CoER : Biofuels

Department of Microbiology • Faculty of Natural Sciences

From biomass to sustainable biofuels in Southern Africa

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Biofuels in South Africa

1. South African Biofuels Strategy

2. Current biofuel production in South Africa

3. Potential of South Africa for biofuels production

4. Next generation technologies for total biomass conversion

5. Chair of Energy Research: Biofuels and other clean alternative fuels

6. Global Sustainable Bioenergy Project

South African Biofuels Strategy

South African Industrial Biofuels Strategy

The final Industrial Biofuels Strategy appeared 5 Dec 2007

1. Mandate was to develop a 5-year Biofuels Industrial Strategy to create jobs in the energy-crop and biofuels value chain, act as bridge between 1st and 2nd economy.
2. Target for 2008-2013 is 2% penetration level of biofuels in national liquid fuel supply.
3. The proposed crops for Bioethanol: sugar cane and sugar beet; for Biodiesel: sunflower, canola and soya beans.
4. The exclusion of maize (corn) was based on food security concerns. *Jatropha curcas* was excluded because DoAgric considered it an invasive species.
6. Fuel levy exemption incentives: Biodiesel - 50%, Bioethanol - 100%
7. Note, biofuel blending *will not be mandatory*?

South African Industrial Biofuels Strategy

The primary objectives of the South Africa IBS were:

- Attract investment into rural areas;
- Promote agricultural development;
- Reduce import of foreign oil and improve current account;
- Overcome agricultural trade distortion of South Africa with the developed countries.

However, the general consensus is that the IBS does not incentivize a biofuels industry in South Africa, particularly because:

- blending is not mandatory, thus no guaranteed uptake;
- lack of funding for startup entrepreneurs and regulatory red tape, including
- applying for a license to produce biofuels (no licenses beyond 2% target is guaranteed).

Current biofuel production in South Africa

Current Biofuel production in South Africa

1st generation biofuels: Bioethanol

1. With the exclusion of maize for the production of bioethanol in the Industrial Biofuels Strategy, eight bioethanol plants in the planning were indefinitely put on hold. This basically stunted private funded bioethanol production in SA.

2. South Africa has longstanding producers of neutral ethanol, such as NCP (70 ML/an) and Illovo (60 ML/an), however, this is for non-fuel local and international markets.

3. The only bioethanol production in SA is limited amounts for the production of ethanol gel as safe alternative to kerosene (700 ML/an market) that causes thousands of deaths in the informal housing sector due to accidental fires and ingestion by toddlers.

Current Biofuel production in South Africa

1st generation biofuels: Bioethanol

4. While private stakeholders felt they were left out of the discussions on the proposed biofuels program, the South Africa's Industrial Development Corporation (IDC) and Energy Development Corporation (EDC) have announced they will invest 3.2 Bn Rand (€327 M /US$437 M) in 2 biofuels projects, with erection of the plants set for sometime in 2009.

5. About 100 ML bioethanol will be produced from sugar cane grown by commercial and emergent farmers under irrigation in the Hoedspruit area of the Limpopo lowveld. A further 90 ML of bio-ethanol will be produced from sugar beet cultivated in the Cradock area of the Eastern Cape.

6. In the meantime, Mozambique and other neighbouring countries attract private investments because of more favourable leasing contracts and tax exemptions, as well as good agricultural soils.

Current Biofuel production in South Africa

1st generation biofuels: Biodiesel

1. More than 200 small entrepreneurs that produce biodiesel on small scale – mostly from waste vegetable oils.
2. Major concerns for these entrepreneurs are feedstock costs (virgin oils too expensive), uptake (no mandatory blending) and meeting specifications required by petrochemical industries.
3. It is generally accepted outside governmental circles that, until blending becomes mandatory, major petrochemical industries have no obligation to step up to the biofuels blending challenge.
4. Rainbow Nation Renewable Fuels (RNRF) Ltd in Coega (close to Port Elizabeth) will be the first commercial manufacturer that will erect a 1.1 Mt/an soybean crushing facility –producing and distribute 228 ML biodiesel fuel, 19 000 t glycerine and 825 000 t soybean meal for South African and international markets. They just acquired a license and use Australian technologies (Desmet Ballestra).

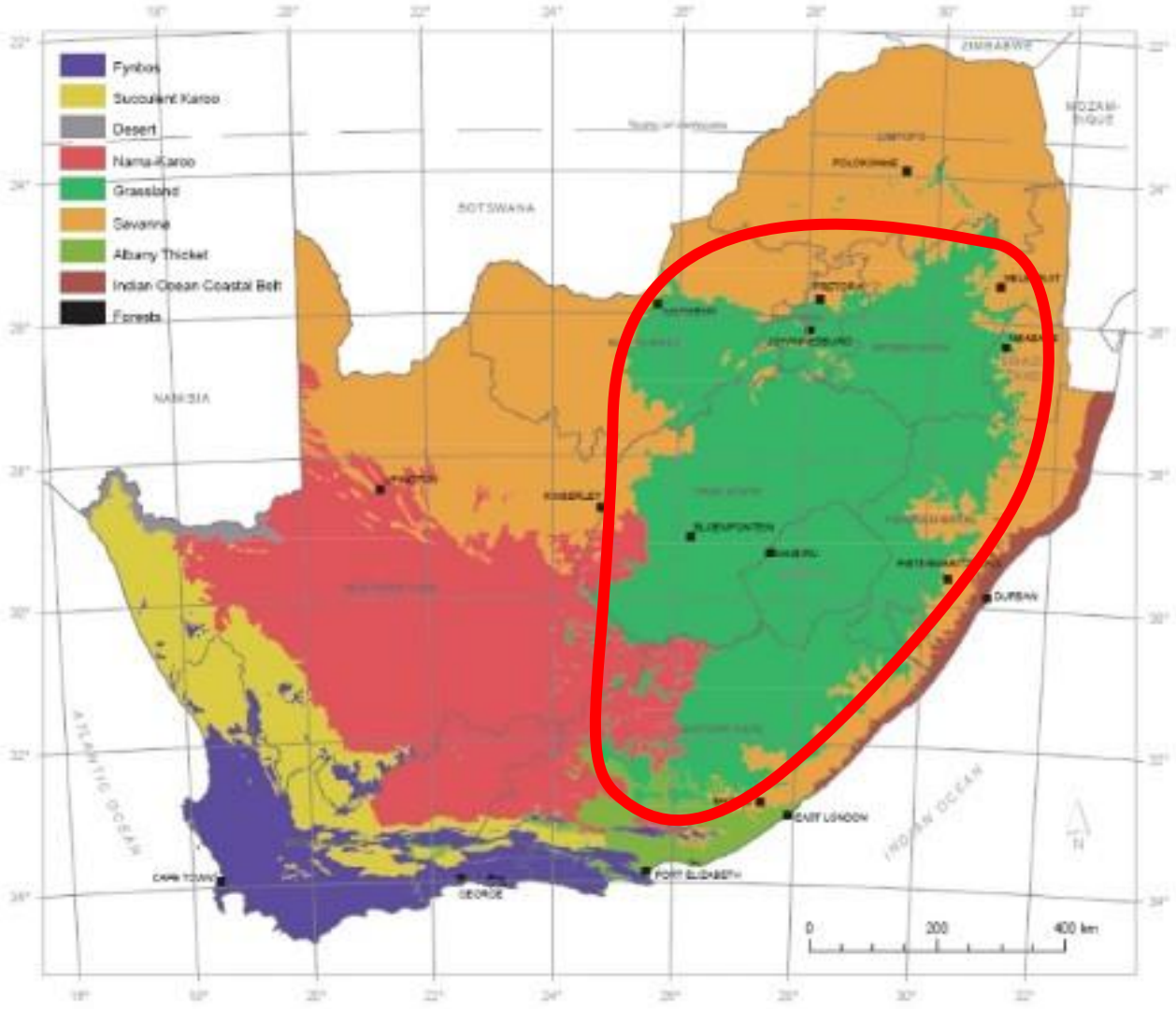
Potential of South Africa for biofuels production

South Africa's potential: Renewable biomass available

1. Residues	
Agricultural	
Maize stover	6.7 Mt/a
Sugar cane bagasse	3.3 Mt/a
Wheat straw	1.6 Mt/a
Sunflower stalks	0.6 Mt/a
Agricultural subtotal	**12.3 Mt/a**
Forest industry	
Left in forest	4.0 Mt/a
Saw mill residue	0.9 Mt/a
Paper & board mill sludge	0.1 Mt/a
Forest industry subtotal	**5.0 Mt/a**
2. Energy crops	
From 10% of available land (Marrison and Larson, 1996)	**67 Mt/a**
3. Invasive plant species	**8.7 Mt**
Total, annual basis	**93 Mt/a**

Lynd et al. 2003. Plant Biomass Conversion to Fuels and Commodity Chemicals in South Africa: A Third Chapter? South African Journal of Science **99:** 499 – 507.

Vegetation map for South Africa



L Mucina *et al.*, Vegetation of South Africa, 2007

Biofuels production in South Africa

1. Consider South Africa as a country of 120 M hectares.

3. Using about 20% of South African land for natural energy crop harvesting at 1 - 3 ton/hectare would readily yield 24 – 72 Mt!

4. Alternatively, consider high biomass sugarcane! In such a case, using 100 ton/hectare you would need ½% of the land to reach the 67 Mt!

5. Both scenarios still leaves enough land for food production and conservation!

Which bioenergy crops?

Themeda triandra (red grass)

Sugar cane (100+ t/ hect?)

Harvesting red grass

Invasive trees

Future bioenergy potential in Africa

http

Next generation technologies for total biomass conversion

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Chair of Energy Research: Biofuels and other clean alternative fuels

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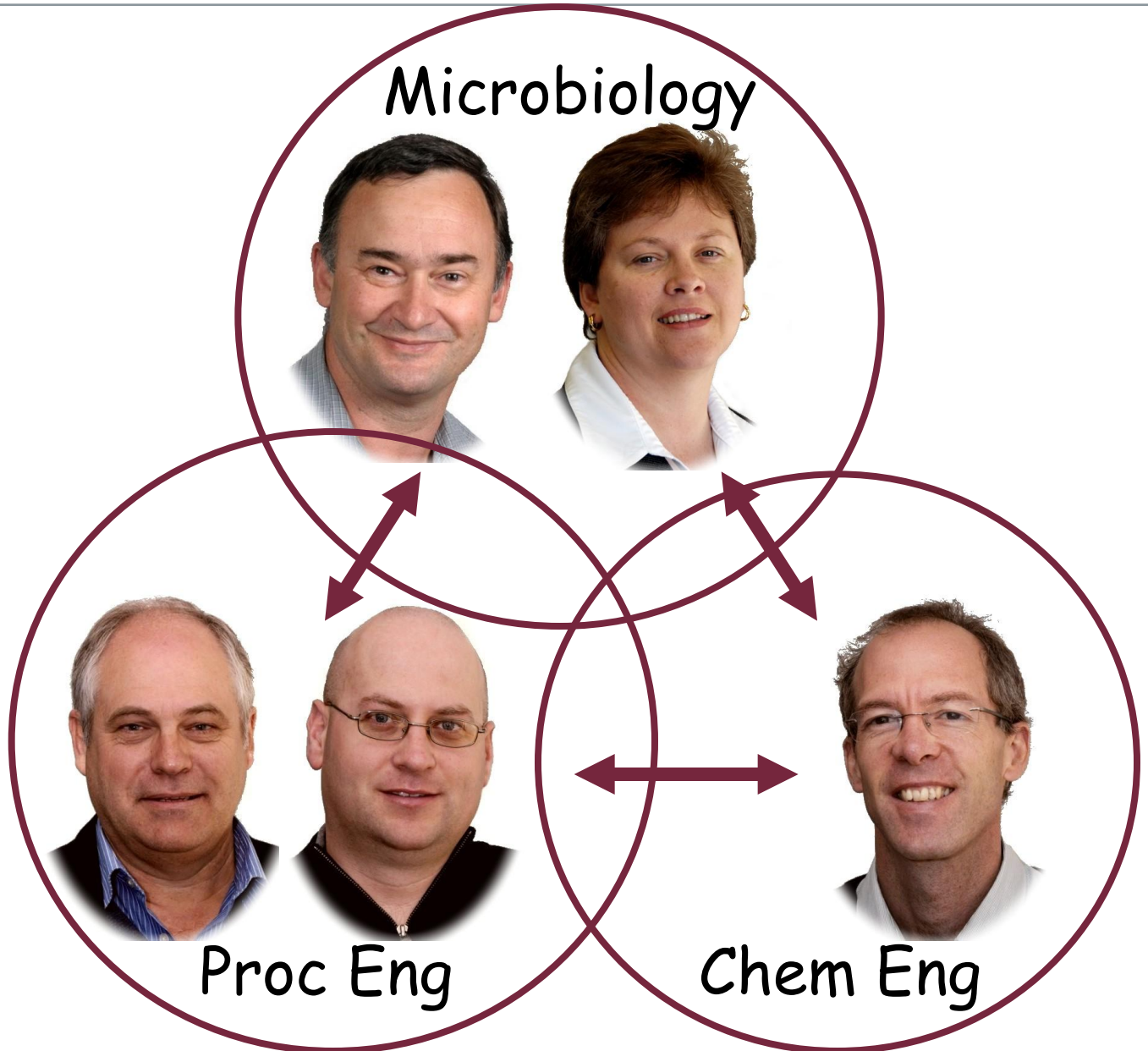
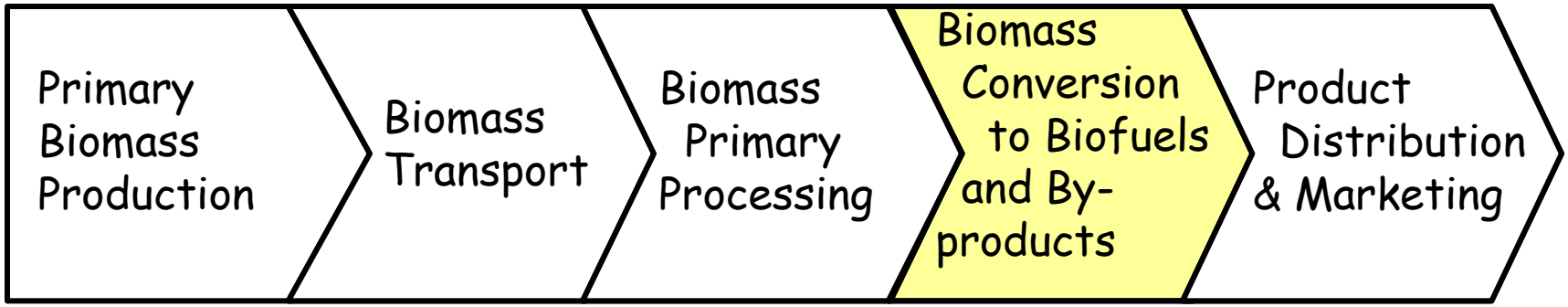
CoER : Biofuels (members)



Technologies for Cellulose Conversion

Cellulosics biofuels production value chain:



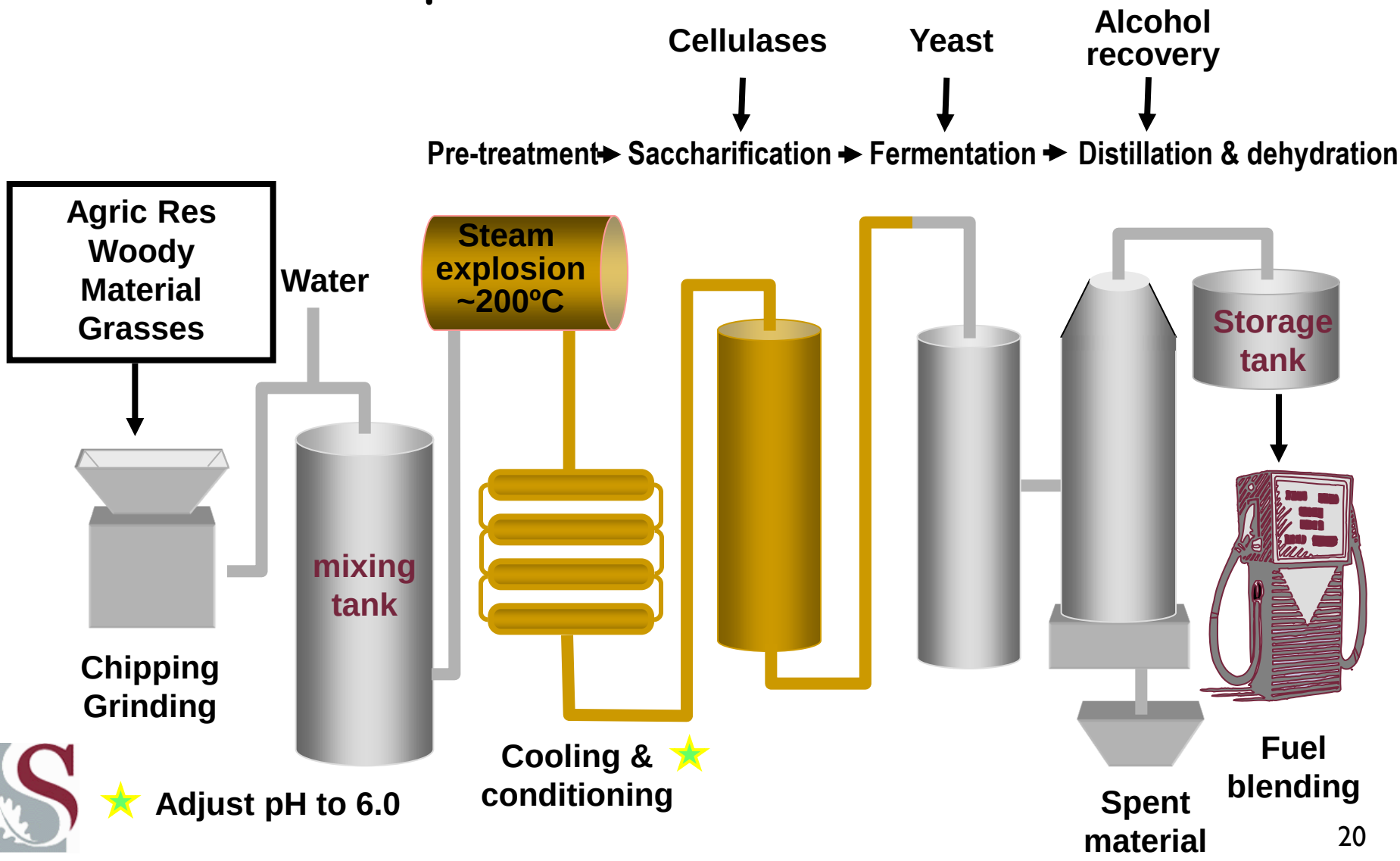
Two types of conversion processes for lignocellulosics:

- Biological via sugars as energy carriers
- Thermo-chemical via gas, oil and/or char as energy carriers

Most interesting is integration of these processes

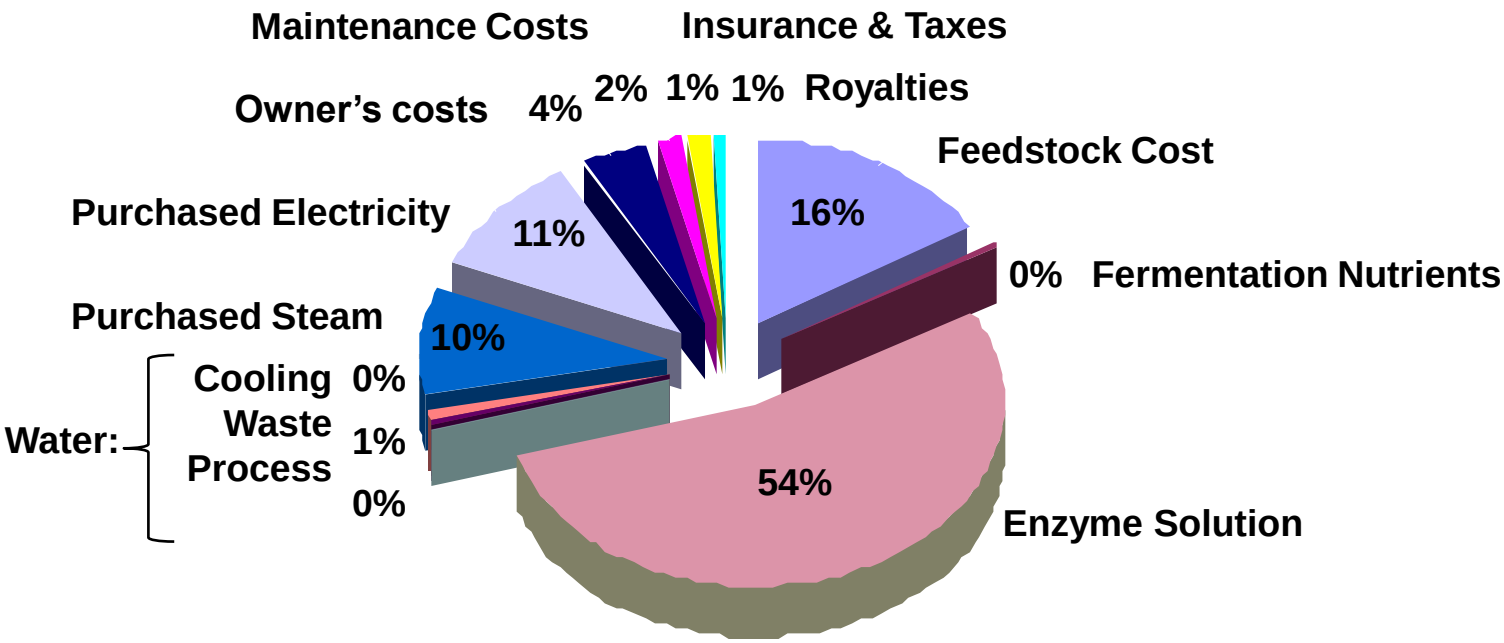
Technologies for Ethanol Production

Ethanol production from cellulosics



Largest Component of Recalcitrance Barrier: Cost of Cellulase

Operating Costs for Lignocellulosic Plant



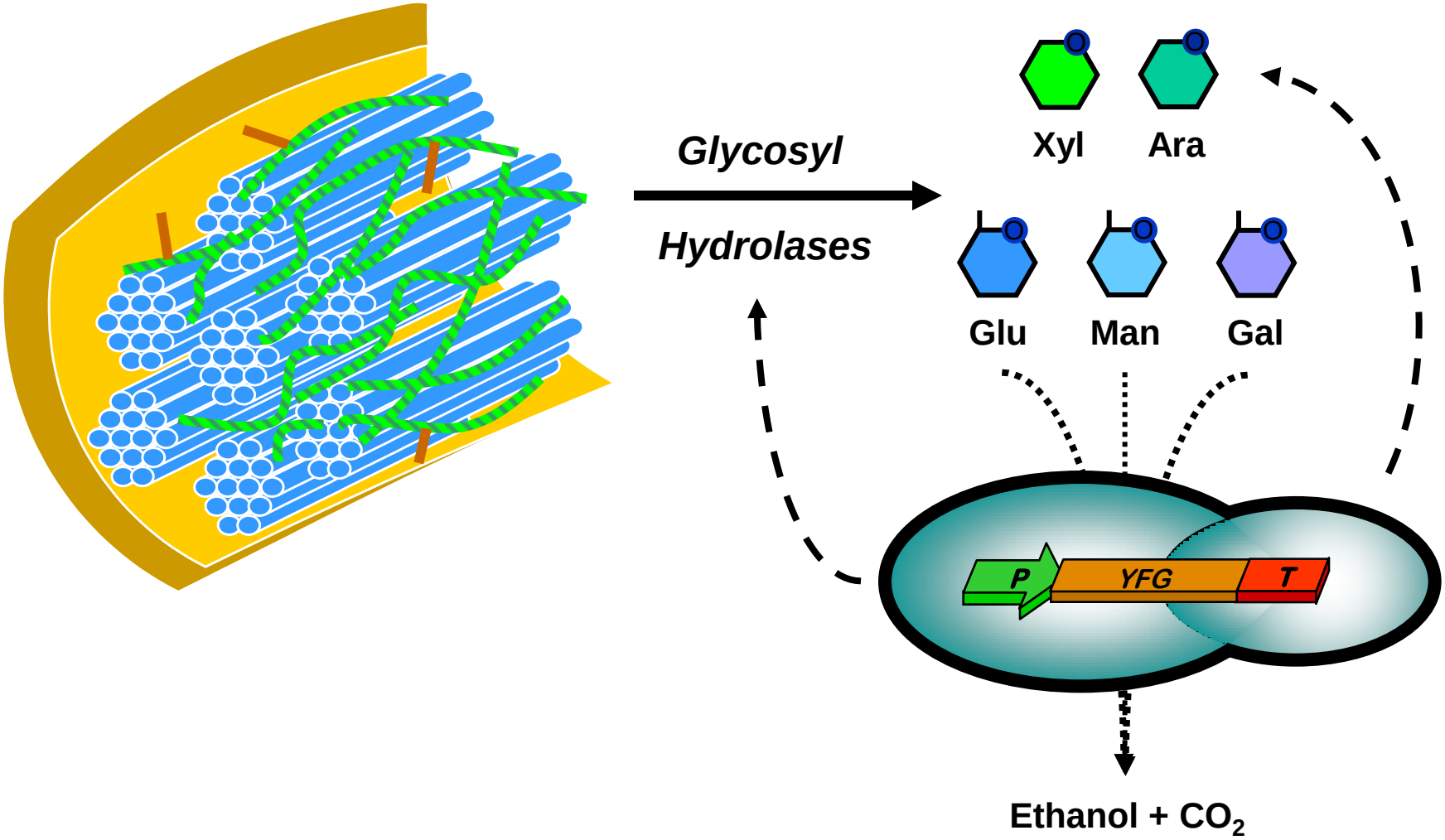
Enzyme dominates projected costs for hardwood ethanol

Cellulase costs, at >2 fold that of feedstock, are excessive for commodity products

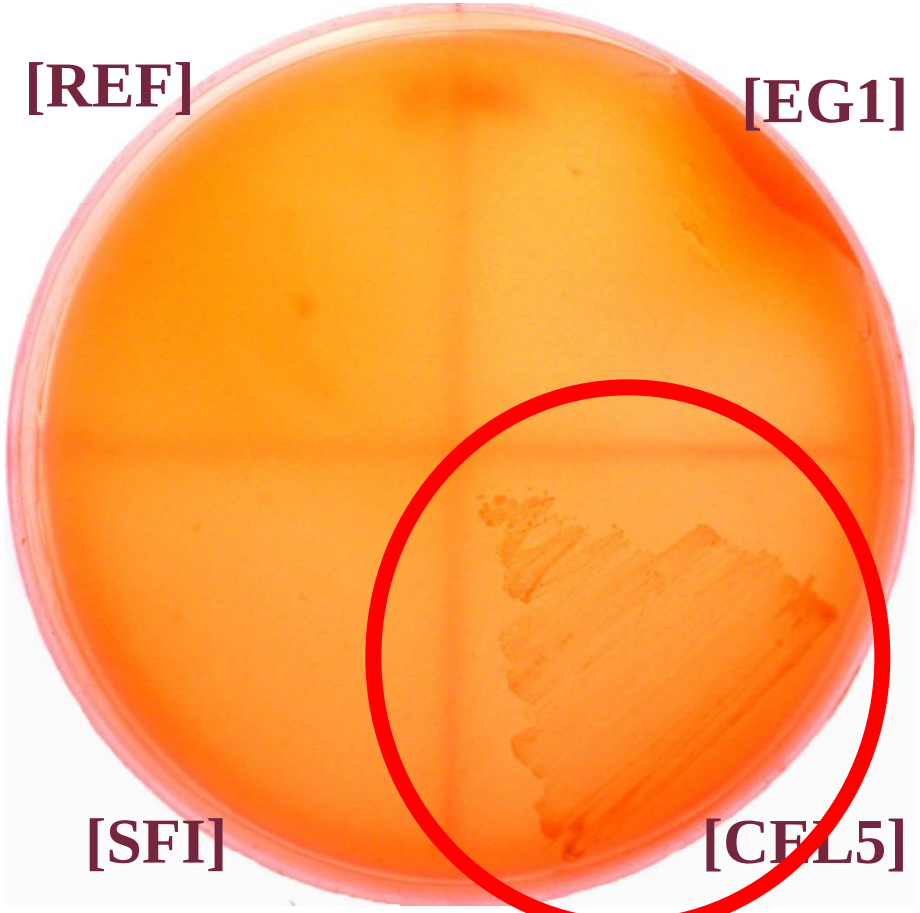
Cost distribution provided by Mascoma Corporation, Lebanon, NH, USA

Technologies for Cellulose Conversion

Consolidated BioProcessing (CBP)



Growth on amorphous cellulose (PASC)



Den Haan, R., S.H. Rose, L.R. Lynd, and W.H. Van Zyl. 2007. Hydrolysis and fermentation of amorphous cellulose by recombinant *Saccharomyces cerevisiae*. *Met. Eng.* **9:** 87–94.

MASCOMA

Leading Investment, Unprecedented Focus on CBP

Technical Focus: Overcoming the biomass recalcitrance barrier and enabling the emergence of a cellulosic biofuels industry via *pioneering CBP technology integrated with advanced pretreatment*

Partners in Mascoma's CBP Organism Development Effort

- VTT
- Dartmouth College
- University of Stellenbosch
- BioEnergy Science Center
- Department of Energy

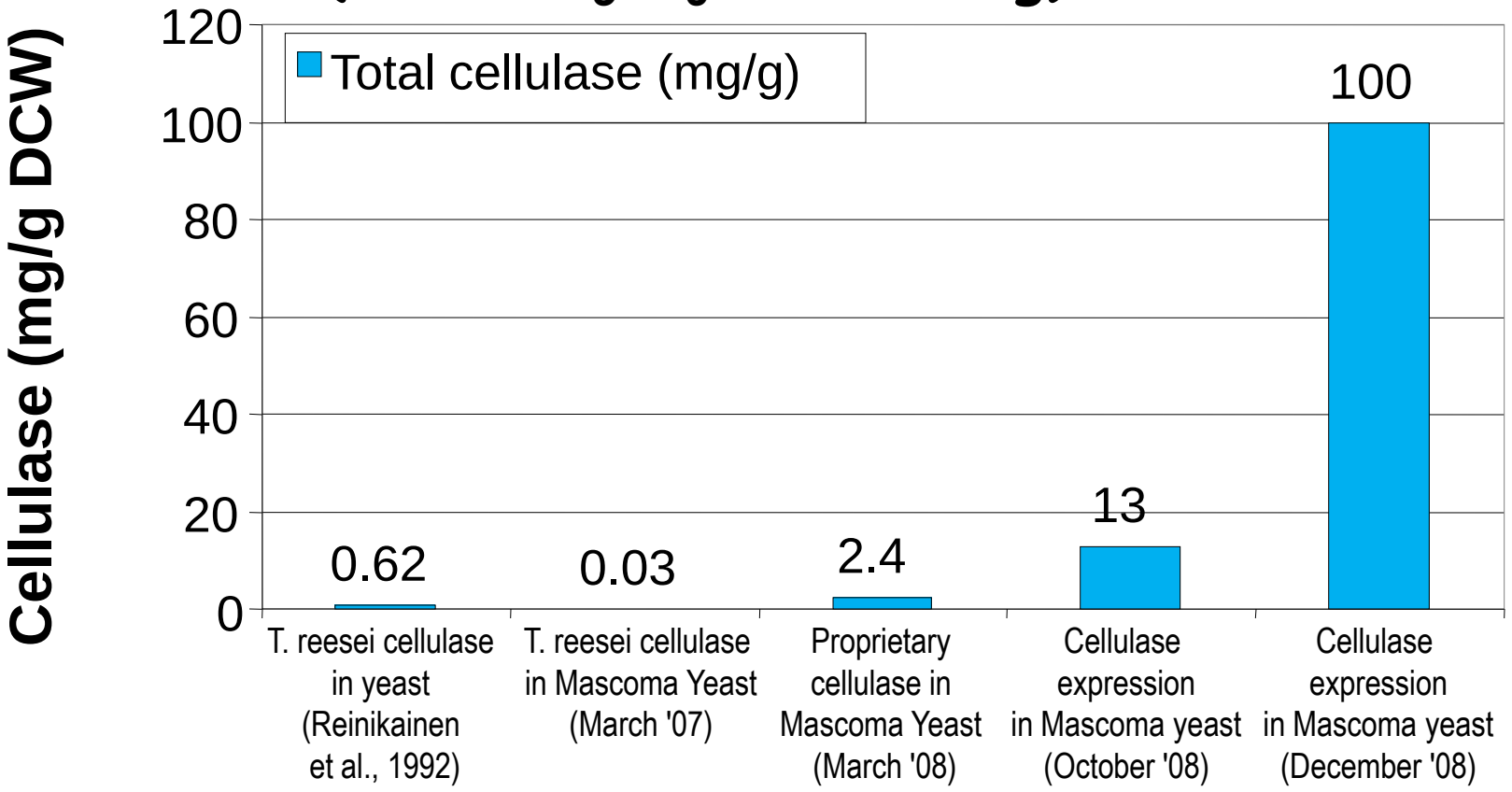
Three Platforms

1. *T. saccharolyticum,* thermophilic bacterium able to use non-glucose sugars
2. *C. thermocellum,* thermophilic cellulolytic bacterium
3. Yeast engineered to utilize cellulose and ferment glucose and xylose

Multiple chances to succeed near-term & long-term

Mascoma Cellulolytic Yeast

Cellulase expression in Mascoma Yeast (robust C_5/C_6 fermenting) vs Time

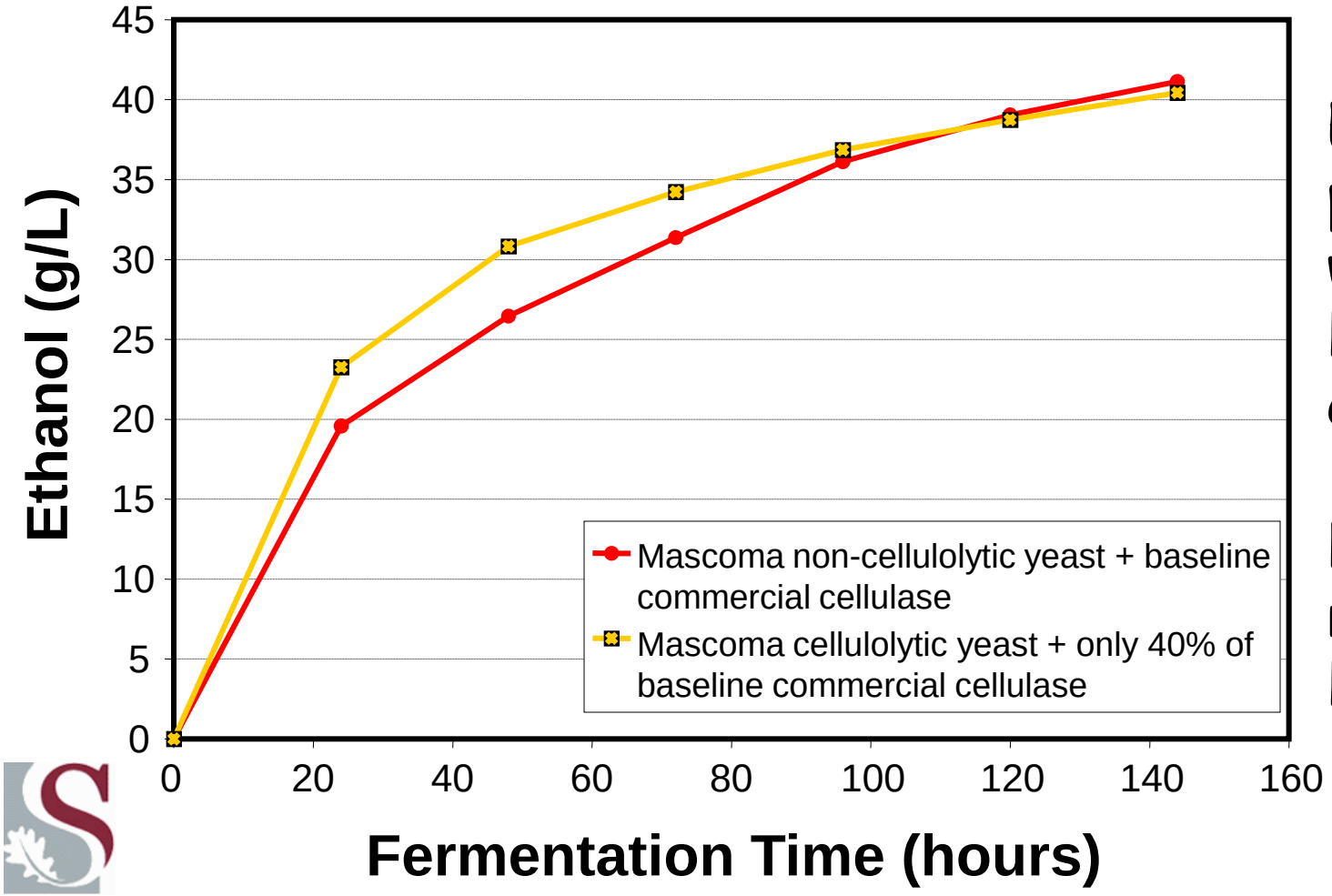


Cellulase expression Time-line

Mar, 2007 to Dec, 2008: >3,000-fold improvement in expression levels

Enzyme Reduction on Hardwood

Mascoma CBP Strain (robust C5/C6 fermenting yeast) + 22% w/w unwashed Pretreated Hardwood + Commercial cellulase

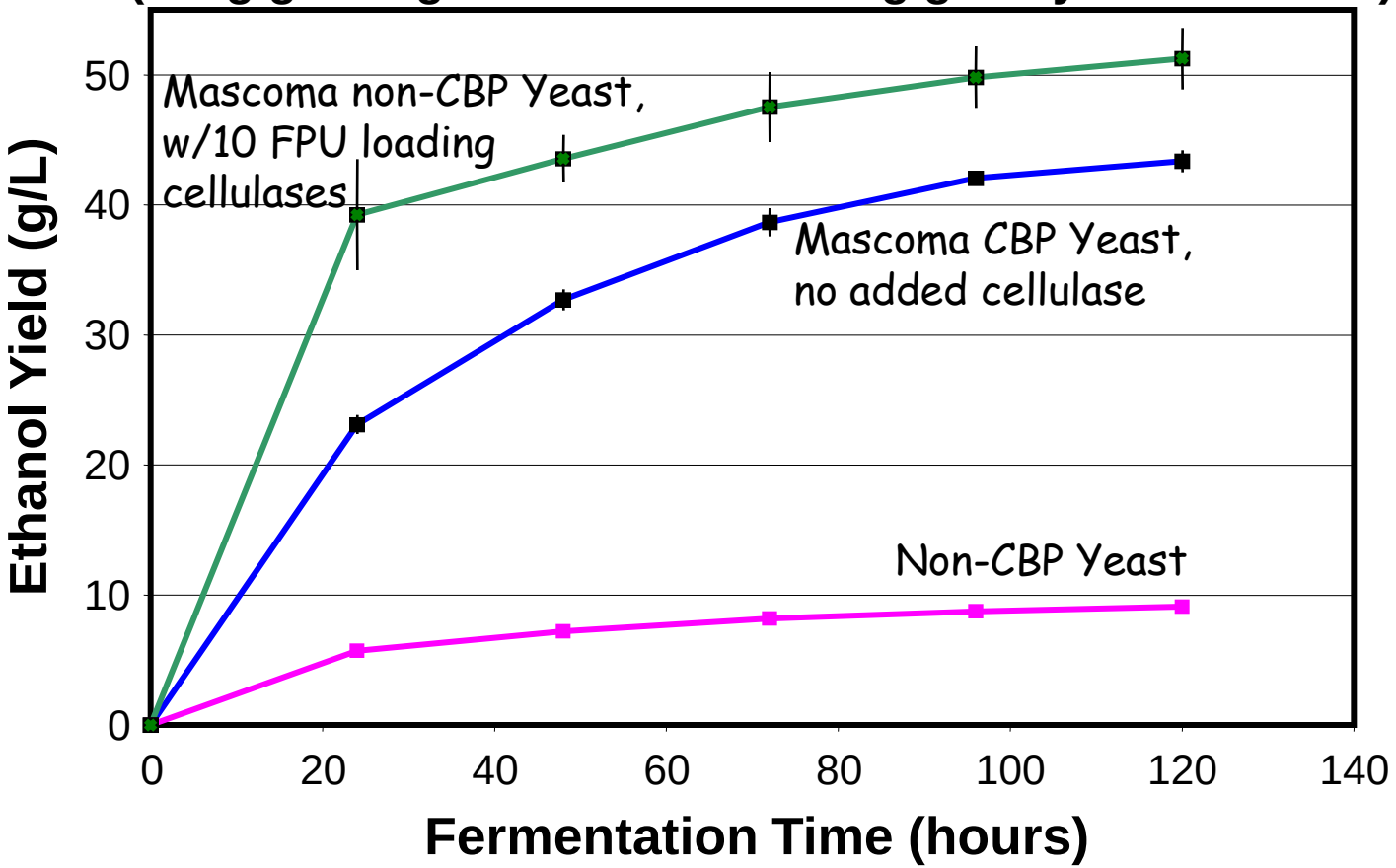


Equivalent performance with 2.5-fold less added enzyme

Further reduction likely

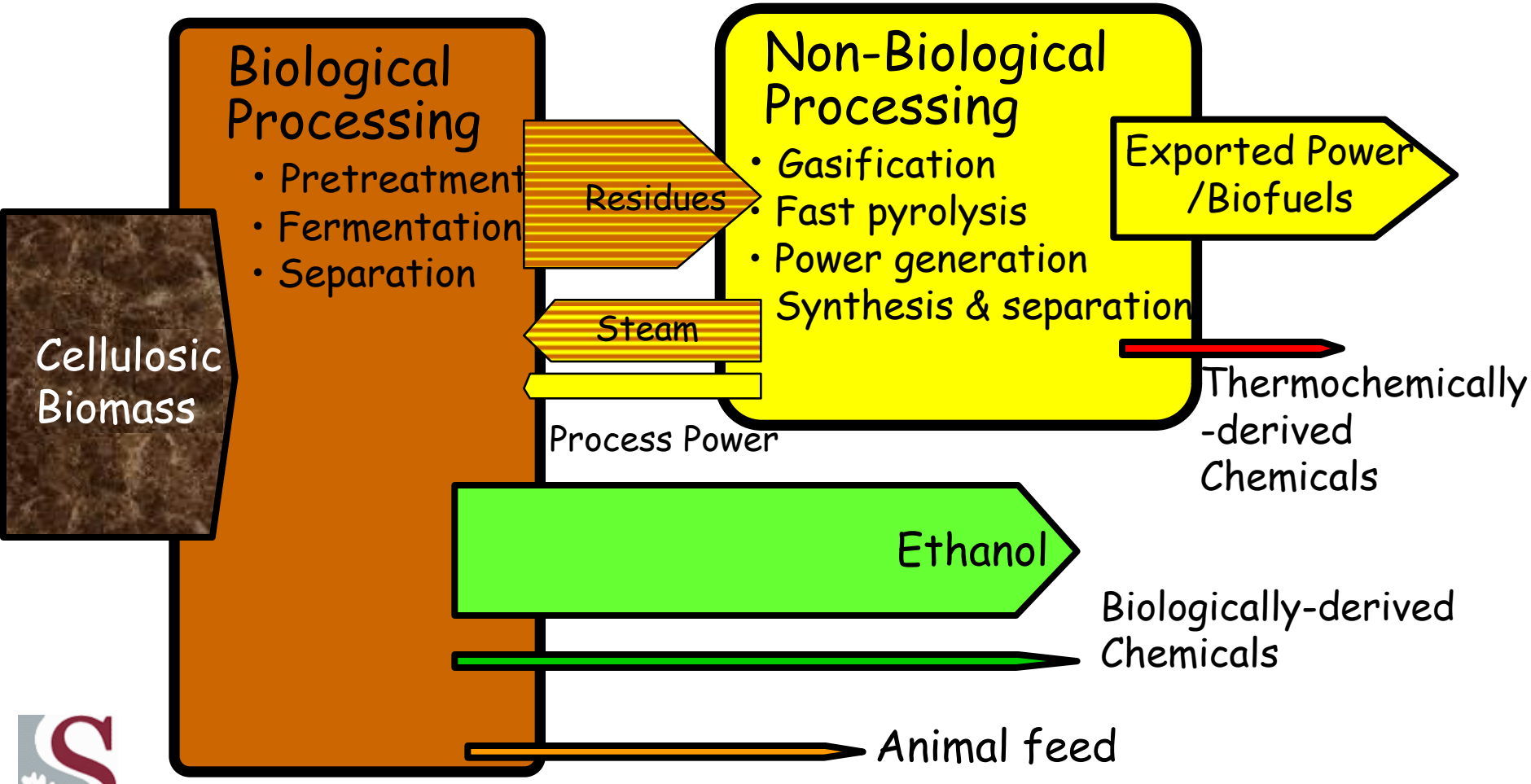
Conversion of Paper Sludge to Ethanol: Proof of CBP Concept

Mascoma CBP technology on 18% w/w paper sludge
(1 mg/gTS b-glucosidase and 1 mg/gTS xylanase added)



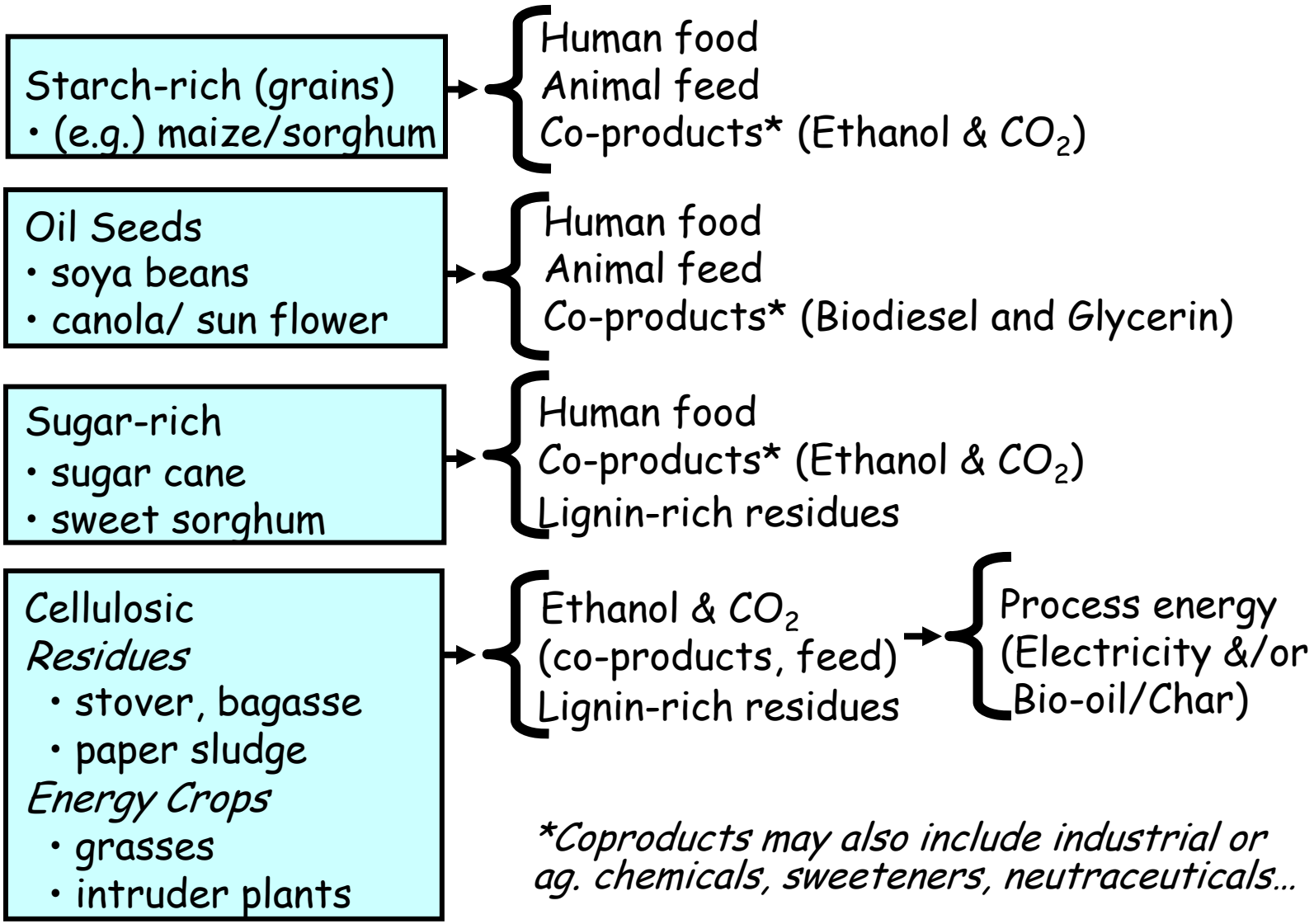
85% cellulose conversion with production of recoverable ethanol with no added cellulase!

Integration of Biological and Thermo-chemical Processing in African context



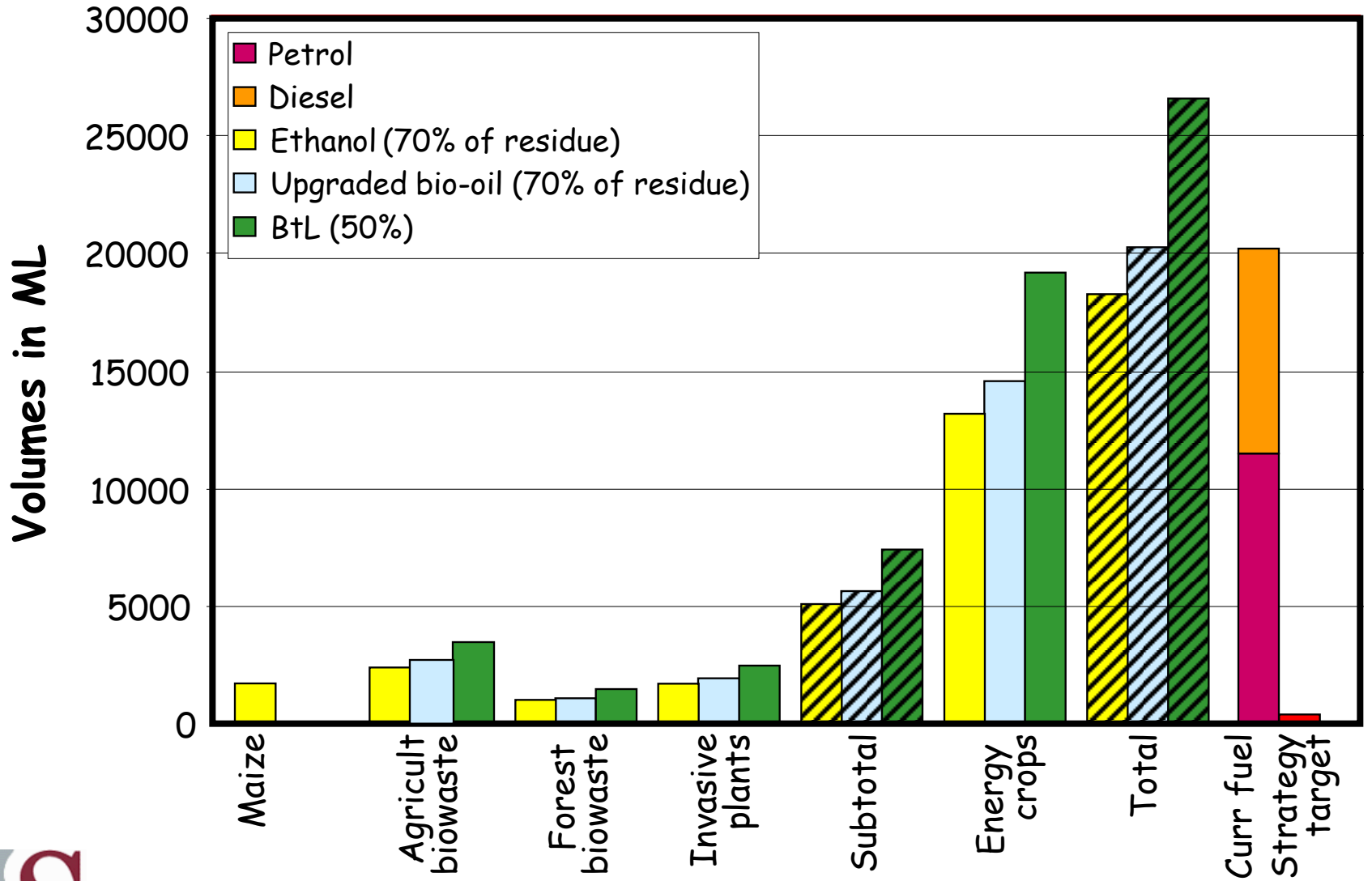
Evolution to Cellulose Conversion

Food, Feed and Biofuel Options



**Coproducts may also include industrial or ag. chemicals, sweeteners, neutraceuticals…*

South Africa's potential: Biofuels production



Maize to Ethanol = 430 L/ton

Biomass to upgraded bio-oils = 310 L/ton

Biomass to ethanol = 280 L/ton

Biomass to liquid (BtL) = 570 L/ton

Thank you!