Realizing the goal of “23% renewables by 2025” via technology innovation and bioenergy

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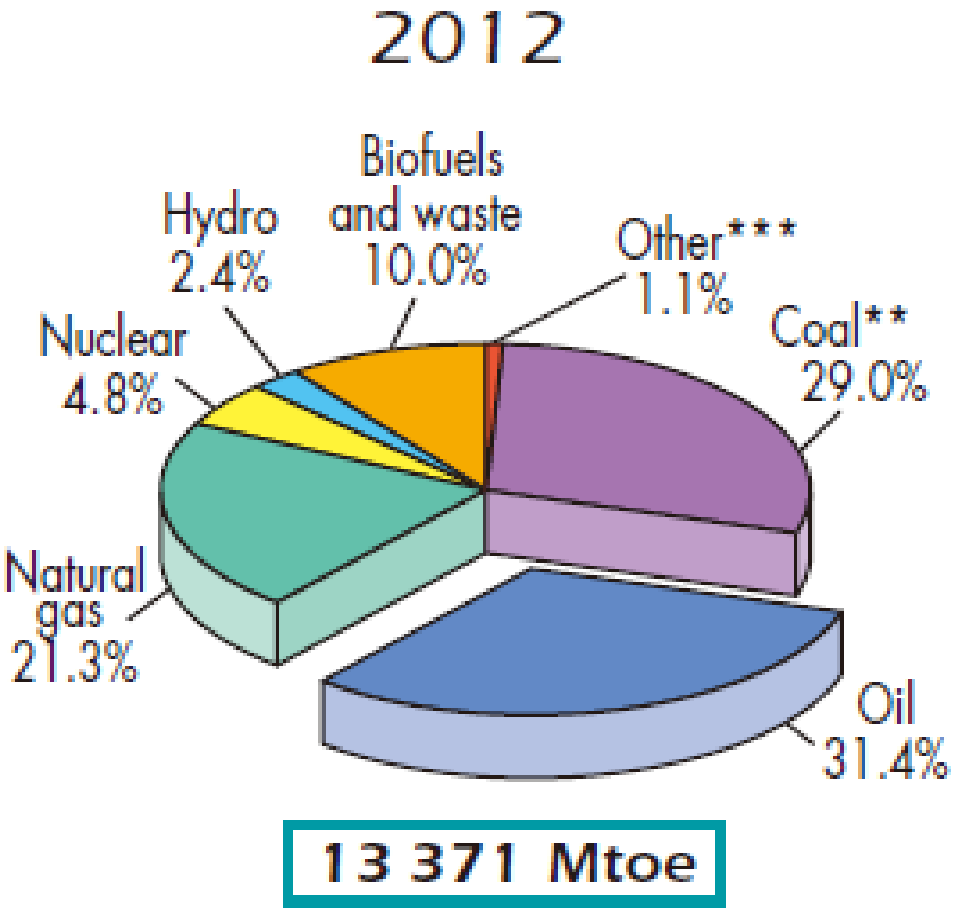
World total primary energy supply in 2012 by fuel



- ✓ **Bioenergy contributes 10% of global energy supply, and is already more than twice as large as nuclear energy.**
- ✓ **Within the renewable energy sector, bioenergy is the dominant source followed by hydropower and to a smaller extent wind power, geothermal energy and solar energy.**

*World includes international aviation and international marine bunkers.
**In these graphs, peat and oil shale are aggregated with coal.
***Includes geothermal, solar, wind, heat, etc.

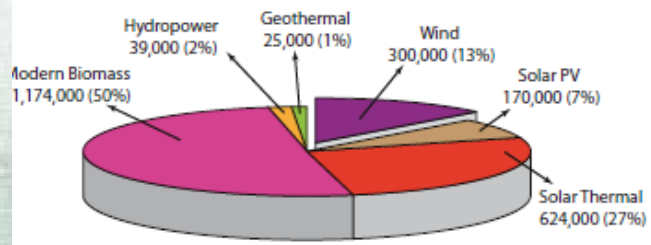
IEA, 2014 Key World Energy STATISTICS

Biofuels are a promising solution to economy recession.

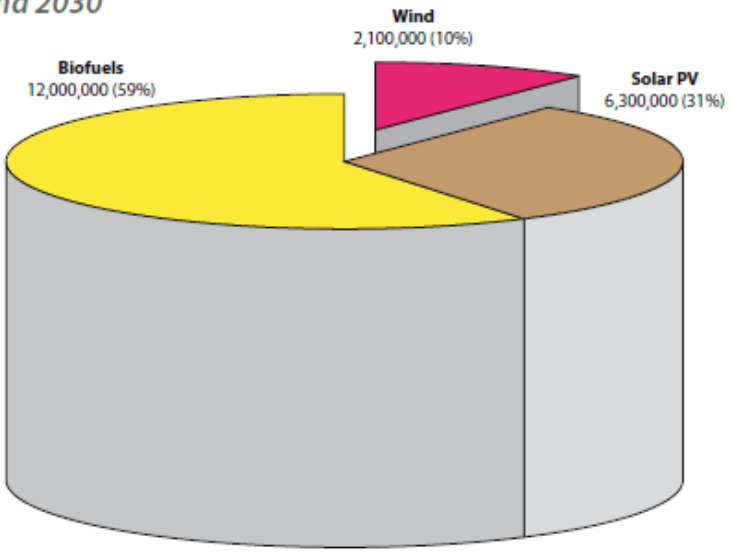
Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World - Sept. 2008

Figure 3: Green jobs in renewable energy 2006 and 2030

Source: Green Jobs - Towards Decent Work in a Sustainable, Low-Carbon World, UNEP/ILO/IOE/ITUC, September 2008

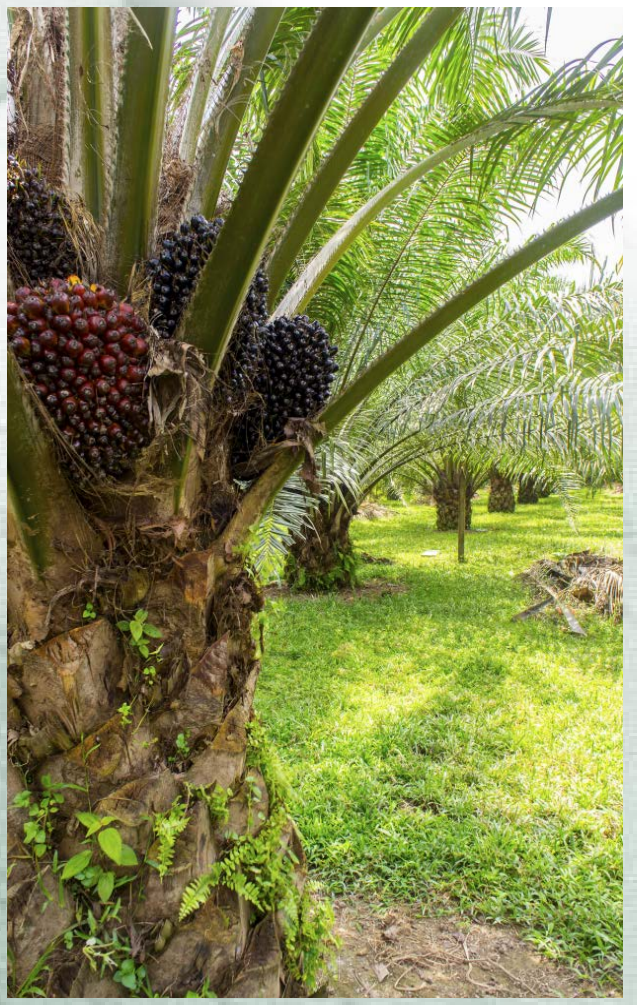


Green Jobs in Renewable energy, 2006



Green Jobs in Renewable energy, 2030

Biomass from Palm Oil Mills in Indonesia



		kTons/a
	空果串 Empty Fruit Bunches	30,000
	纤维 Mesocarp Fibres	18,000
	棕榈仁壳 Palm kernel Shells	7,500
	棕榈油厂廢水处理 Palm Oil Mill Effluent	85,000

4000MW bio-electricity from palm waste by 2025

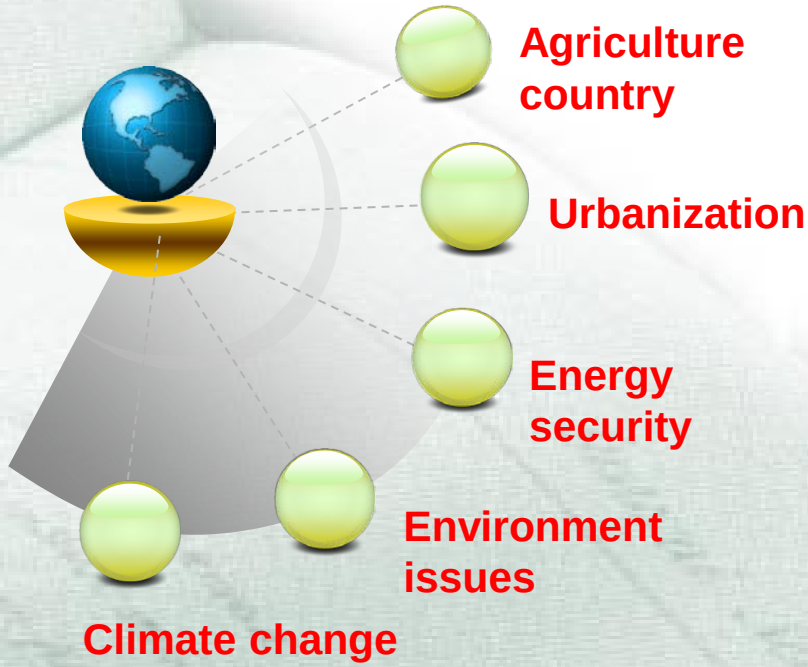
Biogas production from organic wastes

- ✓ **Development of different scaled biogas fermentation platforms, which could be suitable for concentrating total solids (TS) from 2% to 20%;**
- ✓ **Molecular biology and molecular ecology approaches such as metagenomics, metatranscriptomics applied to research the mechanism of action of microorganism for anaerobic digestion**
- ✓ **Biogas purification, including acidic gas absorbent and centrifugal absorbent with the purified biogas directly used as motor fuel.**

Pilot plant for biomethane production from banana stalks.

Anaerobic fermentation facilities for biomethane production（200 L）

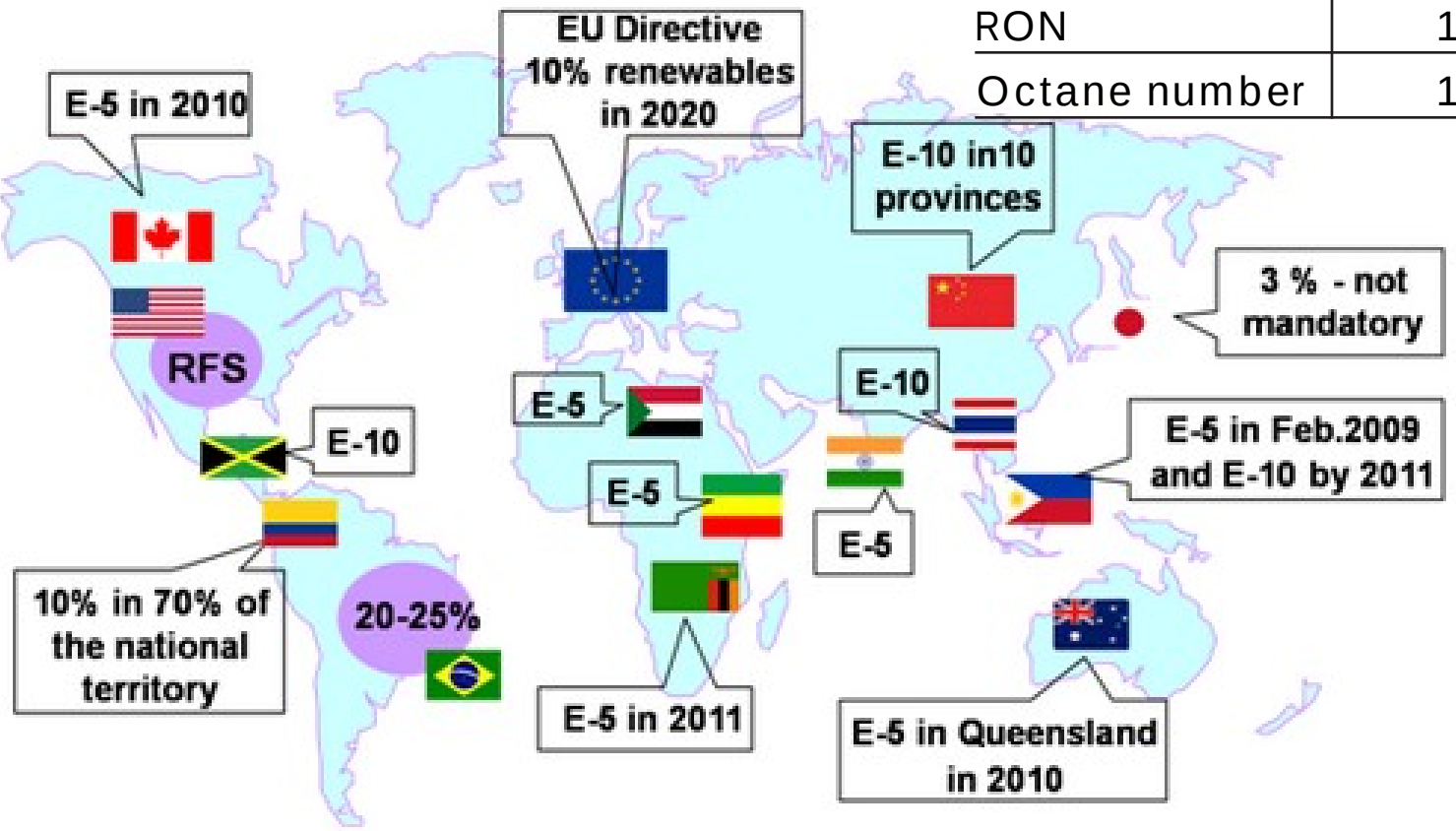
10 billion Nm^3 biogas can be produced by 2025



- ✓ Banana stalks
- ✓ Fruit industry waste material
- ✓ Municipal sewage treatment sludge
- ✓ Organic fraction of Garbage
- ✓ Cattle Manure

Global ethanol production would reach 90.38 billion litres and its use worldwide would reduce GHG emissions by over 106 million tonnes globally in 2014. the Global Renewable Fuels Alliance (GRFA)

Property	bioethanol	Petrol
MON	96	85
RON	130	95
Octane number	113	90



Net gain in Stockholm using ethanol and biogas in buses

- ✓ All inner city bus lines run on renewable fuels
- ✓ A total of 721 ethanol and 298 biogas buses in operation in 2013
- ✓ Reduced diesel use by 29 million litres / year
- ✓ Reduced fossil CO_2 by > 90 000 t / year
- ✓ Reduced PM 18.5 tons and NOx 185 tons

by courtesy of SL

Dilemma Status

Globally, biofuels contribute about 3% of transport energy, but use significant amounts of food production to do so: in recent years biofules accounted for

- ✓ **11% of coarse grains and vegetable oil use**
- ✓ **21% sugar cane use.**

The Handbook of Global Energy Policy, Wiley Blackwell, 2013, P269.

Looking for biofuel plants that can survive drought & other harsh conditions

Chris Woolston,Tough Characters: in search of hardy plants for biofuels

1.5 G can end the dilemma status of biofules

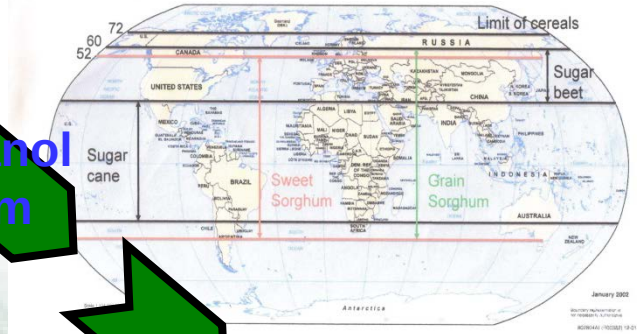
Food crisis!

☹

1st biofuels- ethanol from corn and sugar cane

☺

Potential adaptation of *S. bicolor*



1.5 generation-ethanol from sweet sorghum
Cost effective!

2nd biofules- cellulosic ethanol

Cost expensive!

Sweet sorghum is the most promising feedstock

Sorghum goes epic, or is that EPEC?

Jim Lane , BiofuelDigest, May 30, 2012

Researchers: Sorghum holds promise as next-gen ethanol crop

Kris Bevill, Ethanol producer magazine, July 09, 2012

Drought Kindles US Farmers' Appetite for African Grain Sorghum

Steve Baragona， Voanews，Aug. 22, 2012

Sweet sorghum, the engine for Brazil's biofuels expansion?

Jim Lane , BiofuelDigest, Nov 27, 2012

✓It never had the cachet of algae, the claim-and-flame of jatropha, or the big brand names like BP and Dupont to wave around, as with switchgrass and miscanthus.

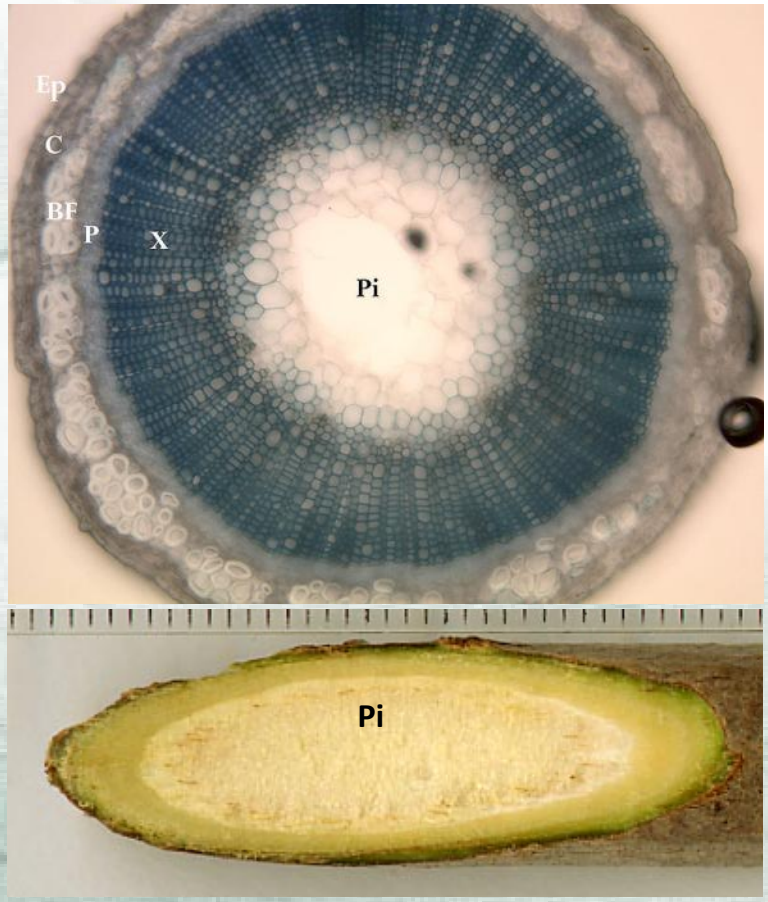
✓The plant holds unmatched versatility for bioenergy applications because sorghum is the only energy crop platform that can provide starch, sugar and lignocellulose.

However, there is no current significant bioethanol production based on sweet sorghum.

BNDES and CGEE, Sugarcane-based bioethanol : energy for sustainable development. ISBN: 978-85-87545-27-5

Liquid Fermentation Using Juice

- ✓ Easy for big capacity
  - –More stable operation due to liquid processing
- ✓ The bagasse (residual of the stalks) can be sent to boilers directly as fuel
- ➢ High energy consumption for process plant, due to juice extraction consuming many power
- ➢ Around 5% sugar loss during juice extraction process
- ➢ More waste water produced due to:
  - –20% water added for juice abstraction
  - –Juice become waste water after fermentation and ethanol abstracted
- ➢ Higher investment cost compare to solid fermentation for similar capacity plant



Pith in different plants

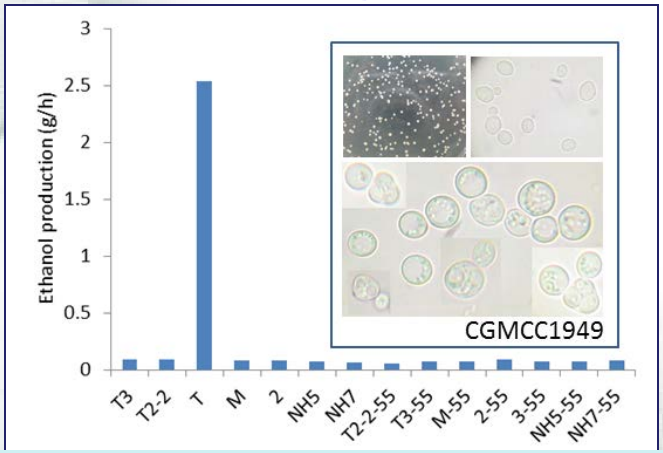
Compositions of sweet sorghum

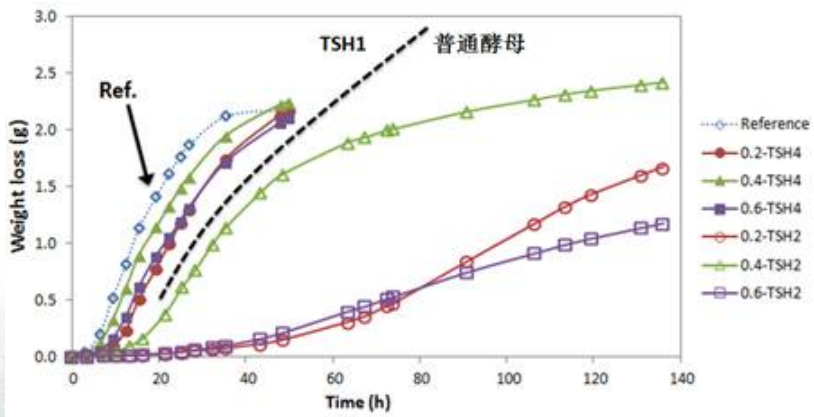
	whole sorghum	pith	bark
cellulose	12.4	8.7	19.2
hemicellulose	10.2	6.3	17.5
lignin	4.8	0.6	8.8
sucrose	55.0	67.4	32.2
glucose	3.2	3.7	2.4
ash	0.3	0.2	0.5

Source: *Billa E, et al . Ind. Crop. Prod.,1997 , 6: 297-302*

- ✓ **Huge energy cost is required for juice squeezing compared with sugar cane.**
- ✓ **Solid-state fermentation is much more suitable for sorghanol production.**

Three basic requirement for ASSF: the excellent yeast, automatically controlled fermenter, and sugar preservation





Du, et al. (2014) A Novel Wild-Type *Saccharomyces cerevisiae* Strain TSH1 in Scaling-Up of Solid-State Fermentation of Ethanol from Sweet Sorghum Stalks. PLoS ONE 9(4): e94480.

Wang, et al, Modeling of rotating drum bioreactor for anearobic solid state fermentation. Applied Energy, 2010, 87: 2839-2845.

Scale up of solid state fermentor

2007

5 m³ (1.3k gallons)

× 25

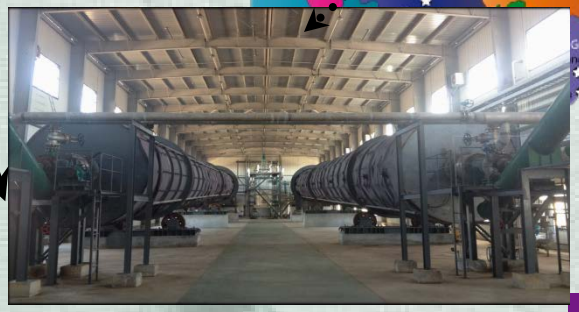
127 m³ (33.6k gallons)

2009

× 4

2011

555 m³ (132.1k gallons)



2015

× 20

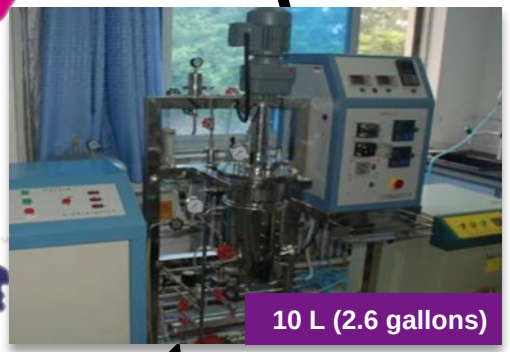
250 L (66 gallons)

× 5

50 L (13.2 gallons)

2007

× 5



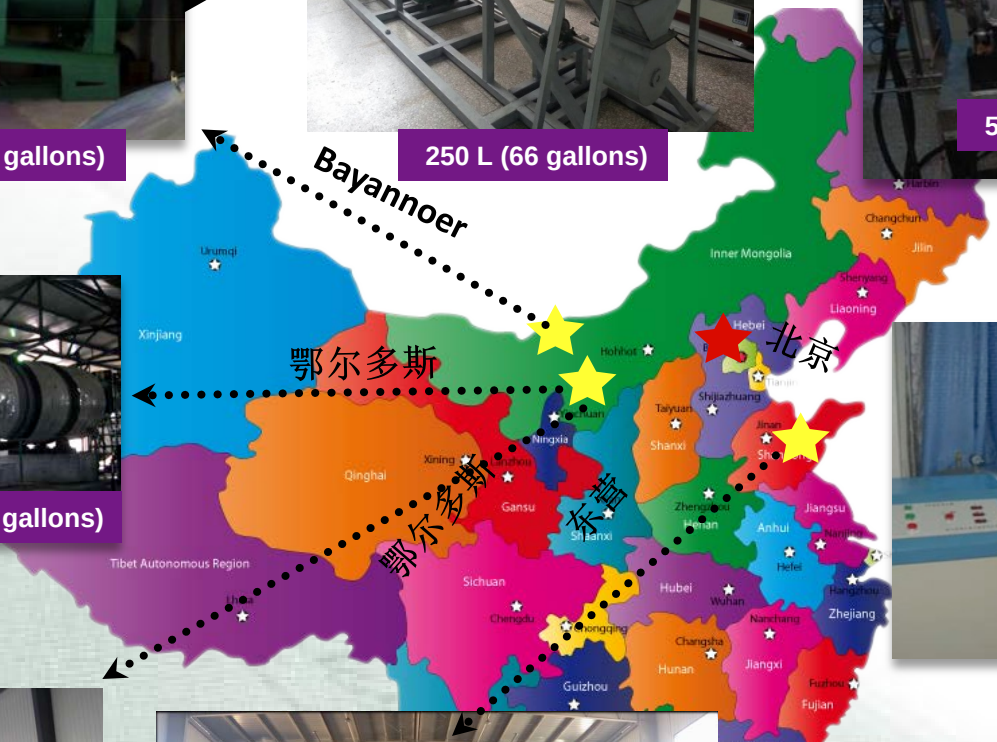
10 L (2.6 gallons)

2006

× 20

Flask Test

2005



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甜高粱生物乙醇.mp

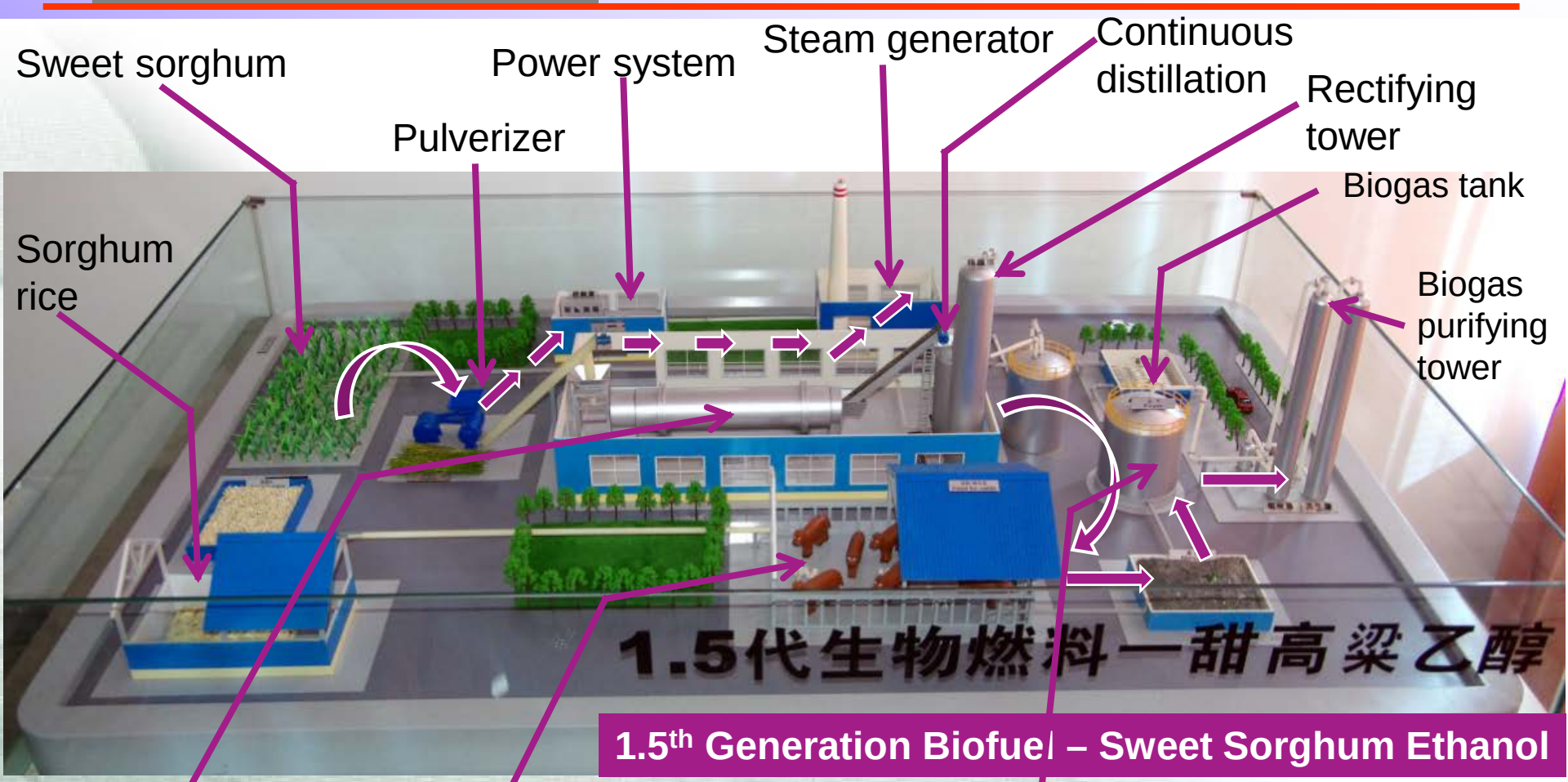
Dr. Buchanan, former under secretary of USDA visited the demon on 15 Sept. 2014.

The new demon. plant is successful in operation in Dongying, Shandong Province, China.

50 % of fibrous residues (1.28t) for boiler fuel, 50% (1.28t) 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
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

Sweet sorghum to fuel & feed module



A 'close loop': 1500ha/10000t ethanol and 4500t grain/6000 cattles/2.8 million Nm^3 biogas and 60000t organic fertilizer

Sweet sorghum farm

Crude EtOH (95wt%) plant

REPU

REPU

……

REPU

Rough EtOH
Production Unit (REPU)

×10-20

Rough EtOH (95wt%)

Fuel EtOH

Anhydrous EtOH (99.5wt%) plant

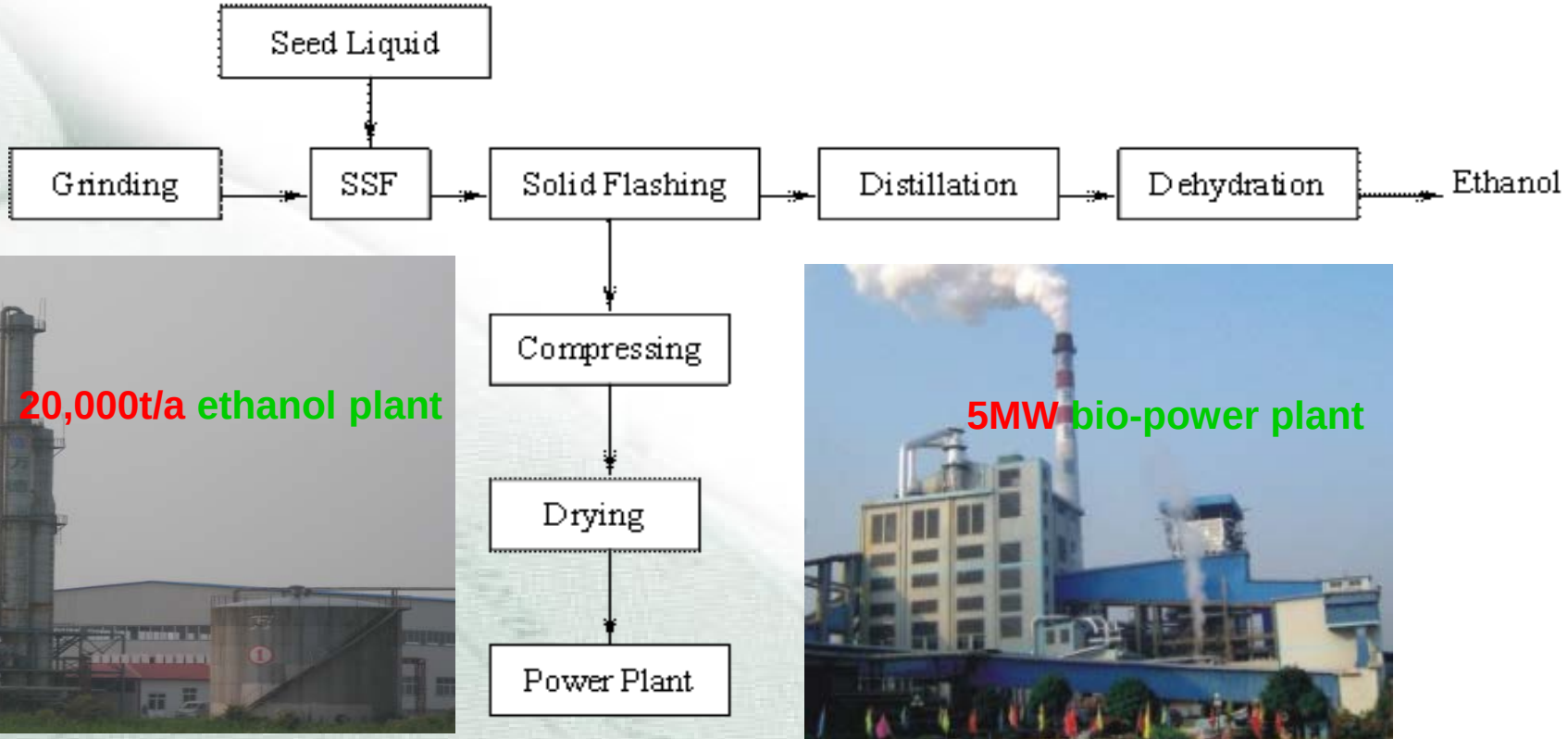
Estimated Ethanol Production Cost (fuel-feed model, $/t)

No.	Item	Cost (USD)		Remarks
1	Feedstock	stalks	400	$25 /t stalk, 16t
		other materials	26.2	enzymes+yeast
2	Utility	water	1	
		electricity	21	
		steam	20	self supply
3	Labor	57		120 people,
4	Maintenance	31.6		
5	Depreciation	102.9		14 years
6	Admin. Expense	18		
7	Finance	40.5		interest @4%
	Total	718.2		
8	Ethanol Sale value	**846**		**Price: @2.54/gallon** (current international price)
9	Fermented bagasse sale value	140		7 tonnes price: $20/fresh tonne
10	**Ethanol production cost**	**578.2 ($1.74/gallon)**		**718.2-140=$578.2**
Total sale		1048 (MESP **$1.90/gallon, 10% profit**)		
		No tax (VAT, business tax, income tax) has been included.		

The US corn ethanol production cost: $2.72/gal

Renewable Fuels Association （RFA）, Updated, January 31, 2014

Sweet sorghum to ethanol & power module



- Using 2,300 hectares land to grow sweet sorghum to produce 20,000 tons of ethanol, and supply 24 million Kwh electricity to national grid per year.
- The energy input of ethanol is only fossil fuel in plantation and transportation, and environmental benefit is much high compared with other biofuels.
- Ash from bio-power plant is rich of K, can be used as K fertilizer.

Production Cost for Ethanol ($/t)

No.	Item	Cost (USD)		Remarks
1	Feedstock	stalks	400.0	$25 /t stalk, 16t
		Other materials	26.5	Enzymes+yeast
2	Utility	water	1.0	
		electricity	-	Self supply
		steam	20	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	718.2		
8	Ethanol sale value	846		Price: @2.54/gallon (current international price)
9	Electricity sale value	84		1200kwh Price: 7 cent/kwh
10	Ethanol production cost	634.2 ($1.90/gallon)		718.2-84=$634.2
Total		930 (MESP $2.09/gallon, 10% profit)		
		No tax (VAT, business tax, income tax) has been included.		

Typical Project Data of Etahnol and Power model

Plant location:	South east Asia
Plant capacity:	24 mil liter ethanol (99.5%v)
Total installed cost:	US$ 28 million
ethanol plant:	US$ 18 million
power plant:	US$ 10 million
Sweet sorghum stalk required:	320,000t/a
Land area required:	1,500ha @ 75ton/ha @ 3=337500t

Finance Data

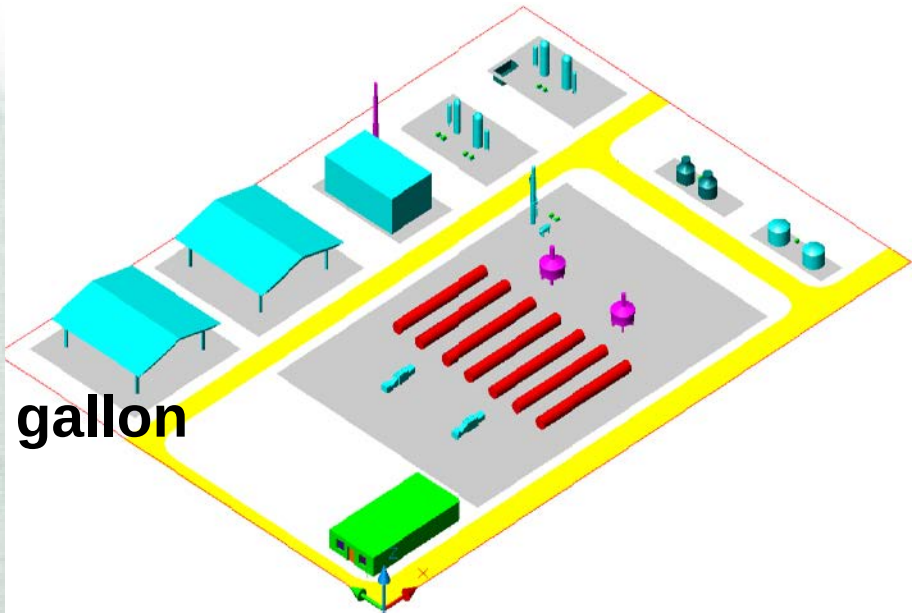
Capital loan interest 4%

Construction period: 12 months

Stalk price: $25 per ton at plant

Ethanol price (ex-works): $2.54 per gallon

Electricity price: 7cent/kwh



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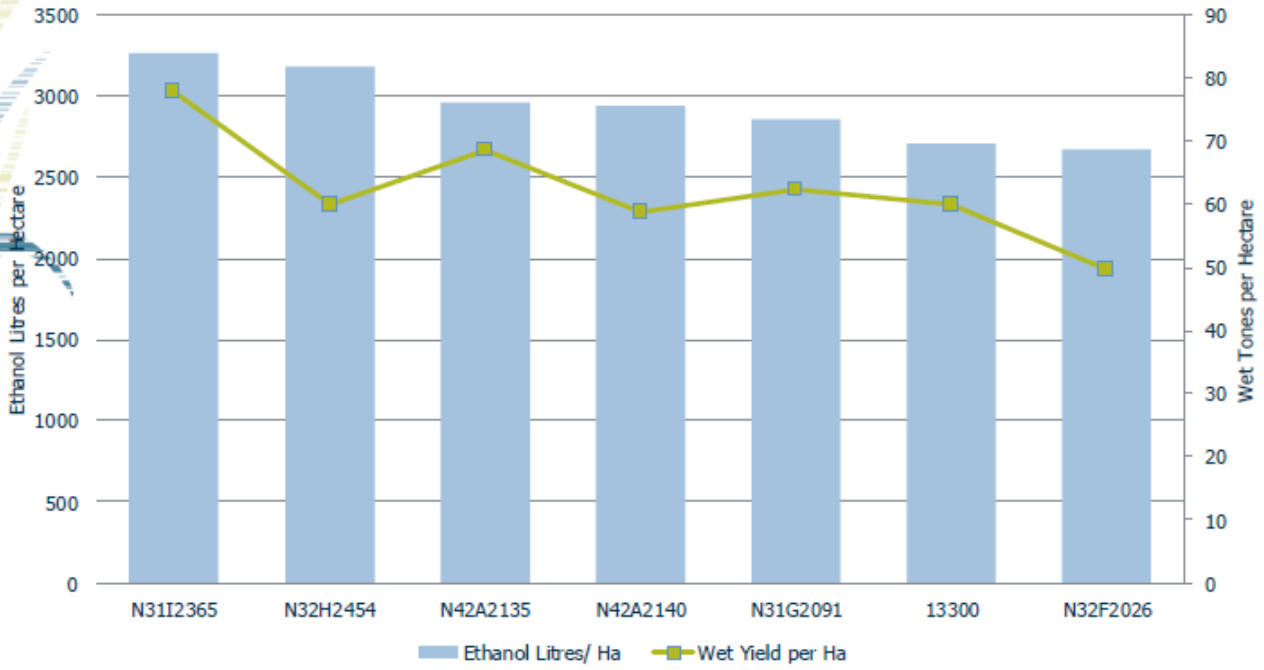
Indonesia: Bogor University

Planted 27th December – Photo taken 7
11th March 2015

Indonesia - Bogor University Trial
Malibu Sweet Sorghum Hybrids

Planted 27th December 2014, Harvested 7th April 2015



nexsteppe

1 million ha are available to be used to produce 10 million tons of ethanol competitively to supply the domestic need, and 2500 MW electricity annually by 2025.

Bioenergy and biofuels by 2025

- ✓ **4000MW** electricity from palm waste
- ✓ **10 billion Nm^3** biogas from banana stalks, fruit industry waste material, organic fraction of garbage, and other organic wastes.
- ✓ **10 million tons** of ethanol and **2500MW** electricity from sweet sorghum.

Income of US farmers

	Grain/acre	Stalks/acre	USD	remarks
Grain sorghum	150 bu (4.2t on)	-	1050	$7/bu grain
Sweet sorghum	35.7 bu (1ton)	40 tons	1450 (250+1200)	$30/ton stalk

Sweet sorghum can be planted all over the US, and help the US to realize the goal of 35 billion gallons of ethanol by 2022.

On 29 July 2015, Dr. Yongyuth Sawatdisawanee, director of Bureau of Biofuel Development, Department of Energy, Thailand, headed a delegation to visit Tsinghua, and discussed the potential collaboration:

- √ To introduce ASSF technology to Thailand for cost-effective production of ethanol
- √ To establish Sino-Thailand Joint Research Center for Biofuel

- ✓ Now, Thailand's ethanol is mainly from cassava and molasses. Ethanol demand in 2018 is **2.96 billion liters**.
- ✓ Khon Kaen University plans to develop sweet sorghum as a new feedstock for ethanol.

Ethiopia is keen to establish bioethanol industry


Dr Li met with Mr. Ato Girma, former President of Ethiopia

- If 1.6 million ha grain sorghum is replaced by sweet sorghum, 10 million tons of ethanol can be produced per year.
- 1 million ha are available to be used to produce 7.5 million tons of ethanol competitively to supply the domestic need, 5 million tons of sorghum grain, and 10 billion Kwh electricity annually.
- A new industry of more than $7.5 billion/a will be built in 3-5 years in Ethiopia.


Dr Li met with Mr. Hailemariam, PM of Ethiopia.


A Ethiopian delegation visited demon plant in Inner Mongolia, China

"It always seems impossible until it's done".

Thank You