner Mongolia

- The sorganol production cost of is estimated at $463.3/t ethanol at the sorghum stalk cost of $20/t
- The capital cost is around $9 million for the ethanol plant with the capacity of 10,000t/a.



清華大學

USGC to Japan and the Philippines: Why not Sorghum?

June 3, 2010 *Global Update* www.grains.org

Constraints and solutions

- **Constraints**

  -There is lack of cost-effective conversion technologies.

  -Less financial support to demonstration plants.

- **Solutions**

  -R&D is the priority

  -Governments should support to build demonstration plants

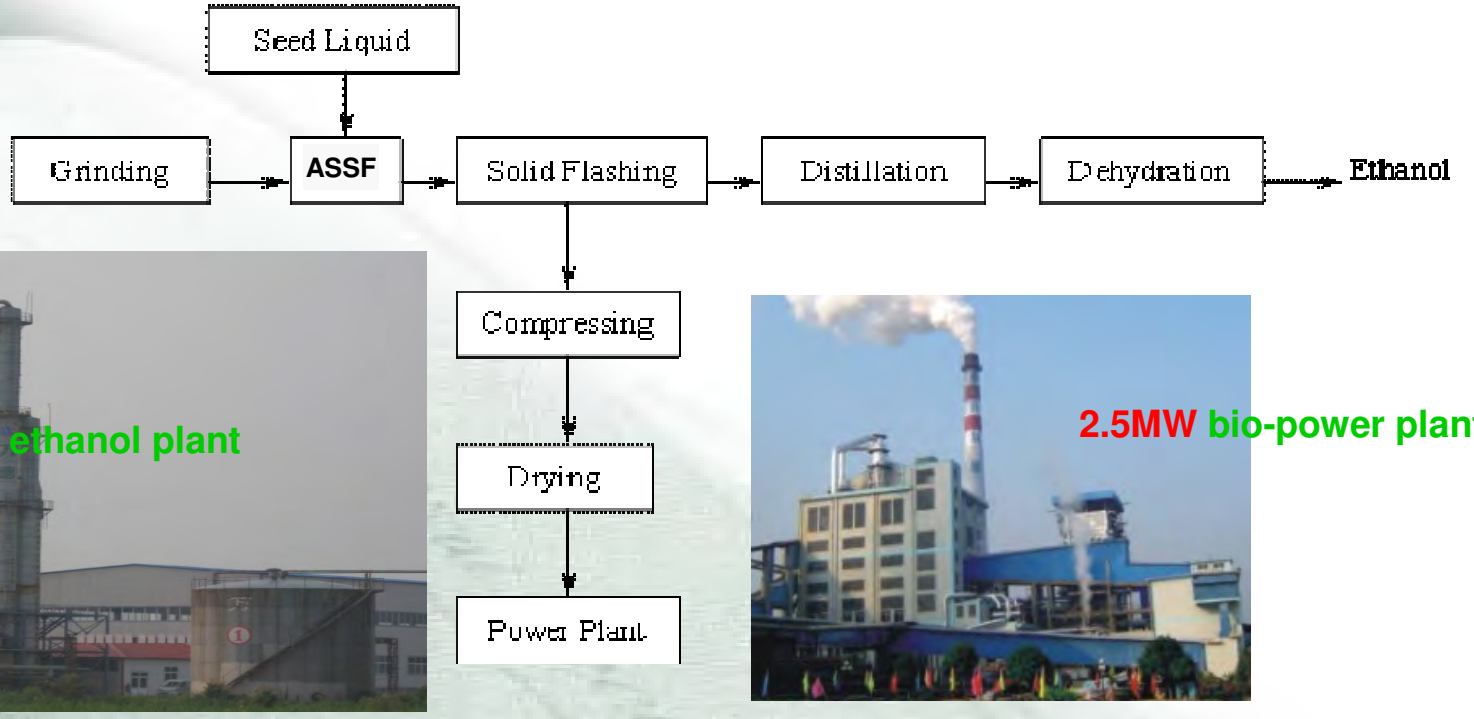
  -Incentive policies to encourage venture capitals flow into IFES

FAO can help Africa to make great opportunity using sweet sorghum

As African economies strain under the burden of importing oil this session will examine the critical issues of how African countries can lessen their energy dependence, improve their balance of payments, create new jobs and industry in a sustainable manner without impacting food production.

Where billions of dollars were going to overseas oil producers, some can now be invested locally- in poor rural communities to benefit Africa

Sweet sorghum to FUEL and POWER



- Using 2,000 hectares land to grow sweet sorghum to produce 10,000 tons of ethanol per year , and generate 18 million Kwh electricity.
- During this module, the energy input of ethanol is only fossil fuel in plantation and transportation, has much environmental benefit.

Benefits of ethanol & power production using sweet sorghum feedstock and ASSF Technology in tandem:

- Low cost production of ethanol from Sweet Sorghum using single or multi-modular plants.
- Export and local consumption, creating jobs for local communities.
- Provides other bi-products, such as fertilizer, animal feed, pellets for use for cooking, elimination of trees cutting and power generation.
- Provides rural electrification for the villages

Production Cost for Ethanol ($/t)

No.	Item	Cost (USD)		Remarks
1	Feedstock	stalks	235.2	Sweet sorghum stalks,
		Other materials	26.5	Enzymes+yeast
2	Utility	water	1.0	
		electricity		Self supply
		steam		Self supply
3	Labor	57		120people,
4	Maintenance	31.6		
5	Depreciation	102.9		14 years
6	Admin. expense	18		
7	finance	40.5		Interest @4%
	Total	513.4		
8	Ethanol sale value	848.1		Price: @67cent/liter
9	Electricity sale value	70.9		1200kw Price: 5.9cent/kwh
		No tax (VAT, business tax, income tax) has been included.		

Typical Project Data

Plant location:	Africa
Plant capacity:	12mil liter ethanol (99.5%v)
Total installed cost:	US$ 15 million
Sweet sorghum stalk required:	160,000t/a
Land area required:	2,300ha @ 70ton/ha

Finance Data

Capital loan interest 4%

Construction period: 12 months

Stalk price: $14.7 per ton at plant

Ethanol price (ex-works): $67cent per liter

Electricity price: 5.9cent/kwh

IRR: 21% @no business and income tax

The US-Sino Joint Center for biofuel Research was established on 19 Aug 2008

B. At the discretion of either Party, this Annex may be terminated upon 6 months advance notice in writing to the other Party.

Done at Houston, Texas, this day of August 19, 2008, written in English and Chinese and in duplicate, each text being equally authentic.

FOR THE DEPARTMENT OF AGRICULTURE OF THE UNITED STATES OF AMERICA (USDA)

Gale Buchanan
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FOR THE MINISTRY OF SCIENCE AND TEHNOLOGY OF THE PEOPLE'S REPUBLIC OF CHINA (MOST)

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Copies of correspondence and documentation between ARS and MOST should be sent to:

Thank You