Sugar - The New Crude

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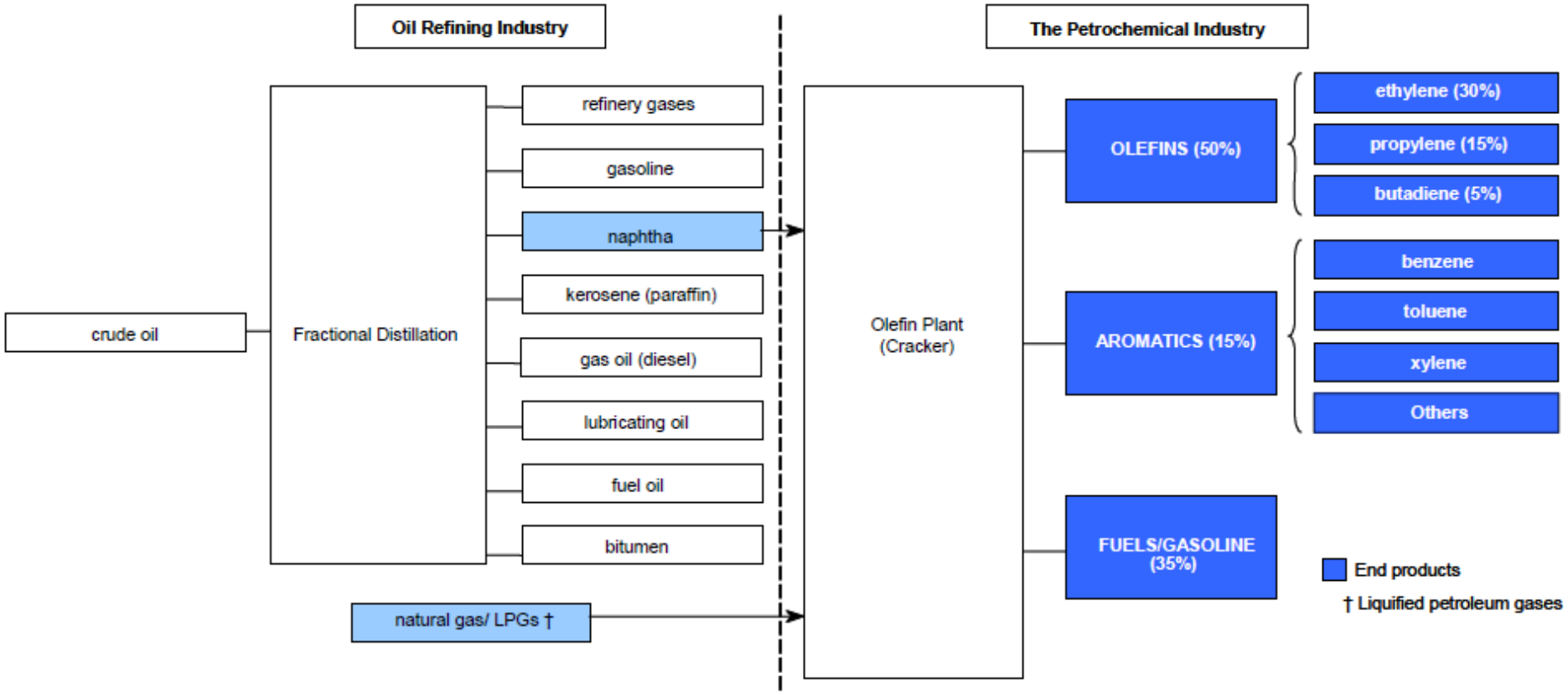
From Petrochemistry to Green Chemistry

1960 1970-2000 2010 2020 2030

Most petrochemicals originate from the naphtha stream of the refining process (a residual from demand for fuels)…



The Incredible Revolution of Metabolic Engineering

- ✓ For 3 centuries, common wisdom has been that the most energy dense raw materials have been gas (8400 kcal) and oil (7000 kcal).
- ✓ Biomasses with 2000 kcal wet or 3500 kcal dry has been difficult to handle and not cost competitive.
- ✓ Common sense has prevented any serious comparison and, competitive chemical production from biomass was science fiction, until 20 years ago.

Metabolic Engineering vs. Petrochemicals

- ✓ Petrochemical engineering is not satisfied with the selectivity of oil and gas fractionation.

- ✓ Although oil and gas feedstock is energy rich and readily available, the target product is made while making a large mixture of other molecules, negatively impacting cost.

- ✓ Separation and upgrading of by-products is expensive.

A New Bio-based Economy

Sugar-Biomass based Chemical Production

- Sugar sourced from herbaceous plants
- Does not compete with food
- Widely available
- Grown on marginal lands

Bio-technology is ideal for sugar conversion

Economics improve at smaller scale

- ✓ Biggest contributor to biomass delivered cost is logistics
- ✓ Therefore it is FAR BETTER bringing the plant to the biomass rather than the biomass to the plant
- ✓ If the plant uses multiple feedstock in the same facility, the supply chain may be optimized.
- ✓ Availability of locally sourced sugars favors smaller scale plants

Chemistry vs. Biotechnology

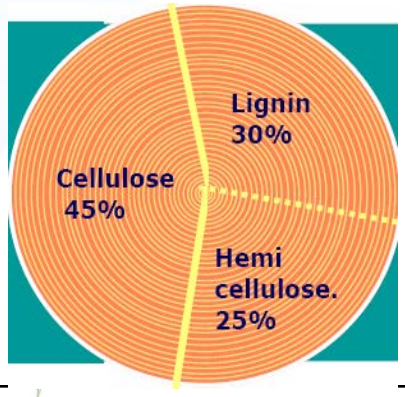
Bio-technology

- Higher Selectivity
- Generally smaller plants, less capital
- Favored in new synthesis

Classical Chemistry

- Better in Adverse Conditions
- Faster
- Favored in fossil fuel conversions

Biorefinery Concept - Today



C5 sugars

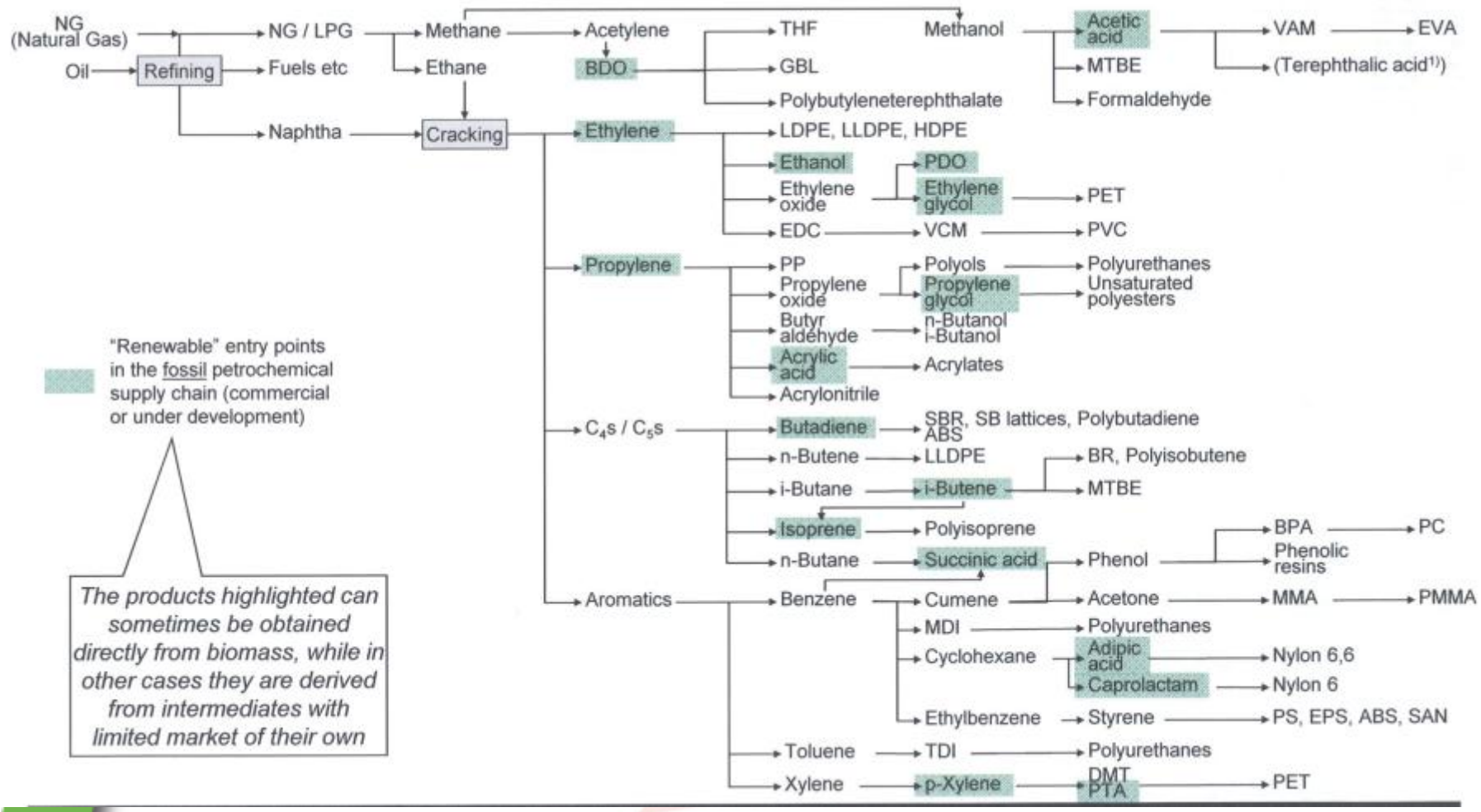
C6 sugars

Ethanol

Lignin

Energy

This may open an economic alternative to the production of conventional petrochemicals…



...because renewable products can become "platforms" to produce not just the molecules that are made from them conventionally

Examples of conversion processes for renewable chemicals

(commercial production / ongoing development)

- Ethanol → Ethylene
- Succinic acid → BDO, THF, GBL
- PDO → PTT, Malonic acid, Polyurethanes, Copolyester ethers
- Lactic acid → Acetaldehyde, Acrylic acid, PDO, Propionic acid, Oxalic acid
- BDO → Succinic acid, Butadiene
- Sorbitol → Isosorbide, Propylene glycol, Ethylene glycol, Glycerol, Lactic acid
- 3-HP → Malonic acid, Acrylic acid, Acrylamide, PDO, Serine, Alanine

Gruppo M&G:
Biomass Technology & Experience

$3 B per year producer of PET

Engineering division

Technology for biomass to sugars

Our R&D Centers

Rivalta, Italy

3000 m^2 dedicated to renewable resources biochemistry and technology

100+ dedicated staff

Chemtex also operates an R&D center in **Sharon Center, Ohio** focused on cellulosic sugar chemistry and engineering research

- Catalytic Conversion of Sugar
- Lignin conversion
- Intermediate and final product separation technologies

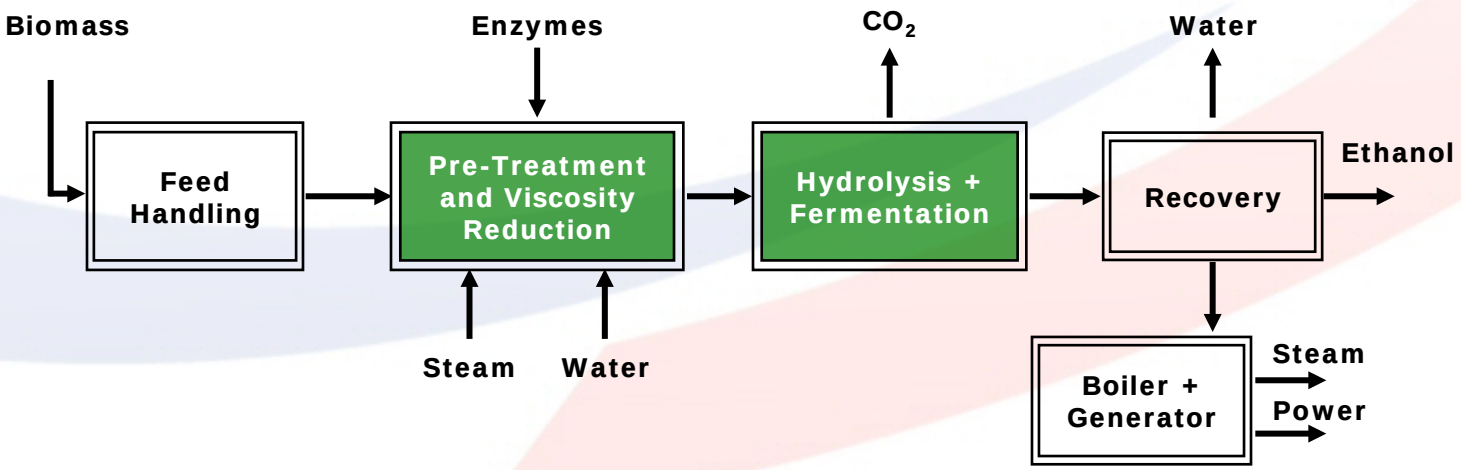
Our Vision

For biofuels and bio-based chemicals to be viable:

1. Competitive at 60-70 $/barrel;
2. Environmentally sustainable ref. full lifecycle greenhouse gases;
3. Agronomically sustainable: no competition with food;
4. Profitable for farmers.

PROESA™: Cost-effective Sugars from Biomass

1. Agronomy: best energy crops, based on field experiments;
2. Biomass pre-treatment and viscosity reduction: continuous process;
3. Hydrolysis and fermentation: Unique hybrid SSCF process yielding high ethanol concentrations.



Biotechnology

PROESA™ is the enabler, the technology that makes simple cellulosic sugars available at low cost.

The Bio-refinery converts this sugar with enzymes and micro organisms into new building blocks replacing crude oil.

Beta Renewables: Profile

TPG | CHEMTEX | novozymes Rethink Tomorrow

BETA RENEWABLES S.p.A.

- ✓ A JV between Chemtex, TPG, and Novozymes
- ✓ Beta Renewables has developed the PROESA® Technology for the conversion of non-food lignocellulosic biomass to biofuels and biochemicals.
- ✓ The company is currently commissioning the world's first commercial-scale cellulosic ethanol facility in Crescentino, Italy

Our Partners:

GraalBio
novozymes Rethink Tomorrow
genomatica
gevo
MYBIOMASS
AMYRIS
CODEXIS

Proesa® for Renewable Chemicals

Codexis and Chemtex are working together to develop a novel process to produce C12-C14 fatty alcohols from cellulosic biomass.

CODEXIS

Biomass

C5-6 sugars

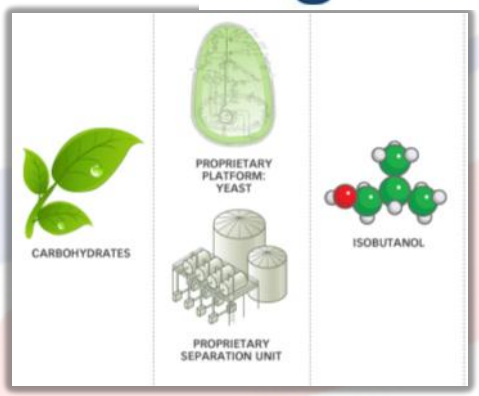
PROESA™ → **Fermentation** | **Separation**

FOH

2G-FOH TECHNOLOGY

Genomatica and Chemtex together for production of 2G bio-BDO from PROESA® sugars

gevo



Gevo and Chemtex together for production of 2G isobutanol from PROESA® sugars

PROESA® is a platform for multiple products

PROESA® Cellulosic Sugar Technology

Pre-Treatment Section

Enzymatic Hydrolysis Section

Biofuels

- Ethanol
- Bio-Jet
  - Butanol
- Marine Diesel
- Green Diesel

Biochemicals

- Fatty Alcohols
- 1,4 Butanediol
- Farnesene
  - Acrylic Acid
  - Adipic Acid
  - Succinic Acid
- Bio-PE
- Bio-EO/EG

Lignin Chemicals

- Phenols
- Xylene
- Terephthalic Acid
- Aromatic Aldehydes

Crescentino Commercial Plant … start

In April 2011 Chemtex broke ground for a 60 ktpa (20 MMgpy) cellulosic ethanol plant based on Arundo Donax & wheat straw.

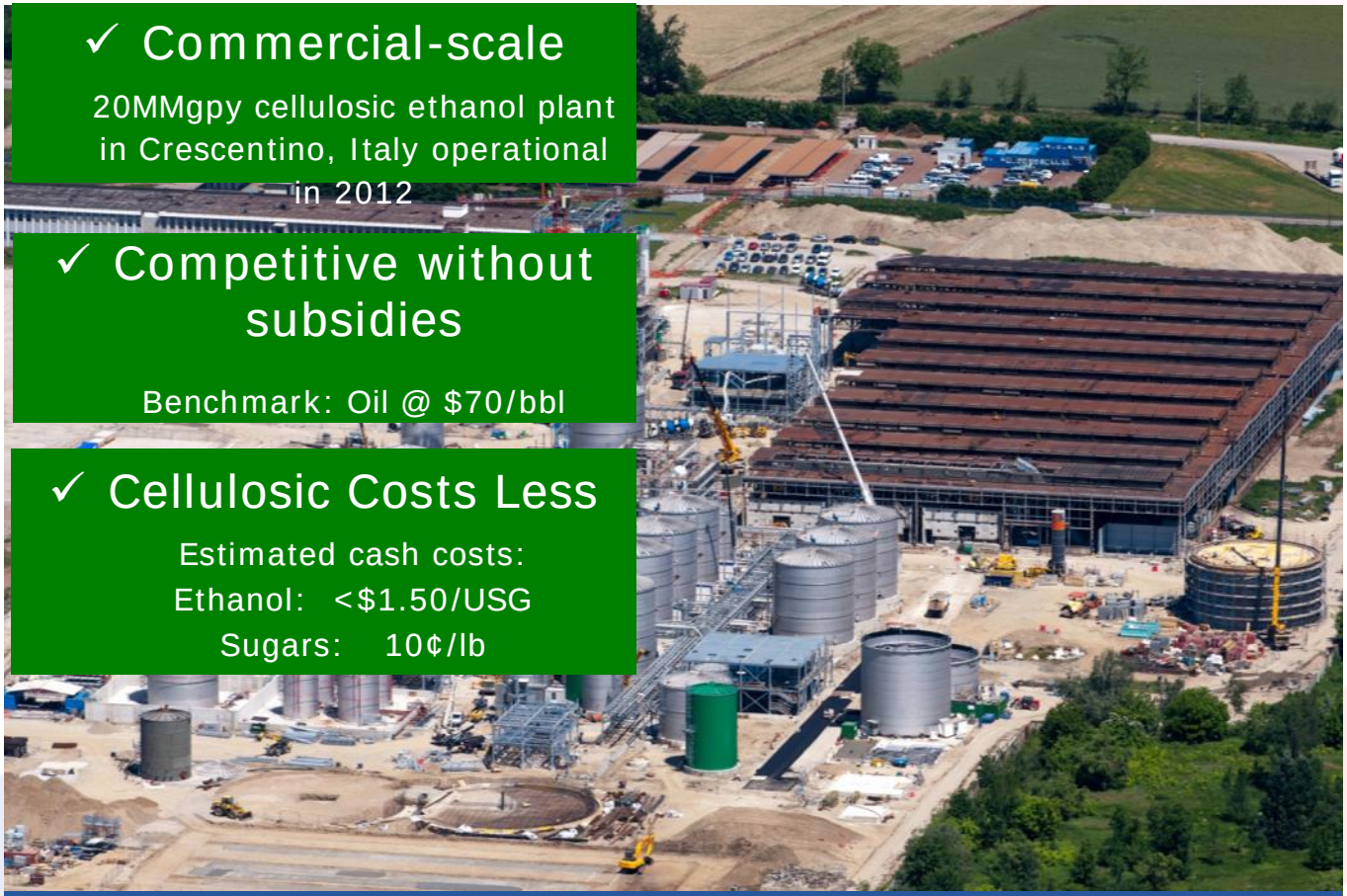
Crescentino Commercial Plant … Q4-2012

18 months later – The Facility is being Commissoned

Project Alpha

- Chemtex is developing *Project Alpha* – a 20mmgpy cellulosic ethanol facility to be built in Eastern NC.
- Received a $99 Million USDA loan Guarantee
- The project is based on using dedicated EPA approved energy crops including Miscanthus, Switchgrass, "soft" hardwoods and potentially Arundo Donax and High Biomass sorghum - grown on low productivity/ marginal land.
- Project received a $4 million BCAP award
- Overall 300,000 dry tons per year of feedstock annually sourced from 25,000 acres in the surrounding area
- The project is Phase 1 of a cluster opportunity – similar available land in the region is sufficient to support additional 200-250 mmgpy added ethanol capacity or equivalent bio-chemicals.
- 100 acres of nursery for energy grasses planted with support of North Carolina Biofuels Center
- Best management practices for energy crops published by State taskforce supporting our project

PROESA® – We Are Ready



✓ Commercial-scale

20MMgpy cellulosic ethanol plant in Crescentino, Italy operational in 2012

✓ Competitive without subsidies

Benchmark: Oil @ $70/bbl

✓ Cellulosic Costs Less

Estimated cash costs:
Ethanol: <$1.50/USG
Sugars: 10¢/lb

www.chemtex.com
www.betarenewables.com

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