CanmetENERGY

Leadership in ecoInnovation

Biofuels and Biochemicals: Investment Opportunities?

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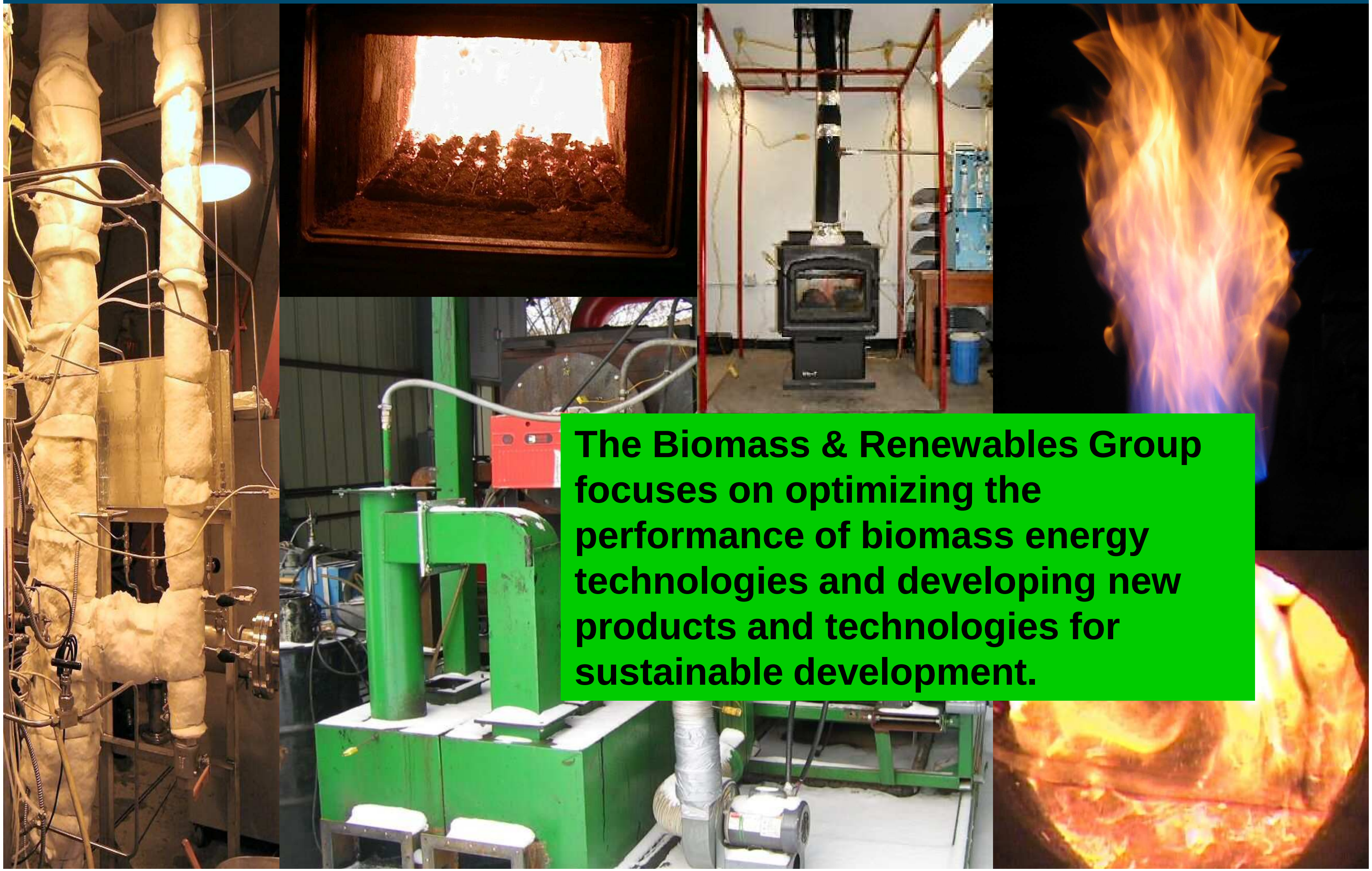
CanmetENERGY, Natural Resources Canada

Bioenergy II – Fuels and Chemicals from Renewable Resources

CanmetENERGY (Natural Resources Canada) assists industry to develop cleaner, energy-efficient and cost-effective biomass conversion processes.



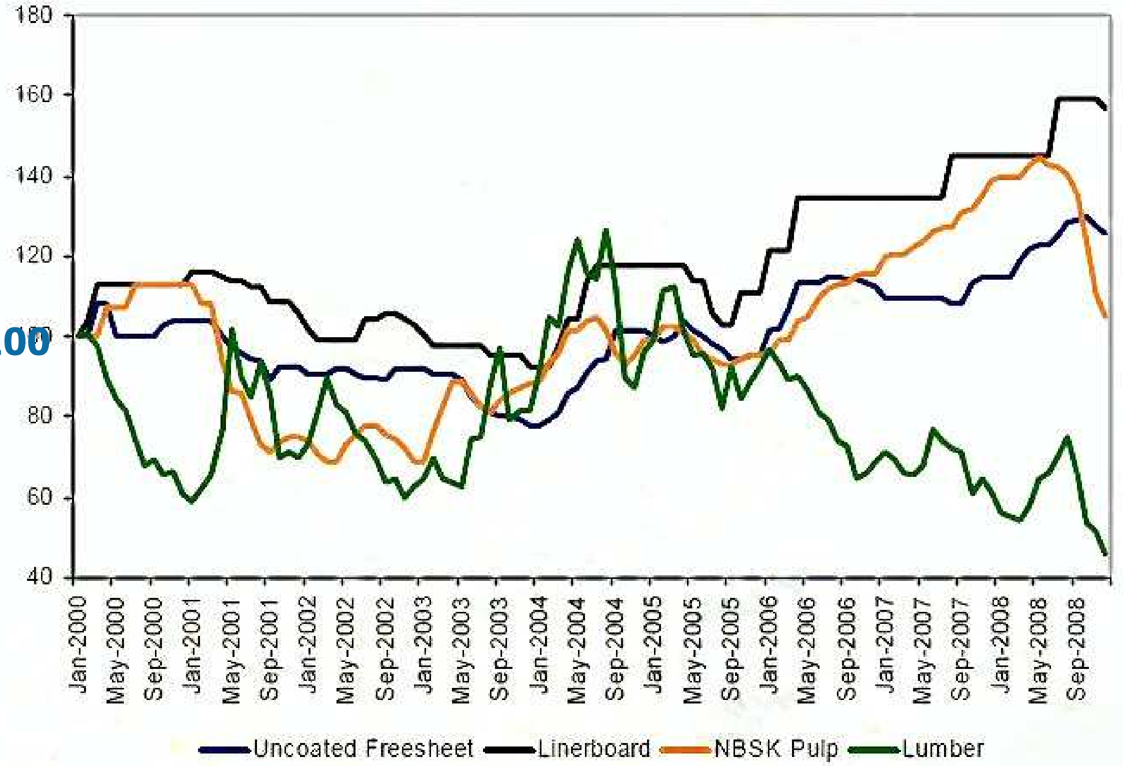
The Biomass & Renewables Group focuses on optimizing the performance of biomass energy technologies and developing new products and technologies for sustainable development.


How do you select the technology/research in which to invest?

Difficult Financial Times

Forest Industry Commodity Prices Very Weak

Jan. 2000 = 100



Source: Don Roberts, CIBC World Markets Inc

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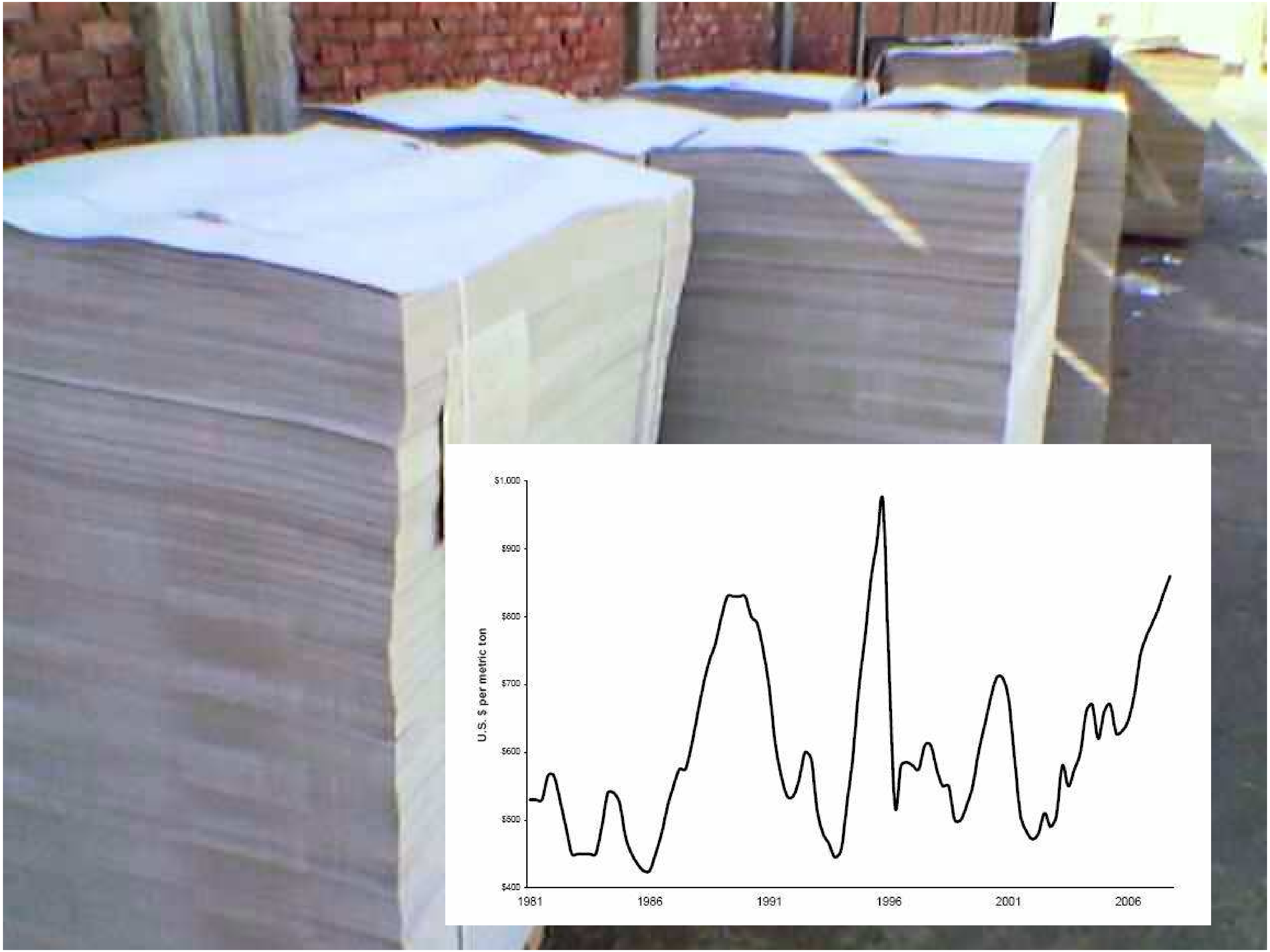
$1,000
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U.S. $ per metric ton
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- **The world economy may be weak but public support for environmentally (GHG) friendly technologies is strong**

- **Technological breakthroughs are emerging that will allow the “biomass” industry to take advantage of new markets for a broad array of new “biofuels” and “biochemicals”**

- **Systematic analysis is needed to identify the most promising “bioproducts” and their economic and environmental impacts with a view to investment opportunities**

Inquiry Tree

- Assess the status of emerging bio-fuels and bio-chemicals technologies
- Assess the potential to secure biomass feedstock at a reasonable price
- Assess economic return potential

Unit Operations

Thermochemical processes
Combustion
Gasification
Pyrolysis

Chemical processes
Chemical reactions
Catalytic Processes
Esterification
Hydrogenation
Hydrolysis
Methanisation
Steam reforming
Electrolysis
Water gas shift

Biochemical processes
Sugar fermentation
Methane fermentation
Syngas fermentation

Thermal/Mechanical/Physical processes
Drying
Comminution
Extraction
Fiber separation
Mechanical fractionation
Pressing
Separation
Upgrading
Distillation

Ethanol Pathways (Starch)

Thermochemical processes

Combustion
Gasification
Pyrolysis

Biochemical processes

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Thermal/Mechanical/Physical processes

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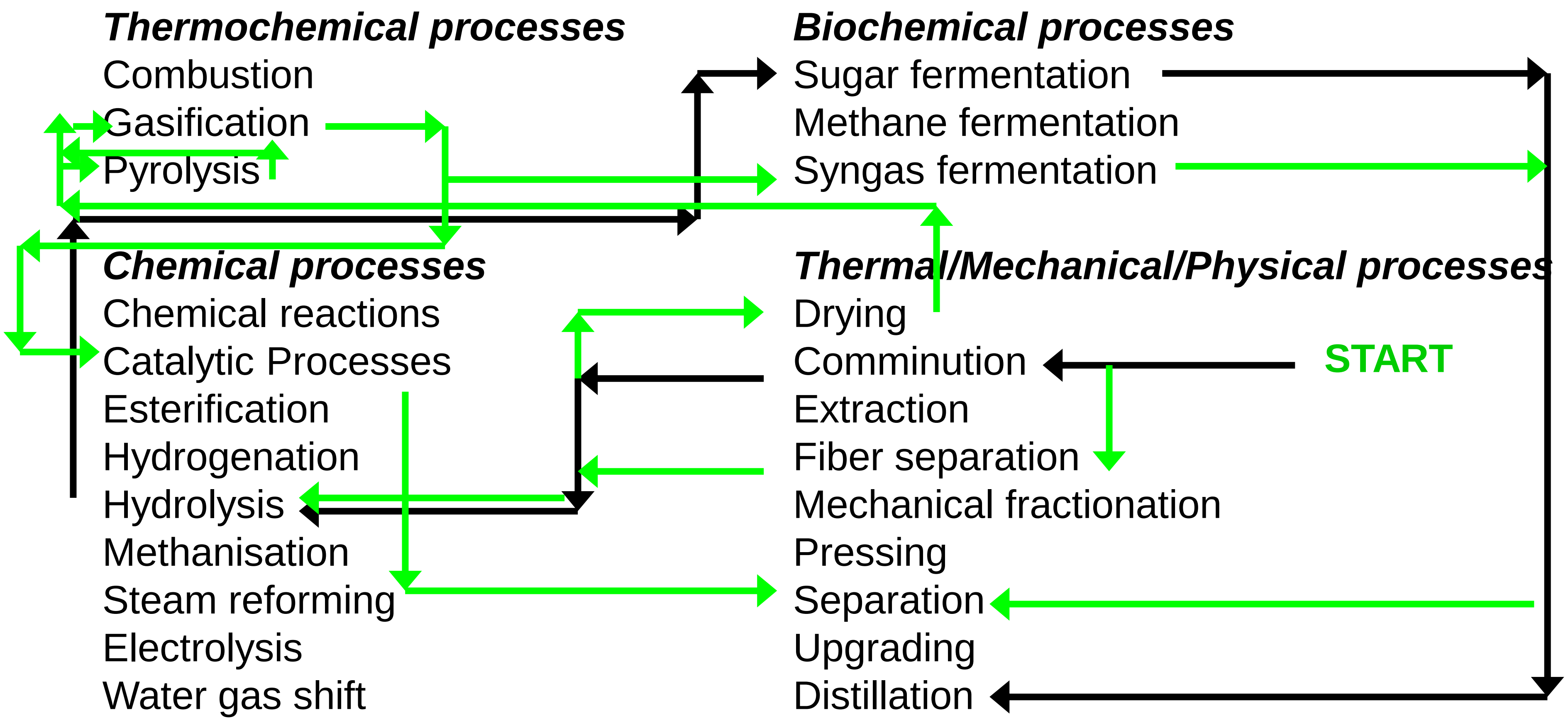
Upgrading
Distillation

START

Ethanol (Future) Pathways



Assess Biomass Opportunities

Biomass

Thermochemical processes
Chemical processes
Thermal/Mechanical/Physical
Biochemical processes

→

Energy & Fuels
Structural Materials
Fibre-based Materials
Chemicals
Food

Assess Investment Opportunities

Buy Low → Sell High

Biomass

Thermochemical processes
Chemical processes
Thermal/Mechanical/Physical
Biochemical processes

→

Energy & Fuels
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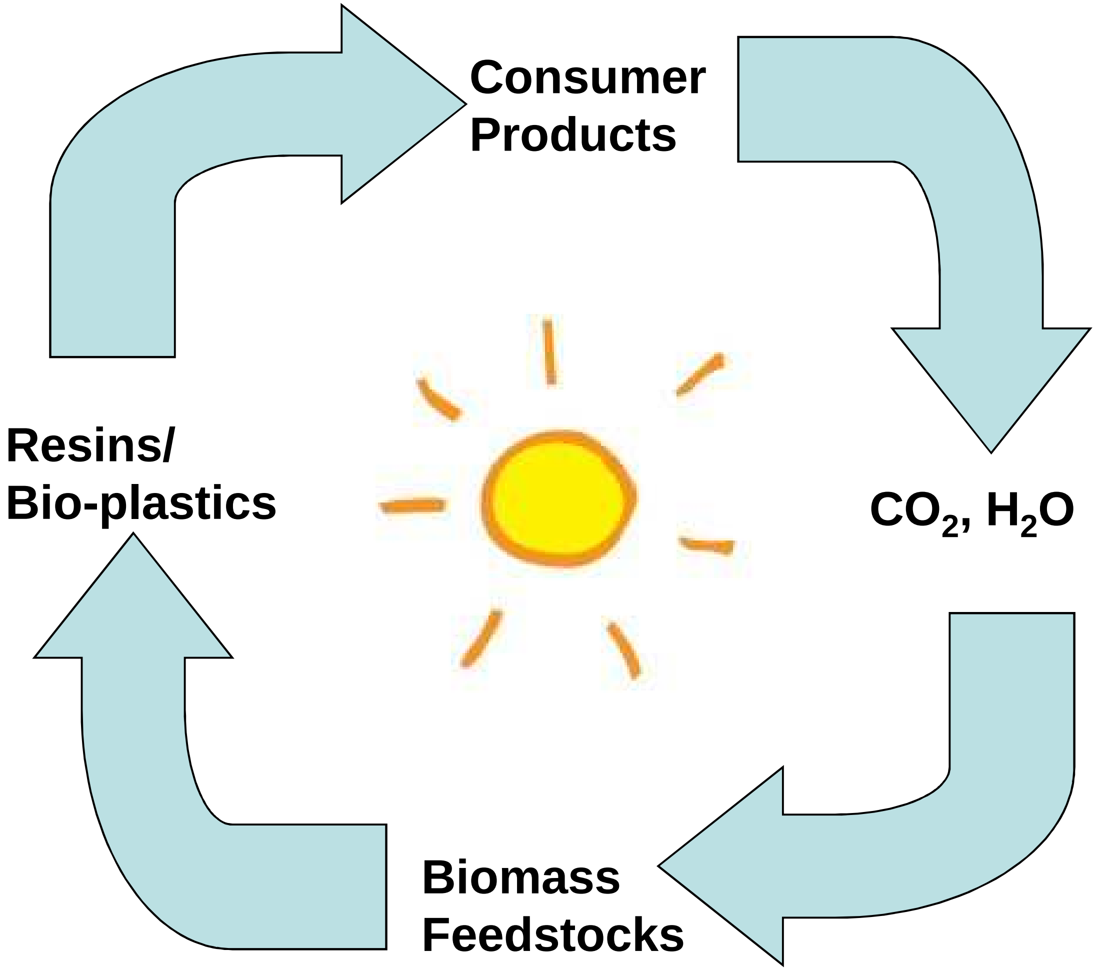
Food

"The Future is Bio-Plastics"



Benefits of “Bio-Plastics”

- **Reduced CO_2 emissions**
- **Commonly bio-degradable**
- **Benefit to rural economy**
- **Enhanced properties (composites)**

Bio-Plastics

The common types of bio-plastics are based on cellulose, starch, polylactic acid (PLA), poly-3-hydroxybutyrate (PHB), and polyamide 11 (PA11).

Cellulose-based plastics are usually produced from wood pulp and used to make film-based products such as wrappers and to seal in freshness in ready-made meals.

PLA is a transparent plastic whose characteristics resemble common petro-plastics such as polyethylene and polpropylene. PLA is produced from the fermentation of starch from crops, most commonly corn starch, into lactic acid that is then polymerised.

PHB is very similar to poylpropylene, which is used in a wide variety of fields including packaging, ropes, bank notes and car parts.

PA 11 is derived from vegetable oil and is known under the tradename Rislan. It is prized for its thermal reistance that makes it valued for use in car fuel lines, pneumatic air brake tubing, electrical anti-termite cable sheathing and oil and gas flexible pipes and control fluid umbilicals.

Plant-based Chemicals

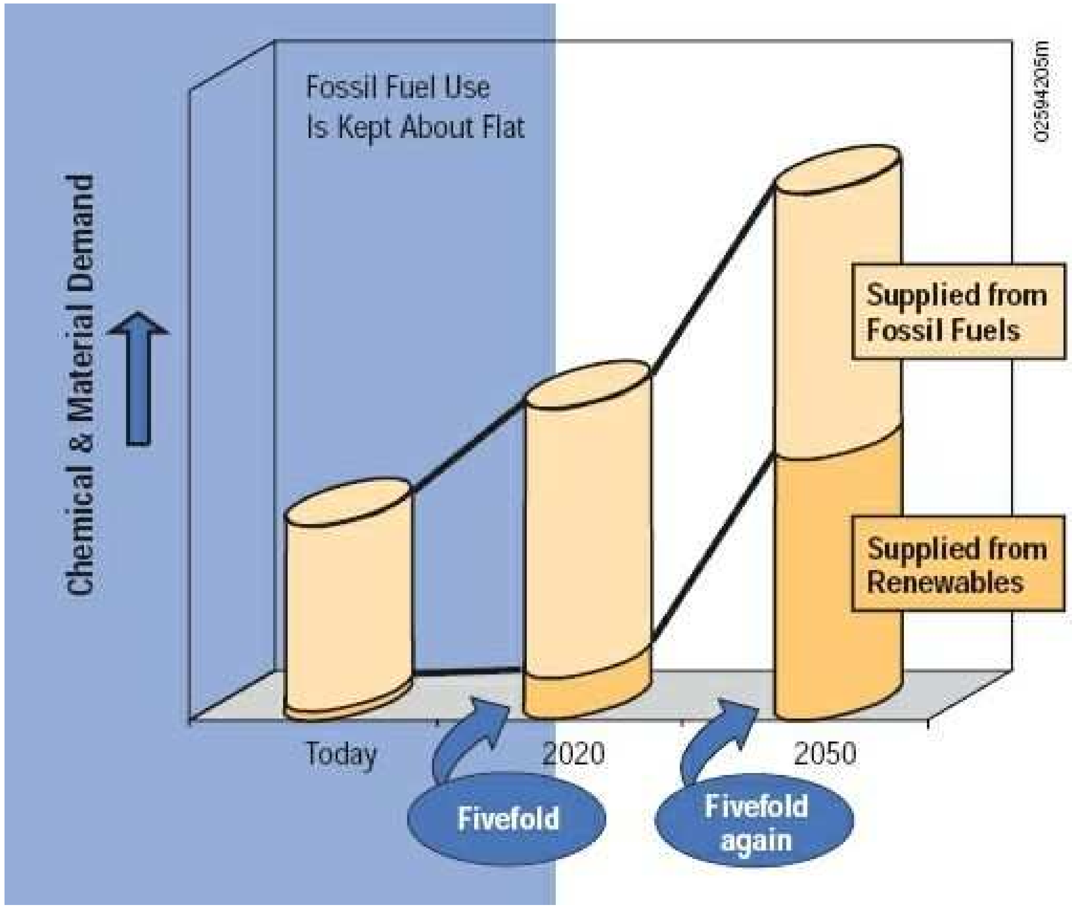
U.S. agriculture and forestry, plant-based sources cannot automatically shoulder a major share of our chemical feedstock demand. Today, U.S. industry only makes minor portions of some classes of chemical products from plant-derived materials.

Important scientific and commercial development breakthroughs are needed. Petrochemicals, agriculture, forestry, and other industries—as well as government—must make major coordinated efforts to most effectively increase the use of plant-derived chemicals.

“THE TECHNOLOGY ROADMAP FOR PLANT/CROP-BASED RENEWABLE RESOURCES 2020” U.S.

Global Chemical Industry

(>$1,500 billion)



R&D:
Dow Chemical
BASF
P&G
Solvay
Toyota….

"THE TECHNOLOGY ROADMAP FOR PLANT/CROP-BASED RENEWABLE RESOURCES 2020" U.S.

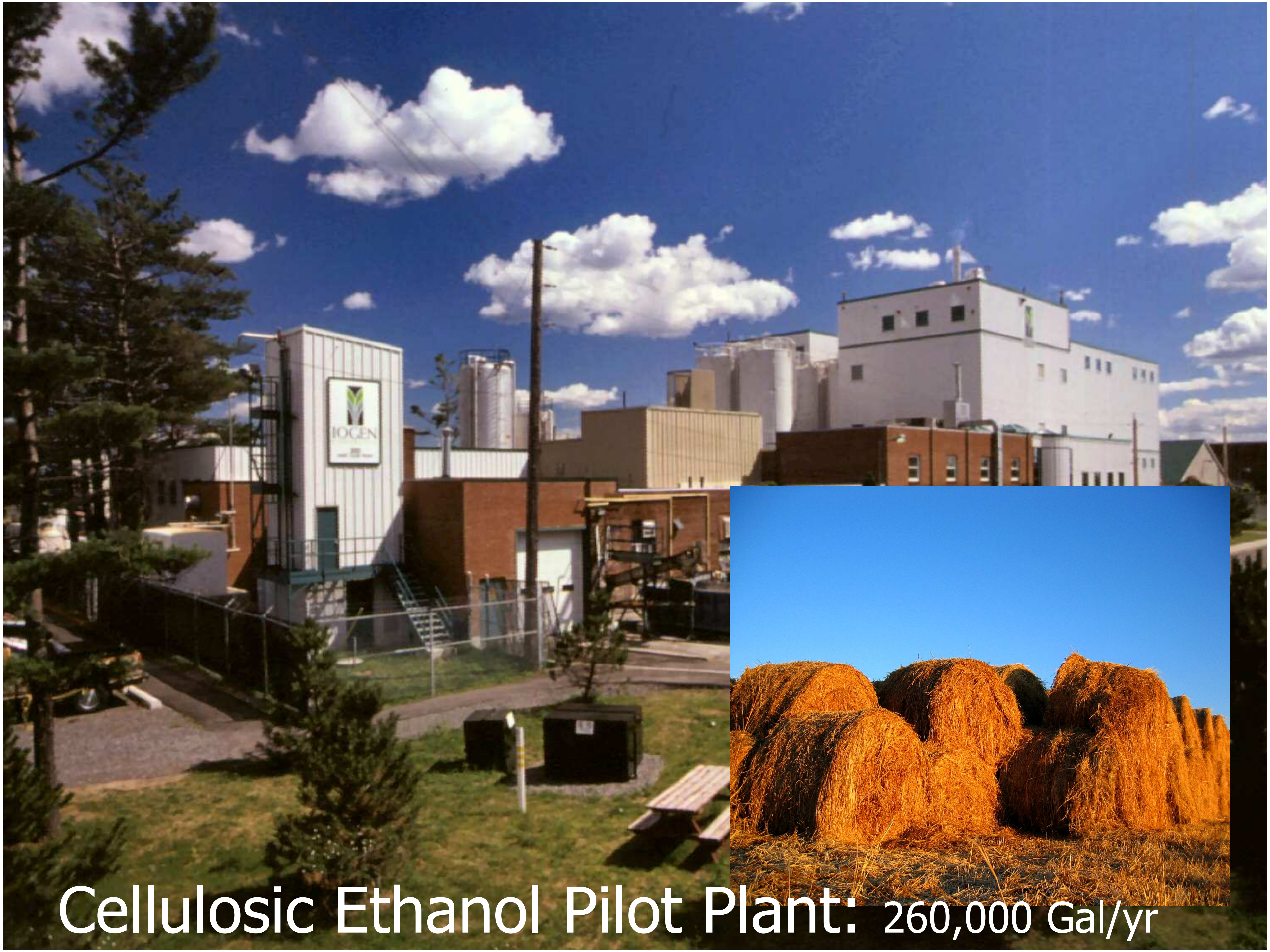
Investment Potential

PLA production costs estimated at $1.5 – 3 per kg

Fossil Fuel Polyethylene price is $1.70 per kg

Polyproylene price is $1.30 per kg

Ethanol



Cellulosic Ethanol Pilot Plant: 260,000 Gal/yr

Cost of Straw Feedstock

- Harvesting, storage, collection and transportation cost range between $28 to $41/tonne
- Add in the cost of procurement of the straw ($5 - $25 per tonne) and the final cost to plant could be $33 to $66/tonne

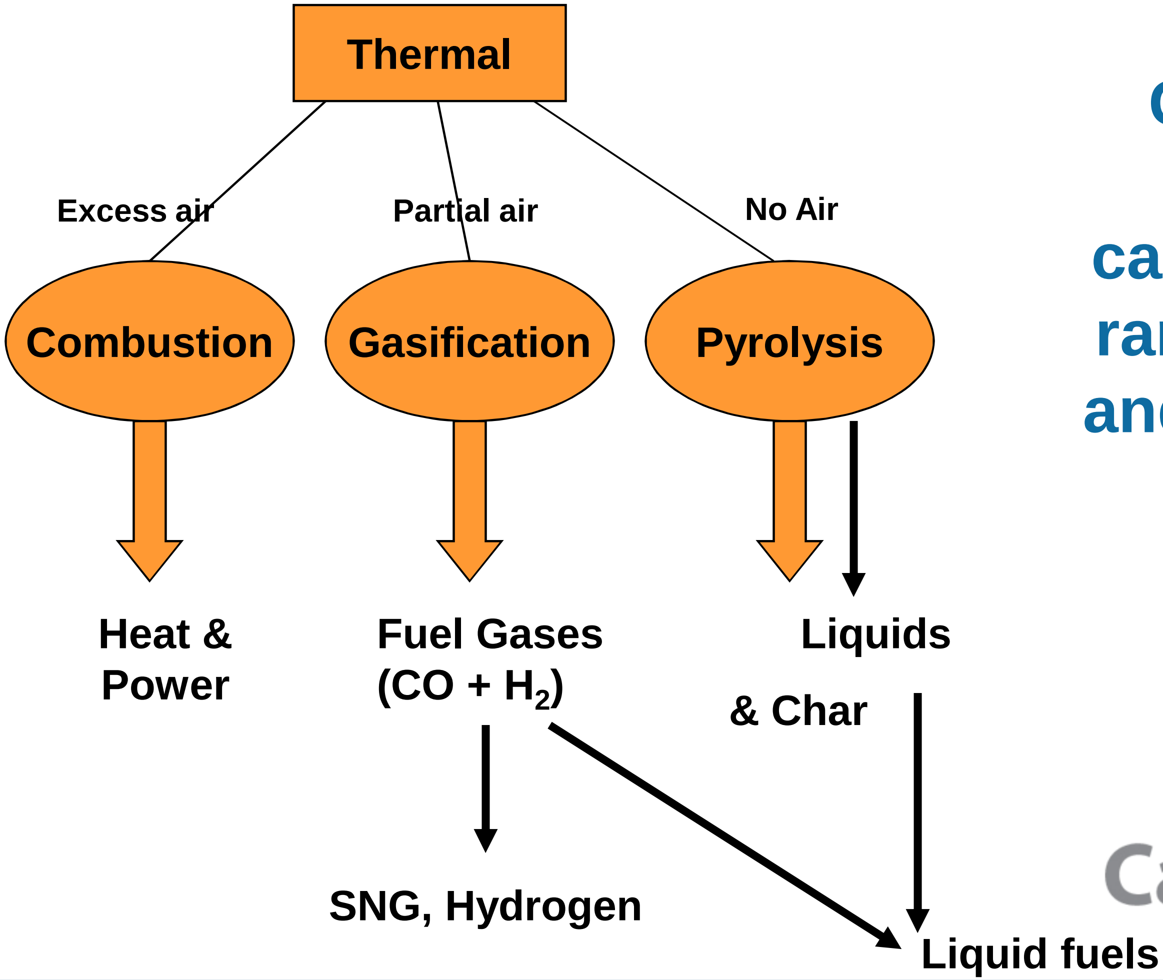

Cost of feedstock is usually negative

Large-scale chemical and biochemical conversion processes require consistent standardized homogeneous feed

Strict fuel requirements makes it difficult to "Buy Low" if you cannot take advantage of opportunity or heterogeneous waste fuels

Thermochemical (as opposed to biochemical) conversion is more suited to take advantage of non-homogeneous feedstocks

Thermochemical Pathways



Gasification and Pyrolysis can accommodate a range of feedstocks and produce a range of biofuels and biochemicals

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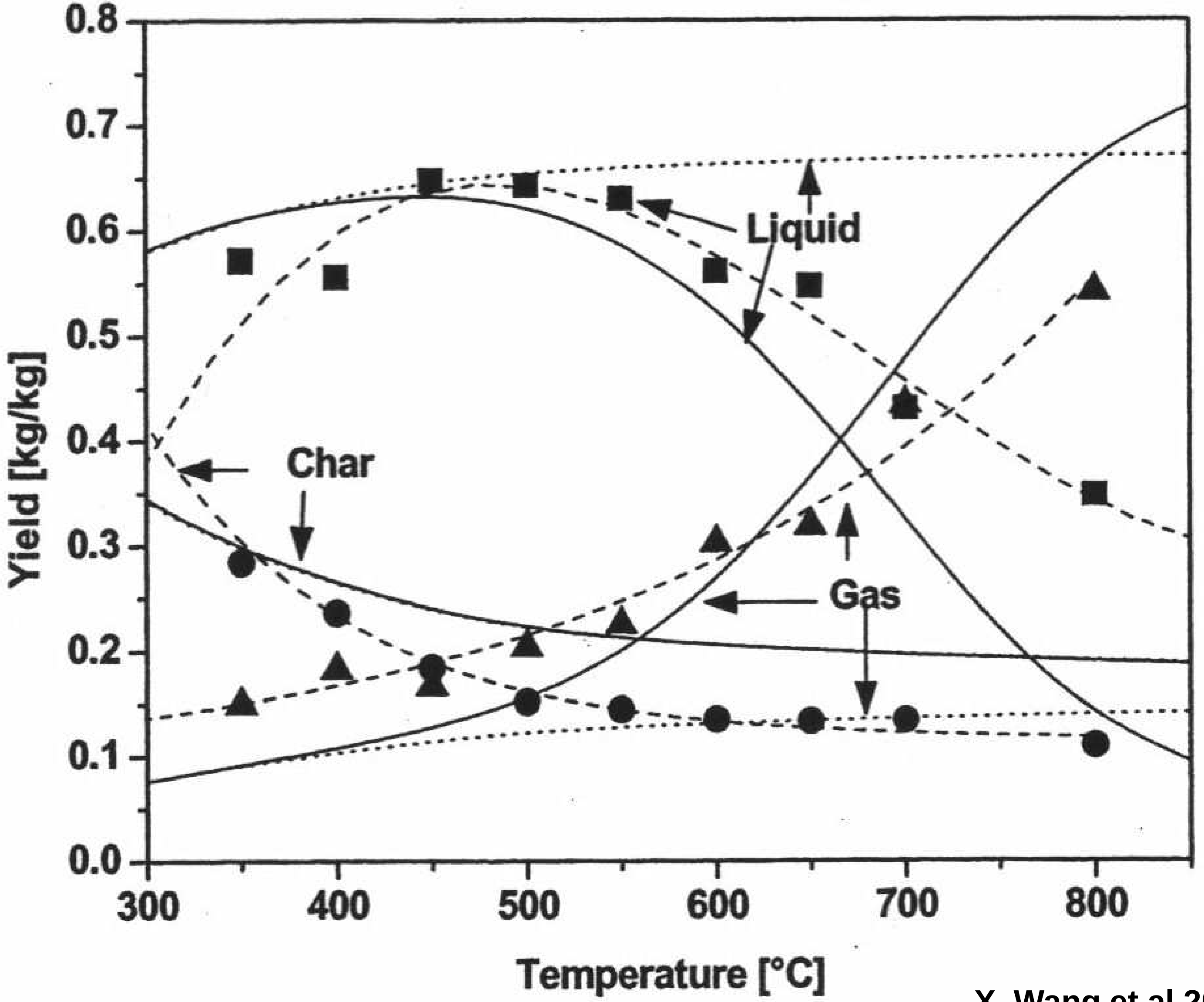
Pyrolysis and Gasification

Mode	Conditions	Liquid	Char	Gas
Fast pyrolysis	Moderate temperature, short residence time	**75%**	12%	**13%**
Slow Pyrolysis	Low temperature, very long residence time	**30%**	35%	**35%**
Gasification	High temperature, long residence time.	**5%**	10%	**85%**

A.V.Bridgwater

Product(s) Yield as f(Temperature)



X. Wang et al 2006

Biochar

- Pyrolysis produces charcoal, “which is called biochar when buried in the ground… Carbon from the waste biomass is retained in biochar and permanently sequestered in the soil, effectively removing that carbon from the atmosphere. The carbon in a ton of biochar is equivalent to 3 to 3.5 tons of CO2. Biochar is not only a carbon sink, it increases soil fertility—increasing cat-ion exchange and water retention capacity in soils, while reducing nutrient leaching and providing a "coral reef" for soil microorganisms—thereby significantly increasing productivity and crop yield.” ***http://www.biocharengineering.com/***

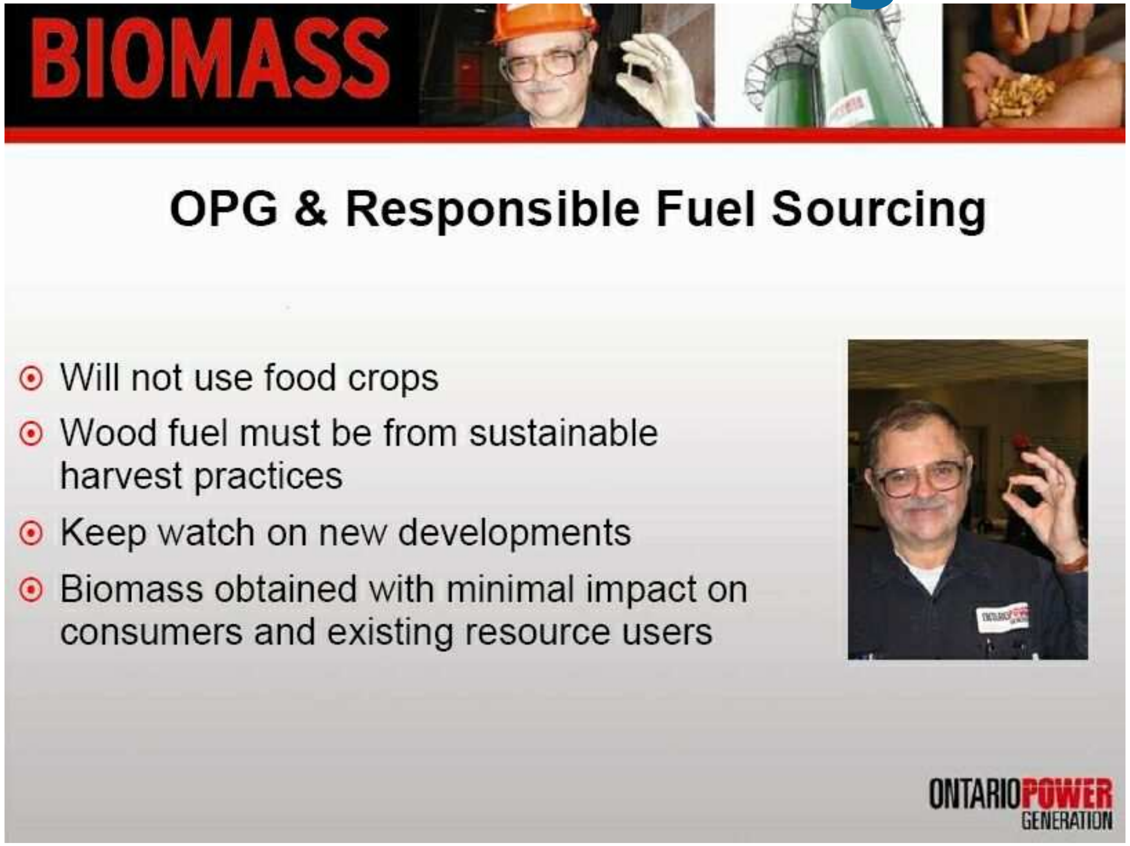
Charcoal

- Charcoal is “brittle” and not “plastic” – pyrolysis breaks down the hemicellulose matrix and depolymerizes cellulose

- Heating Value 28-32 MJ/kg

- Energy Density 9-11 GJ/m3

Charcoal: Co-firing with Coal



Ontario Power Generation has just issued a Request for Proposal to supply 2 million tonnes of biomass per year for co-firing with coal within 2 years – PELLETS ONLY PLEASE!

Torrefaction

- **As is the case for charcoal, Torrefied wood pulverizes easily**
- **Heating value is 19-24 MJ/kg (vs 18-20 for wood)**
- **Energy density is 15-18 GJ/m3 (vs 8-10 for wood)**
- **Torrefaction yield > 80%**
- **Dry fuel**
- **Does not absorb water**
- **Water-proof high energy pellets?**

Pyrolysis Extracts/Byproducts Promise

Biomass Pyrolysis

Pyrolysis is the process to make organic liquid fuel (termed “bio-oil”) and/or charcoal by exposure of biomass to temperatures in excess of 350ºC in the absence of oxygen.

Pyrolysis increases fuel density (>1200 kg/m3) and facilitates fuel transport and handling

“Bio-oil” is NOT OIL but mixture of alcohols, aldehydes, ketones, esters and specialty chemicals…characterization of the “oil” is still an urgent need

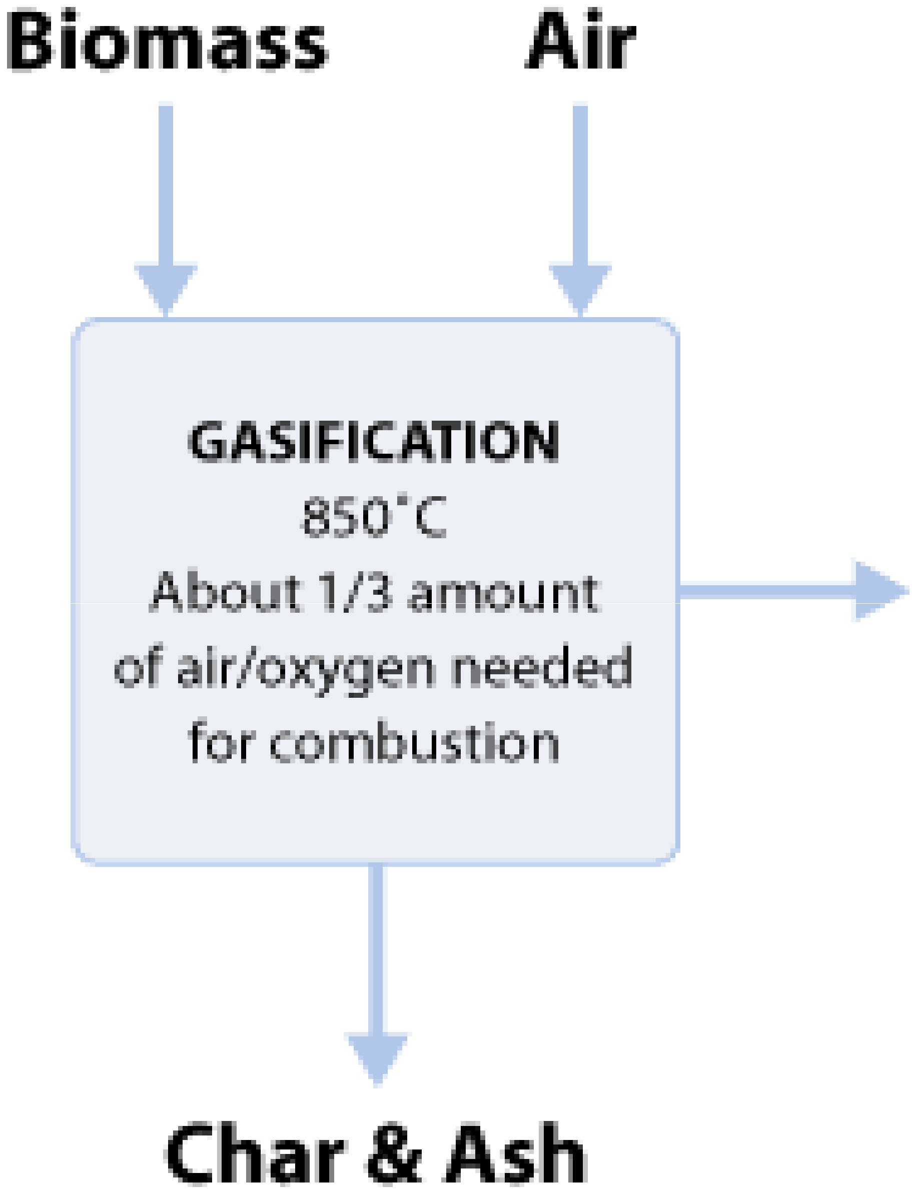
Scale-up continues to be a significant challenge and few plants greater than 100 t/d capacity

Potential Pyrolysis Chemicals

- Levoglucosan
- Acetic Acid
- Acetaldehyde
- Furfural
- Ethanol
- Formaldehyde
- Phenol
- Proprionic Acid
- Formic Acid
- Acetone
- Pharmaceuticals (> $\$10^4$ per kg)

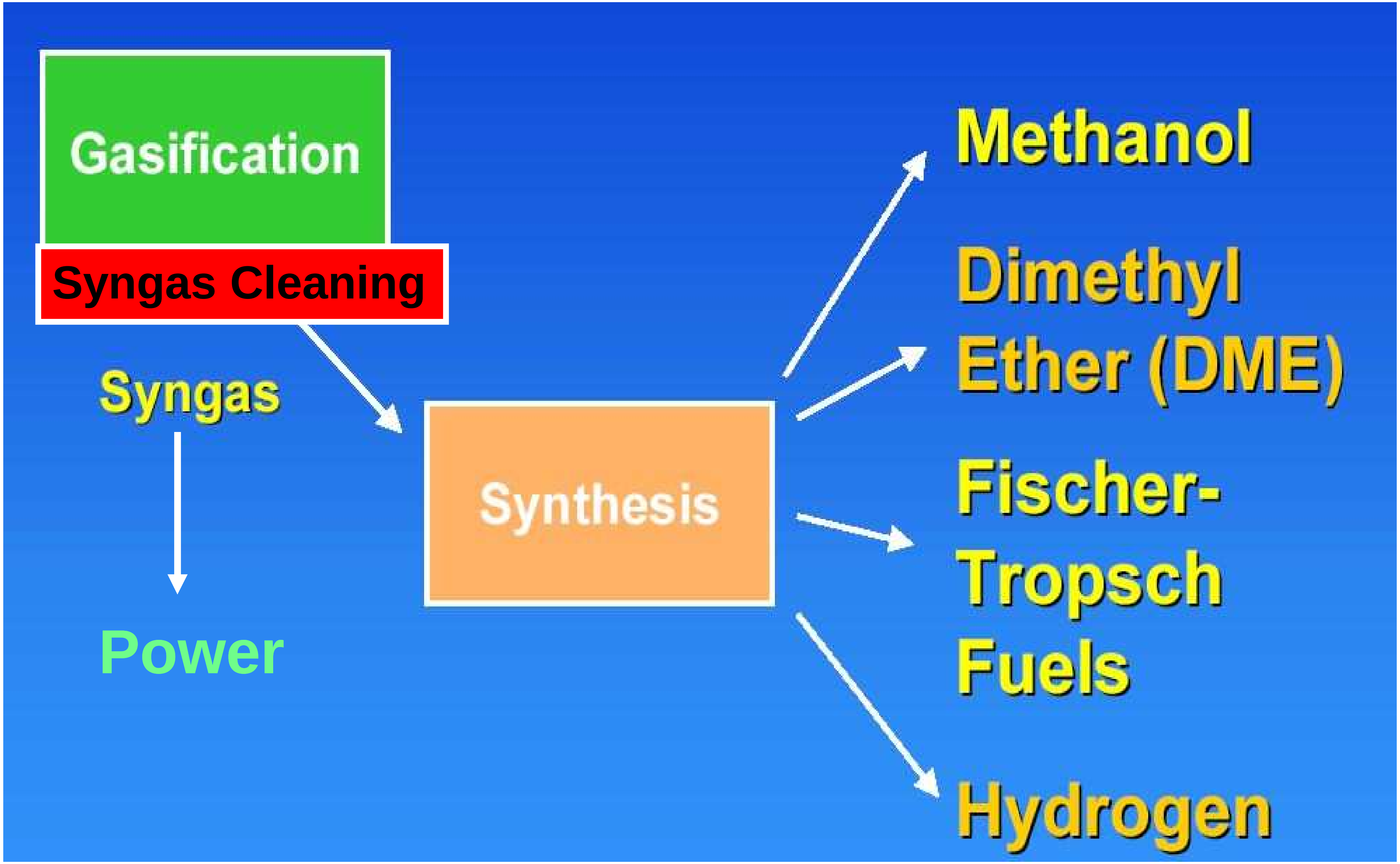
Composition of Bio-Oil (mass fractions)			
	White Spruce	**Poplar**	**Class of compound**
Oligosaccharides	--	0.01	Saccharides
Glucose	0.01	0.006	
Other monosaccharides	0.03	0.02	
Levoglucosan	0.06	0.05	Anhydrosugars
1,6 anhydroglucofuranose	--	0.04	
Cellobiosan	0.04	0.02	
Glyoxal	0.04	0.03	Aldehydes
Methylglyoxal	--	0.01	
Formaldehyde	--	0.02	
Acetaldehyde	--	0.0003	
Hydroxyacetaldehyde	0.12	0.15	
Furfural	0.005	--	Furans
Methylfurfural	0.02	--	
Acetol	0.02	0.02	Ketones
Methanol	0.02	0.002	Alcohols
Ethylene Glycol	0.01	0.02	
Acetic Acid	0.06	0.08	Carboxylic acids
Formic Acid	0.11	0.05	
Water-Soluble – Total Above	**0.52**	**0.52**	
Pyrolytic Lignin	**0.31**	**0.25**	
Unaccounted mass	**0.17**	**0.23**	

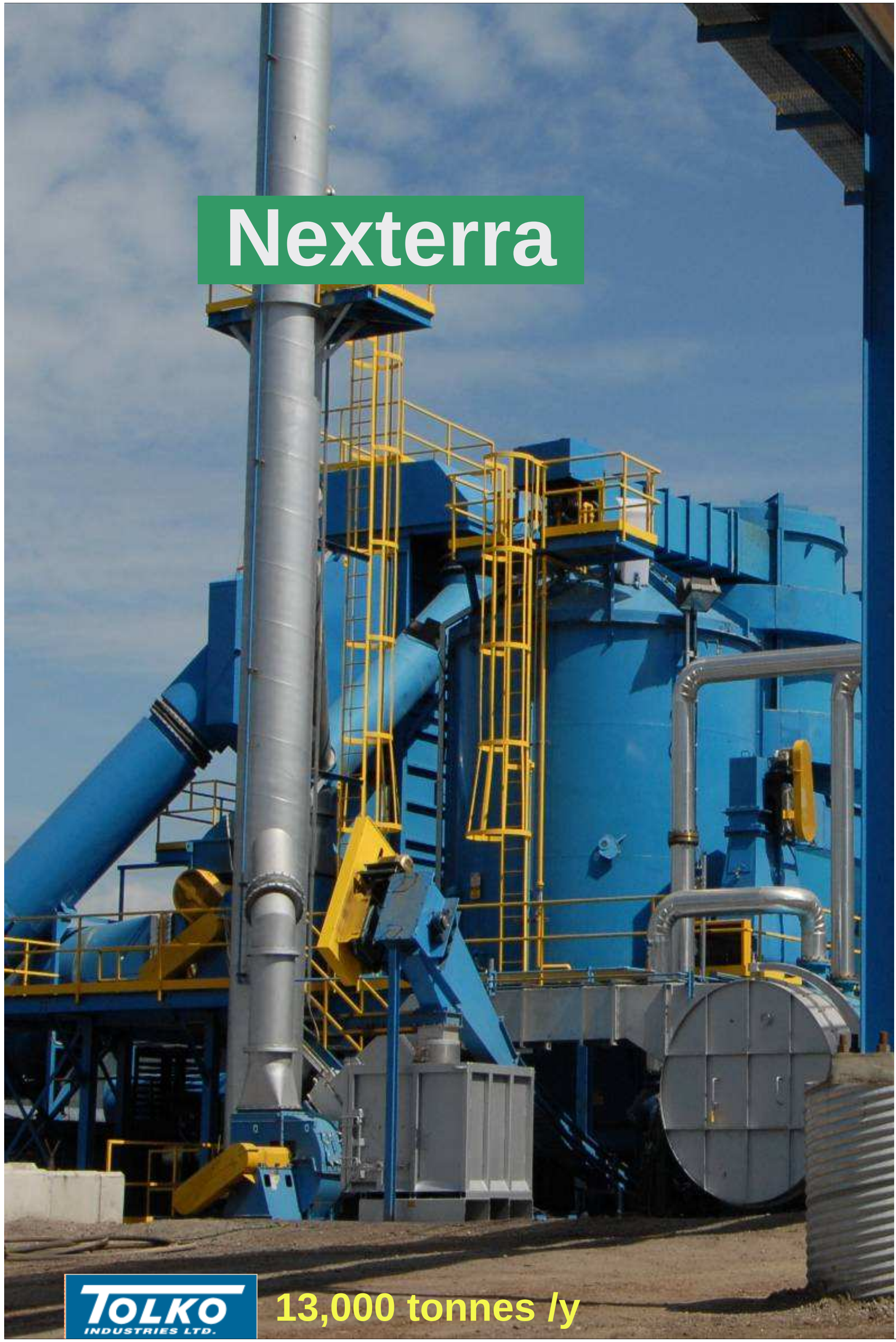
Source: R.C. Brown



Syngas
Carbon Monoxide (CO)
& Hydrogen (H2)

Gasification Potential




Nexterra
TOLKO
INDUSTRIES LTD.
13,000 tonnes /y


Enerkem

Gasification for Combined Heat & Power

Fixed bed gasifier (Updraft & Downdraft)

Many demonstrations - availability generally <75%
Harboore, Denmark intermittent operation since 2000
4 to 8 million euros per MWe
Electricity costs >20 eurocents per kWh

Fluidized bed

Commercial for Co-firing (e.g. Lahti)
Operating experience >60,000 hours Gussing, Austria
3 to 5 million euros per MWe
Electricity costs 10-14 eurocents per kWh

Let's invest in a gasifier at a pulp mill! We can make power and chemicals and ethanol etc…

Pulp mills = 80% of bioenergy use in Canada

Pulp mills have experience with biomass handling etc

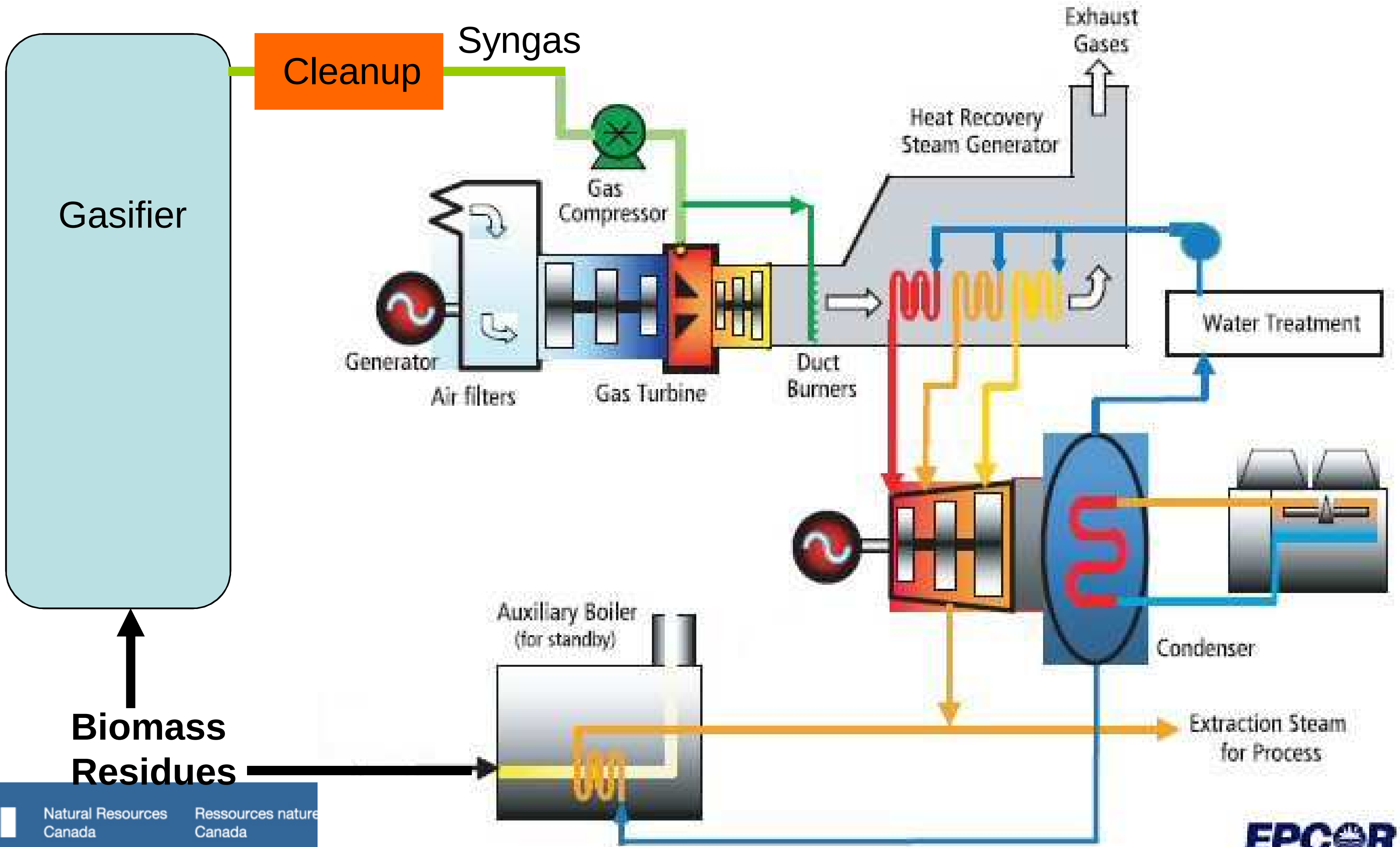
Converted Value of Wood

PELLETS, HEAT @ $6/GJ	$86
POWER @ 9 ¢/kWh	$124
CHP @ 80%	$181

Note: All financial figures in this presentation are based on value of products only; no value is currently assigned to wood input or process modifications

High Efficiency - BIGCC

Biomass Integrated Gasifier Combined Cycle



Converted Value of Wood

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POWER @ 9 ¢/kWh	$124
CHP @ 80%	$181
SYNGAS @ $10/GJ	$143
BIGCC (CHP)	$230

Enerkem – Westbury Plant

Westbury demonstration plant will treat 12,000 tonnes of biomass-rich residues per year and produce 4 million litres of alcohols per year.

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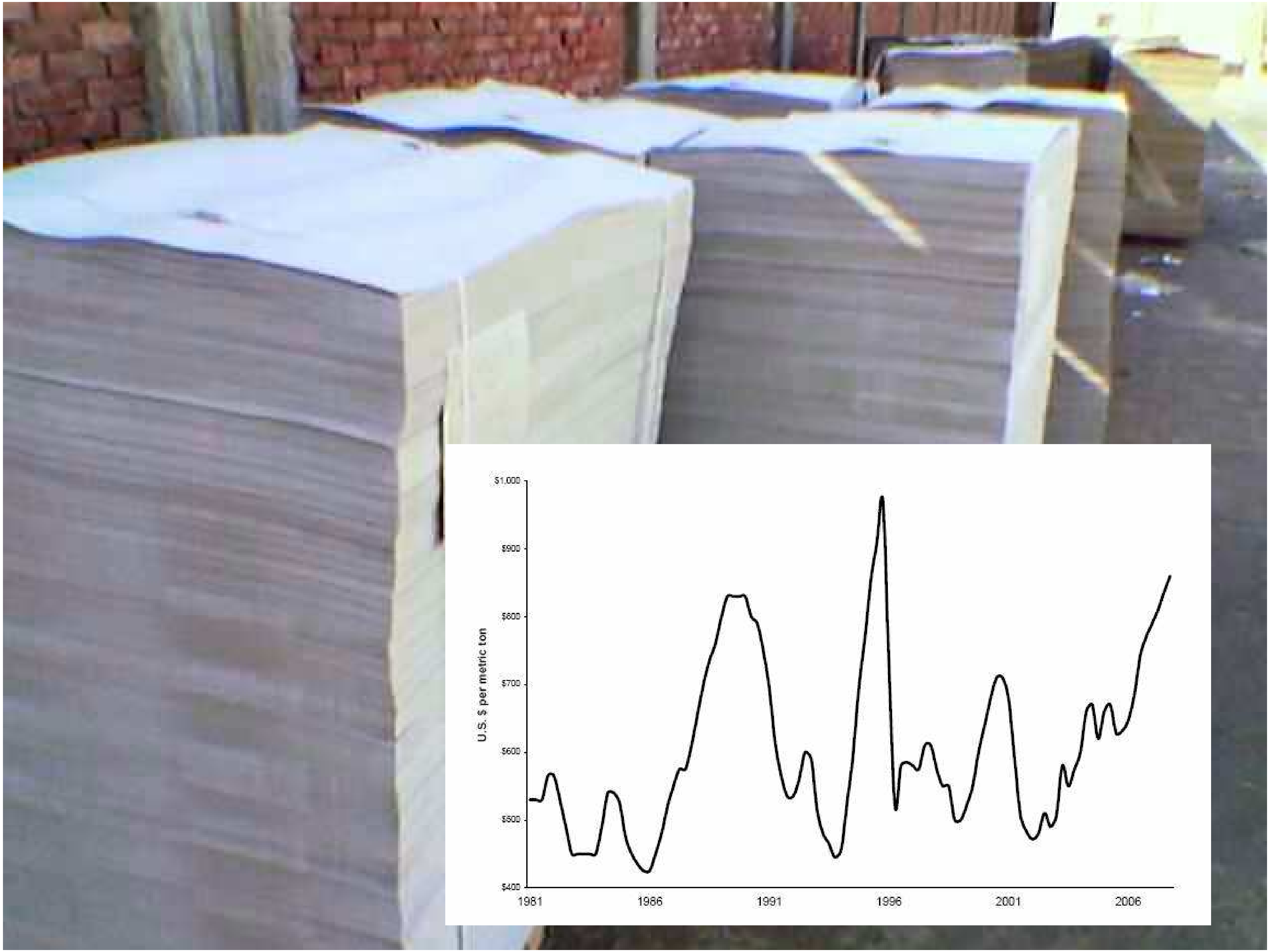
BIGCC (CHP)	$230
Ethanol @ $.45/litre	$158



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CHP @ 80%	$181
SYNGAS @ $10/GJ	$143
BIGCC (CHP)	$230
Ethanol @ $.45/litre	$158
Pulp @ $800/t	$320

Bioenergy Scenario 1 (Current Mill)

Generic Pulp Mill

Kiln NG: 1 GJ

Power: 120 kWh

0.4 tonnes Pulp $320

Value of Products: $296 / tonne of wood input

Bioenergy Scenario 2 (BIGCC)

Pulp Mill with BIGCC (Just Enough Power to be Self-Sufficient)

Power: 165 kWh

Kiln NG: 0 GJ

Power: 0 kWh

0.4 tonnes Pulp

$320

Value of Products: $289 / tonne of wood input

Bioenergy Scenario 3 (Large BIGCC)

Pulp Mill with Large BIGCC (Become Power Producer)

Kiln NG: 0 GJ

Power: 0 kWh

Power: 800 kWh

0.4 tonnes Pulp

$320

Value of Products: $306 / tonne of wood input

Bioenergy Scenario 4 (BIGCC + Ethanol)

Pulp Mill with Large BIGCC and Ethanol instead of Power

Kiln NG: 0 GJ

Power: 0 kWh

Ethanol: 105 litres

0.4 tonnes Pulp $280

Value of Products: $265/ tonne of wood input

Assumptions: Expected Conversion Efficiencies/Costs

	Unit Price	Conversion Efficiency
Pulp Production	$/tonne	Pulp % per tonne of wood
	800	45
SYNGAS GJ	$/GJ	Efficiency of gasification
	10	75
Ethanol		Litres per toone of wood (gasification)
	0.45	350
Power from Syngas (CC)		Electrical Efficiency
	9	40
Combined Heat and Power From Syngas		Overall Efficiency
Power	9	40
Heat	6	35

Bioenergy Opportunities: Summary

- **Biomass Pathways**

  There are a multitude of pathways and selecting one for investment requires careful evaluation including long term supply (at specific cost), sustainability and life cycle analysis

- **Pulp Mills Scenarios**

	Value of products per tonne of wood input
- Current generic	$296
- BIGCC (Self-sufficient)	$289
- Large BIGCC (export power)	$306
- Large BIGCC (ethanol)	$265

Note: All financial figures in this presentation are based on value of products only; no value is currently assigned to wood input or process modifications

Thank You!

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