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Sweet sorghum

A renewable energy feedstock





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What is sweet sorghum?

- *S. Bicolor*, (L.) Monench
 - Type of perennial grass, related to sugar cane, also known as “Guinea Corn”
- Grown in Africa and India for many centuries
 - Easy to grow, resistant to pests, weeds and weather extremes
 - Hundreds of varieties and can be easily groomed to produce more or less cane/seed, depending on requirement
 - Gluten free grain used for human food and animal feed
 - Cane juice boiled into a syrup sweetener, cane fibre used for animal feed
 - Higher juice sugar content than sugar cane but difficult to crystallise sugar from sweet sorghum juice
- Also grown in USA, Europe for the past 100 years
 - Cane juice is used as a high value “natural” molasses sweetener



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Is sweet sorghum like grain sorghum?





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Sweet sorghum grows fast



AgriFuels crop trials December 2007

Left: Sugar cane planted Aug 07 Right: Sweet sorghum planted Oct 07



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Sweet sorghum grows big



Source: EUBIA experimental trials South Italy 2007



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Sweet sorghum is easy to harvest



Sugar cane harvester used in Tennessee, USA for sweet sorghum harvesting



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Many types of sweet sorghum



Different grain heads

Different soils

Large cane stalks

Small cane stalks



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Sweet sorghum advantages

- Lower cost to produce; higher farmer income than sugar cane
 - Less than ½ production cost of sugar cane
 - Grain and stalk income sources - not linked to sugar price
 - Stronger pest, cyclone, drought and flood resistance
- Shorter growing cycle compared to sugar cane
 - 3 x 4 months vs 4x 12-16 mths for sugar cane
- Seed based planting
 - Seed propagated and suitable for mechanized crop production
- Less water per hectare
 - 4000m³ per crop or ⅓ of sugar cane and ½ of maize
- Less fertilizer per hectare
 - ⅓ that of sugar cane
- Superior ethanol quality compared with sugarcane molasses sourced
 - Simpler processing of glucose and fructose juice vs scurose from molasses
 - Less sulfur and higher octane rating



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Sweet sorghum history in Australia

- Virtually no history of commercial sweet sorghum cultivation in Australia other than a few trials as a sugar crop alternative
 - Sweet sorghum juice has higher glucose and fructose but lower sucrose levels
 - No sweet sorghum molasses markets exist in Australia, unlike USA
- No ethanol production using sweet sorghum in Australia
 - No existing industry = focus of conversion only on existing crops to ethanol
 - Only two sugar mills produce ethanol – Sarina (CSR) and Rocky Point
 - Sugar cane ethanol is produced from molasses rather than juice
- Douglas Shire QLD sweet sorghum milling trial with Mossman mill
 - Harvesting successful with both forage and sugar cane harvesters
 - Inconclusive crushing and milling tests were performed
 - Project was suspended in 06



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Sweet sorghum “Food vs Fuel” argument

- Supplements food supply rather than subtracting from it
 - Produces grain for food
 - Produces cane for ethanol, electricity, paper pulp, animal food and more
- Can be grown on lands not currently being used for food crops
 - Suitable for high salinity soils, drought and flood areas
- Leverages existing crop cultivation and harvesting infrastructure
 - Seed planters such as used for sorghum grain
 - Sugar cane harvesters or forage harvesters and cane transport networks



SS cane (photo: Praj.net)



SS flour



Bread from SS



SS grain head (photo: Praj.net)



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The 3Fs of ethanol sustainability

- **F**armers

- Profitable farming from consistent cashflow, long term income;
- Better yield per hectare from better genetics, shorter crop cycle;
- Crop sustainability from high drought, flood, pest resistance;
- Lower input costs from lower water and fertiliser use.

- **F**ood

- Primary food crop (grain) for humans or animal feed for livestock;
- Profitable to grow for food production.

- **F**uel

- Fuel is made from the waste of a farming food crop;
- Controlled or fixed input costs for long term sustainability;
- Value-add income to a vertically integrated farming and fuel production process.



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FFF feedstock suitability

Crop	Farmer	Food	Fuel	Byproduct
Grain	Grain sales	Grain	-	-
Grain	Grain sales	-	Grain	DDGS (food)
Sugar cane Sugar beet	Cane sales Beet sales	Sugar Sugar	Molasses Molasses	Electricity/food -
Cellulosic grasses	Fibre sales	-	Fibre	Electricity/food
Sweet sorghum	Grain sales Cane sales	Grain -	- Sugar Juice	- Electricity/food

- Grains are a primary animal and human food crop.
- Dried Distillers Grain and Solubles (DDGS) is an animal feed by-product of ethanol production from grains
- It is not a primary food crop and less than 1/2 of the energy value per input unit
- Some perennial grasses are used as animal food "roughage"
- Sugar is not a primary food crop for animals or humans – it's a processed food additive.
- Sweet sorghum is a dual food and fuel crop that meets all the FFF requirements



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Ethanol feedstock crops

- **Grains** (wheat, barley, corn, sorghum grain):
 - **DISADVANTAGE:** Grain must be used for production of ethanol
 - **DISADVANTAGE:** Grain market price provides variable profit for farmers and variable input costs for fuel producer
- **Sugar crops** (sugar cane, sugar beet):
 - **DISADVANTAGE:** Sugar is not a primary food crop
 - **DISADVANTAGE:** Long crop cycle, high risk for farmers from single catastrophic crop failure
 - **DISADVANTAGE:** Sugar market price provides variable profit for farmers and variable input costs for fuel producer



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Ethanol feedstock crops cont.

- **Cellulosic** – perennial grasses, biomass, forest waste:
 - **DISADVANTAGE:** Requires expensive acid hydrolysis or new unproven enzymes for C5 and C6 sugar separation prior to fermentation
 - **DISADVANTAGE:** Costly capital equipment and relatively unproven commercial technology
- **Sweet sorghum:**
 - **MAJOR BENEFIT:** Produces a dual food and fuel crop three times a year from a single planting
 - **MAJOR BENEFIT:** Grain sale provides variable profit for farmers, cane sale provides fixed unit price income for farmers underpinning crop profitability
 - **MAJOR BENEFIT:** Fixed price for sweet sorghum cane provides control of input costs for fuel producer



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Sweet sorghum: ideal biofuel feedstock

- Renewable fuel source:
 - Food, ethanol, green electricity, minimal water and fertiliser for cultivation
- Rapid crop cycle:
 - Up to 4 crops/yr tropics, 3 crops subtropics and 2 crops in other areas.
 - Sugar cane requires 380-400 days per crop cycle
- Primary food crop is sweet sorghum grain:
 - Nutritious grain can be sold for human and animal feed consumption
 - Grain sale provides incremental profit for farmers
- Sugar juice from sweet sorghum cane is converted to ethanol:
 - Fixed price for sweet sorghum cane sale provides:
 - control of input costs for fuel producer, predictable income per hectare for farmers
 - Ethanol by-product is bagasse
 - electricity generation, animal feed, natural sweeteners, paper pulp, agro pellets, fibre and more



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Comparison of five ethanol feedstocks

Parameter	Sugarcane	Forage sorghum	Sweet sorghum	Grain sorghum	Maize
Crop duration (irrigated crops)	12 months	2 x 4 months	3 x 4 months	2 x 4 months	4 months
Total water requirement/ha/yr	36,000 m ³	8,000 m ³	12,000 m ³	11,000 m ³	8,100 m ³
Grain yield for food (tonnes/ ha/yr)	-	-	15	-	-
Grain yield for ethanol (tonnes/ha/yr)	-	-	-	17	8.7
Green stalk yield for ethanol (tonnes/ha/yr)	80	120	240	-	-
Total ethanol output (litres/ha/yr)	6,000	6,660	12,000	5,950	3,211



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Sweet sorghum opportunities

- Positive sweet sorghum climate change values
 - Carbon footprint makes acceptance easy to sell to government;
 - Reduced fertiliser and water use compared to sugar cane and maize.
- Ideal climate, soil conditions and water availability for SS
 - Potential for three high-yielding crops per year;
 - Daily harvesting = year-round crushing mill and co-generation operation.
- Introduction of SS as complimentary energy crop with sugar cane;
 - Large, existing sugar cane harvesting and transport industry and infrastructure;
 - Potential for government funding for alternate harvester development;
 - Significant value add by-product opportunities for sugar mills.



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AgriFuels project overview

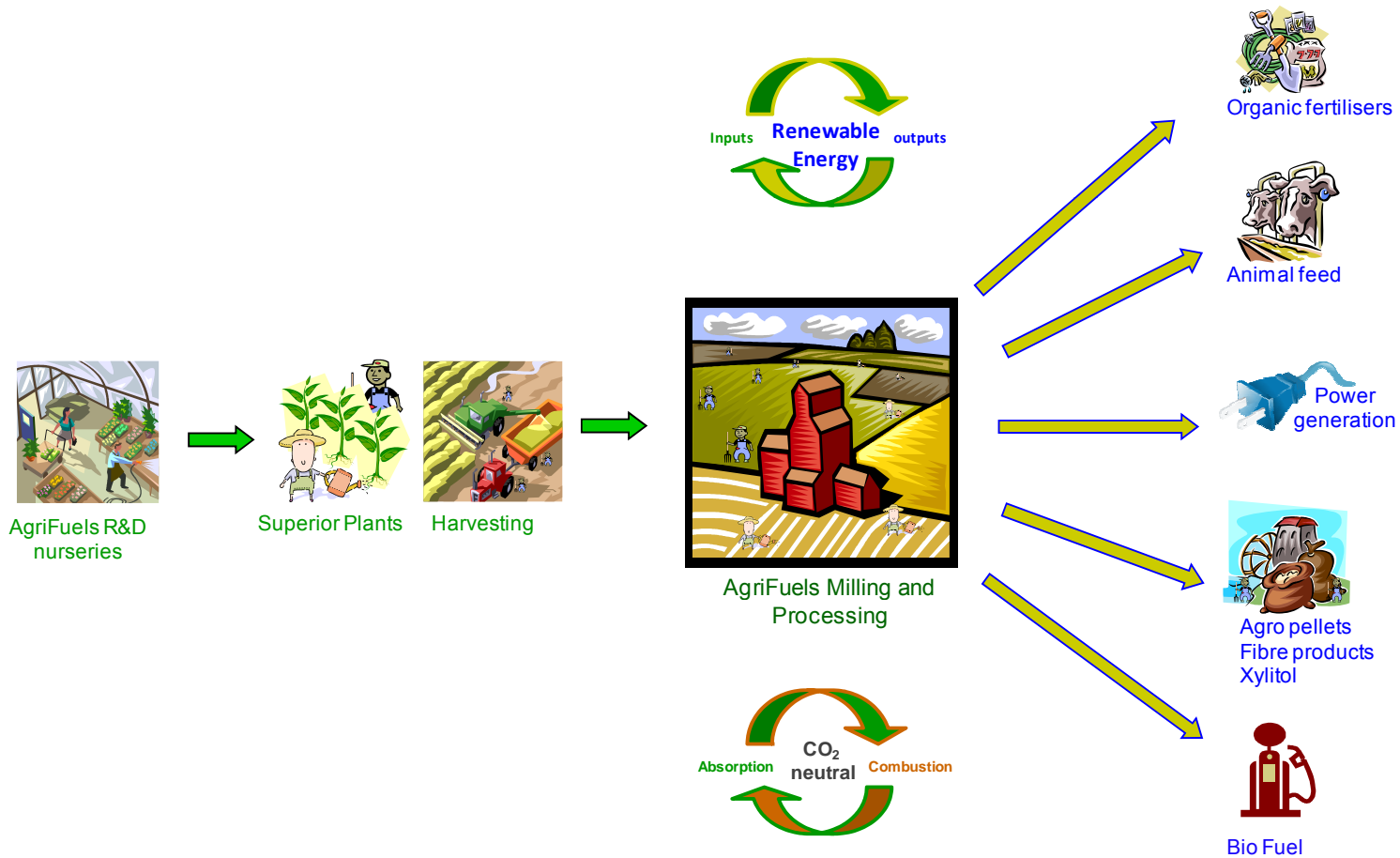
**A vertically-integrated,
sustainable renewable energy project**



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Renewable energy by agribusiness

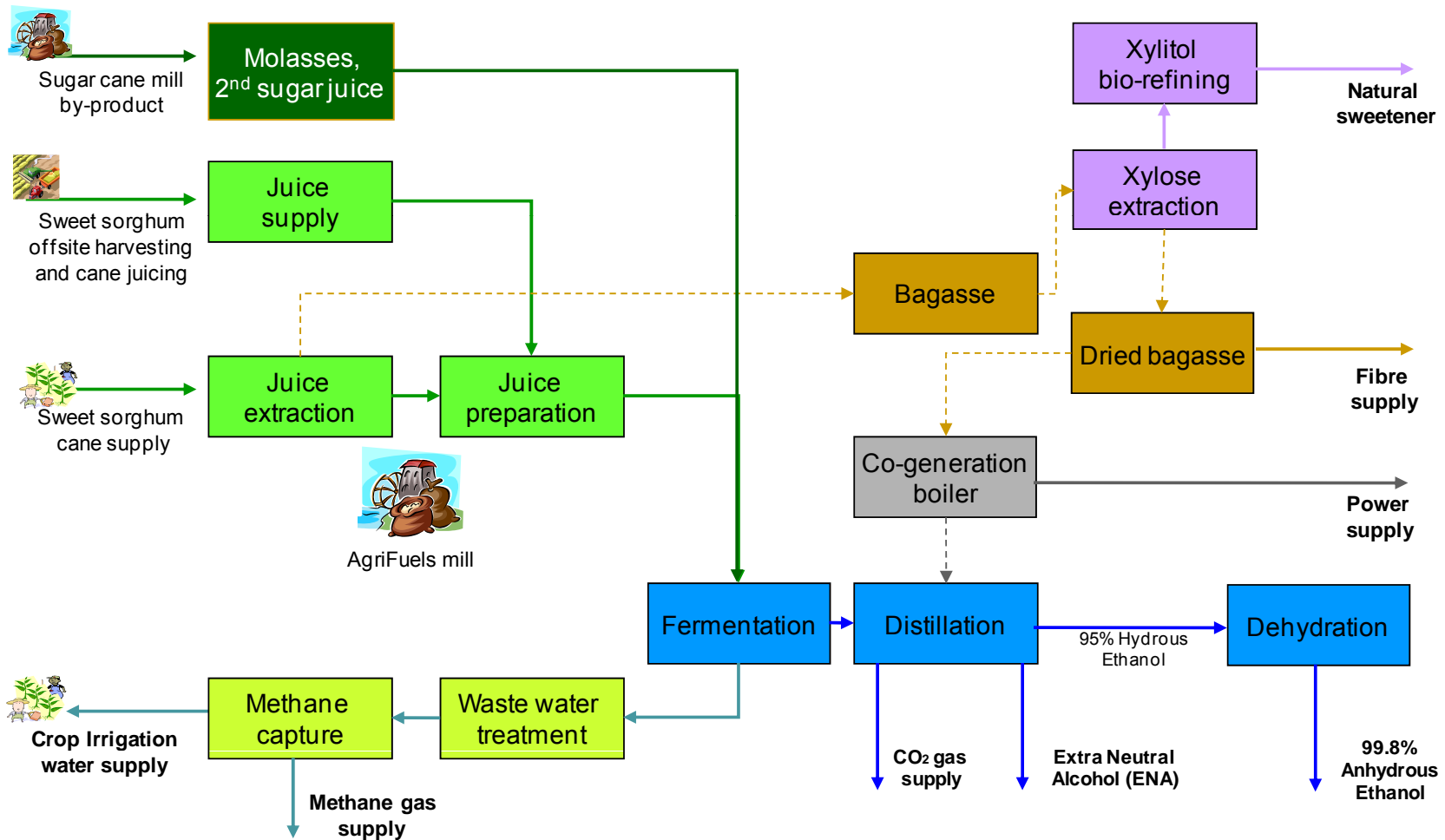




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Sweet sorghum energy model





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AgriFuels Australian crop trials

- Planted on 3 Oct 07 and first emerged on 10 Oct 07
- Trial data performed on average of 10 randomly selected plants

Trial data	11/10/07	19/10/07	26/10/07	2/11/07	8/11/07	23/11/07
No. Leaves	1	4	5	6	7	8.4
Plant height	3.5cm	9cm	19.3cm	38.2cm	57.4cm	138.4cm



Trial 11/10/07



Plant height 19/10/07



Plant height 26/10/07



Trial 19/10/07



Trial 2/11/07



Trial 9/11/07



Trial 23/11/07



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AgriFuels crop trial at 9 weeks





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AgriFuels crop trial at 13 weeks





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AgriFuels project data

- Crop requirements for 400,000 litres per day ethanol facility:
 - Crop suitable for rotation with sugar cane and legumes (peanuts, chickpea, soybean)
 - Crop ideal for land outside of current local sugar cane areas;
 - Approximately 8,750 hectares of land required (26,200 harvested ha at 3 harvests/yr);
 - 2.6m MT sweet sorghum cane harvested per annum
- Gen 1: juice to ethanol :
 - 144 Million litres ethanol production per year;
 - 655k MT of bagasse
 - Grid supply 81MW co-generation capacity (713GWh of electricity for sale);
 - assumes 70% of electricity generation can be sold to the grid
- Gen 1.5: integrated cellulosic ethanol facility
 - C5, C6 sugar fermentation;
 - Reduces land area to 5,725 Ha (harvested Ha reduced to 17,170 at 3 harvests/yr);
 - Reduces grid supply co-generation capacity to 17MW (149GWh electricity for sale).



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Summary

- **Sweet sorghum is the most suitable commercial FFF crop**
 - Dual production crop of grain and sugar juice
 - Lower water and fertiliser requirements than maize and sugar cane
 - Higher yield per hectare of ethanol compared to grains and sugar crops
 - Stronger pest, climate (drought and flood) resilience
- **Sweet sorghum grain**
 - Human food as gluten free grain and source of animal feed for livestock
 - Additional farmer income from grain at market prices
- **Sweet sorghum cane**
 - Cane pressed for sugar juice to be converted into ethanol
 - Bagasse fibre after juice pressing is used for electricity, xylitol, fibre products
 - Predictable farmer income per MT of cane (guaranteed min price per hectare)
 - Predictable renewable energy input cost per MT of cane



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THANK YOU!

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