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Lignin conversion into bio-based chemicals

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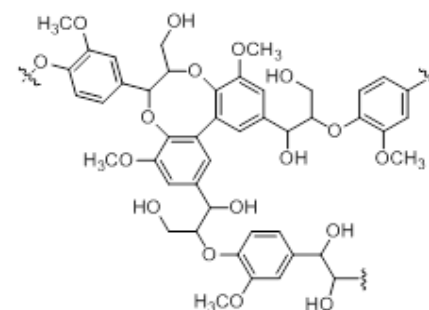
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GRUPPO MOSSI & GHISOLFI

Lignin Conversion into Biobased Chemicals

Otranto, June 12 2013



*Alessandra Bogliano, Chemtex R&D Project Director
Pietro Palmisano, Chemtex R&D Senior Technologist*



M&G Group



GRUPPO MOSSI & GHISOLFI

- **Founded in 1953 by Vittorio Ghisolfi in Tortona (Italy).**
- **M&G today: 3 billion USD /year turnover and more than 2200 employees worldwide.**
- **Operations in Italy, USA, Mexico, Brazil, China, India.**
- **Chemtex (founded in 1947), more than 1000 engineers, since 2004 is a wholly-owned subsidiary of the M&G Group.**
- **Suape largest single line PET Plant in the world, (M&G Technology, Chemtex EPC) in operation since 2007.**
- **Since 2005 started investments in Renewables for the production of Bio-Ethanol (II generation).**
- **Beta Renewables is a unique \$350 million (€250 million) joint venture formed, in 2011, by Chemtex, engineering division of Gruppo Mossi & Ghisolfi and TPG, a fund of private equity. Recently Novozymes, the world leader in bioinnovation, has acquired a 10% share in Beta Renewables.**
- **2013: Engineering design of the new largest PET plant (Corpus Christi, capability of 1 MMt/y PET, integrated with 1.2 MMt/y PTA).**

II Generation Ethanol: M&G choice

- ❖ No food/feed conflict
- ❖ Possibility of farming on marginal land
- ❖ Possibility of creating integrative profit for farmers
- ❖ Possibility of using partially polluted lands
- ❖ Possibility of using agricultural wastes
- ❖ Waste biomasses (Wheat Straw, Rice Straw, Sugarcane bagasse)



PROESA® Technology



2006-2008

- Scouting of Technologies
- Generation of key inventions
- Proof of UNIT OPERATION in the labs



2009-2010

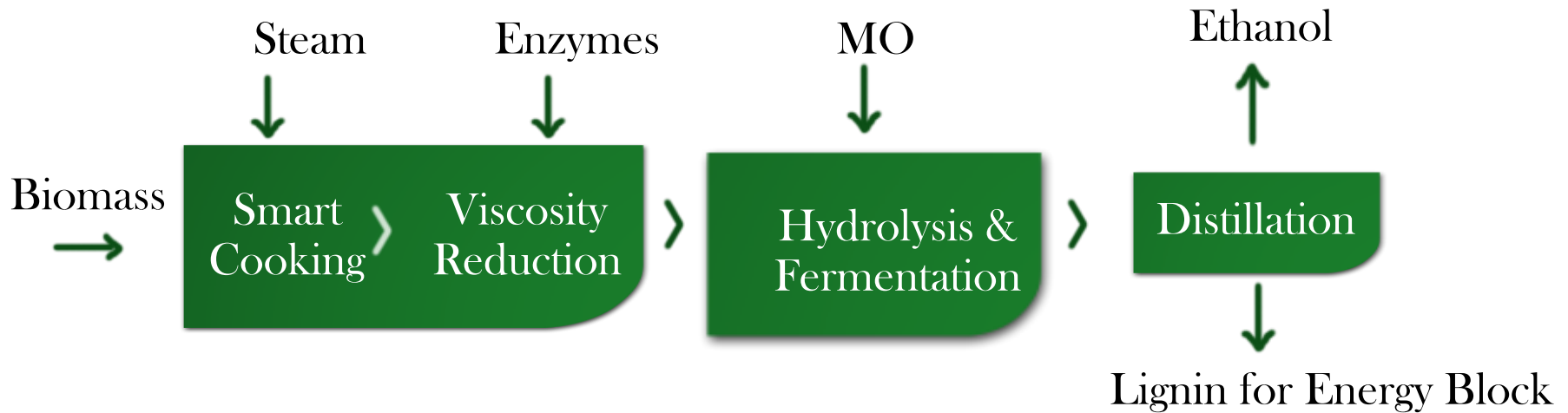
- Pilot plant construction & start up (June 2009)
- Pilot Plant operation and data gathering
- Test of Plant flexibility using multiple biomasses



2011-2012

- Crescentino Plant
- Collaboration Agreements with leading synthetic biology companies
- License Agreements
- Formation of Beta Renewables
- S/U of Crescentino

PROESA® Technology



Proesa® Technology

benefits:



Feedstock flexibility



Continuous process
No chemical addition
Optimal sugar extraction with
low enzyme dosage



Fully integrated process design
using continuous equipment
to enable large scale plants



Best in class technology with
lowest capex and opex backed
with performance guarantees

PROESA® Crescentino

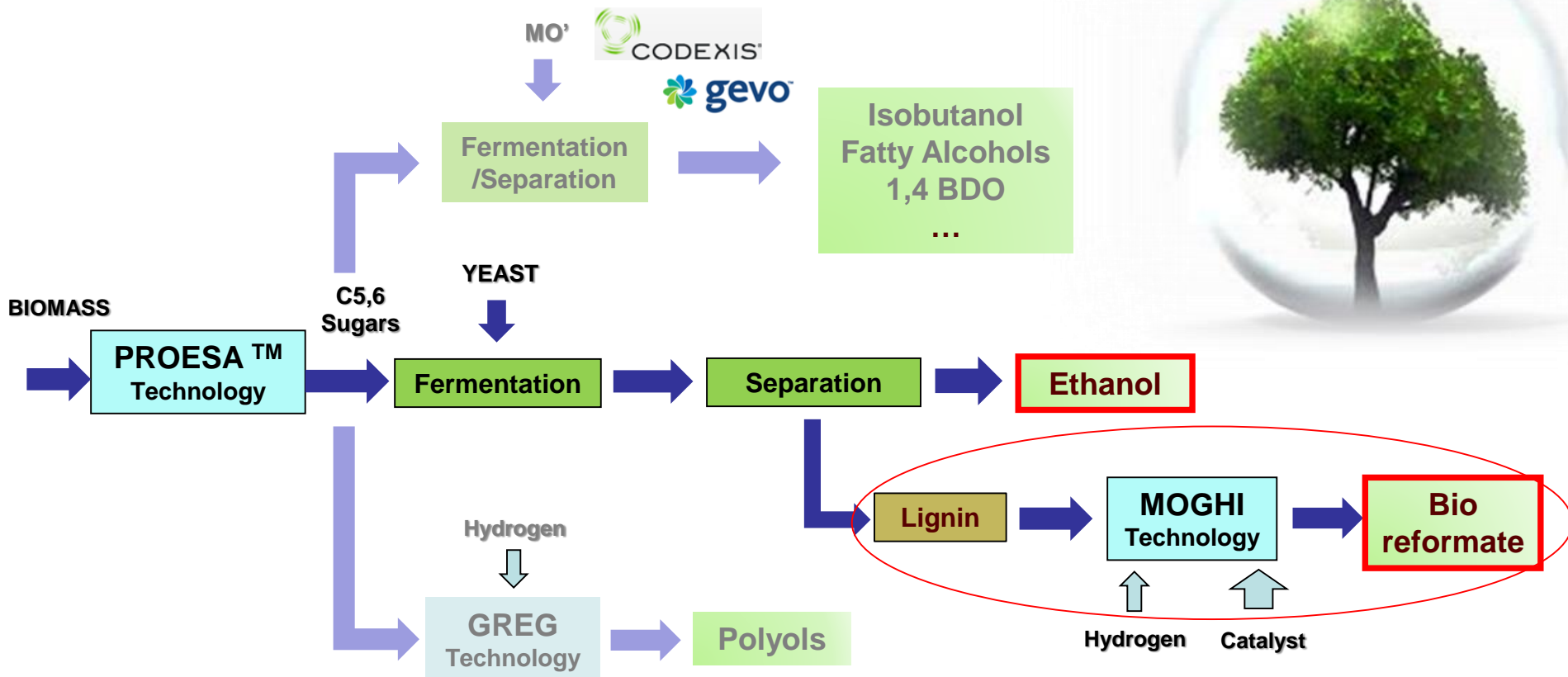


Global Scale plant for second generation ethanol production



The Concept of Biorefinery

- The use of PROESA technology will enable the production of cheap and clean sugars.
- M&G is developing its own technologies for sugars conversion and lignin processing.
- A biorefinery will produce various products: initially ethanol, then diols, later aromatics.



Biorefinery: Opportunities for Development



Process Engineering/
Mechanical Engineering

...separation/purification of the products in order to obtain chemicals ready to be used in existing industry

Catalysis

...study of new catalysts

- improve conversion of lignin to Bio-reformate (MOGHI)
- improve conversion of sugars to chemicals

Biotechnology

...developing new sugar fermentation MO for synthesizing chemicals other than EtOH

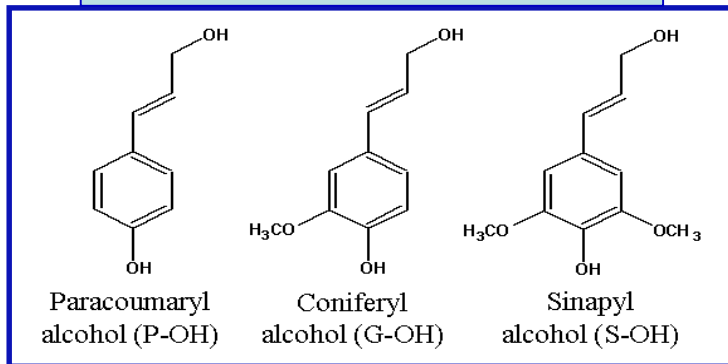
Agronomy

...new crops dedicated to biomass production

- logistic
- agronomic studies

Lignin Structure and Chemistry

Lignin Monomers

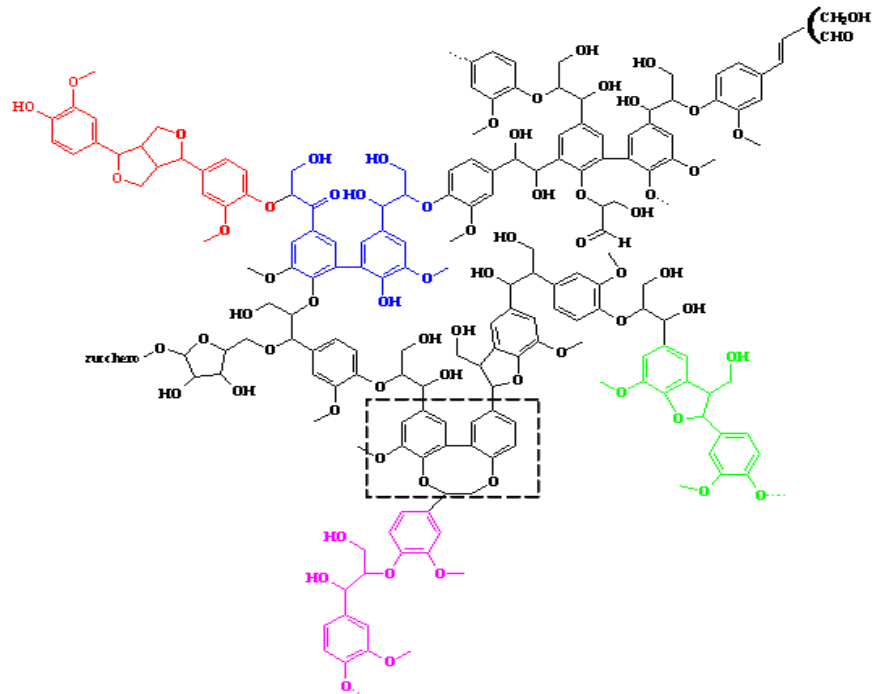


Annual grasses, such as sorghum and Arundo Donax, are mostly derived from P-OH mostly used in Proesa

Phenolic nature.

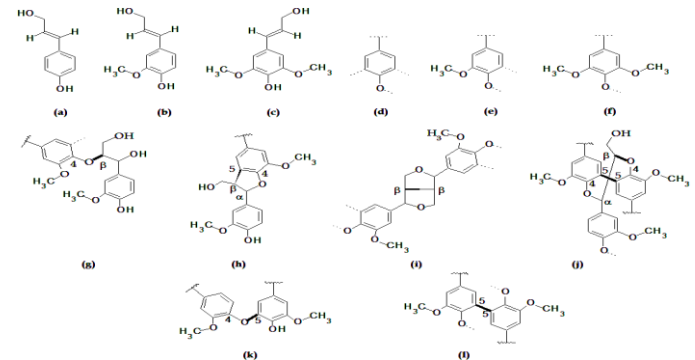
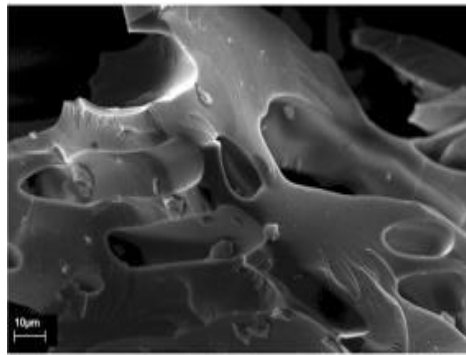
3D macromolecular structure.

Complexity due to the radical nature of the process of biosynthesis and to the diverse connectivity and structural modification of the initial monomers.

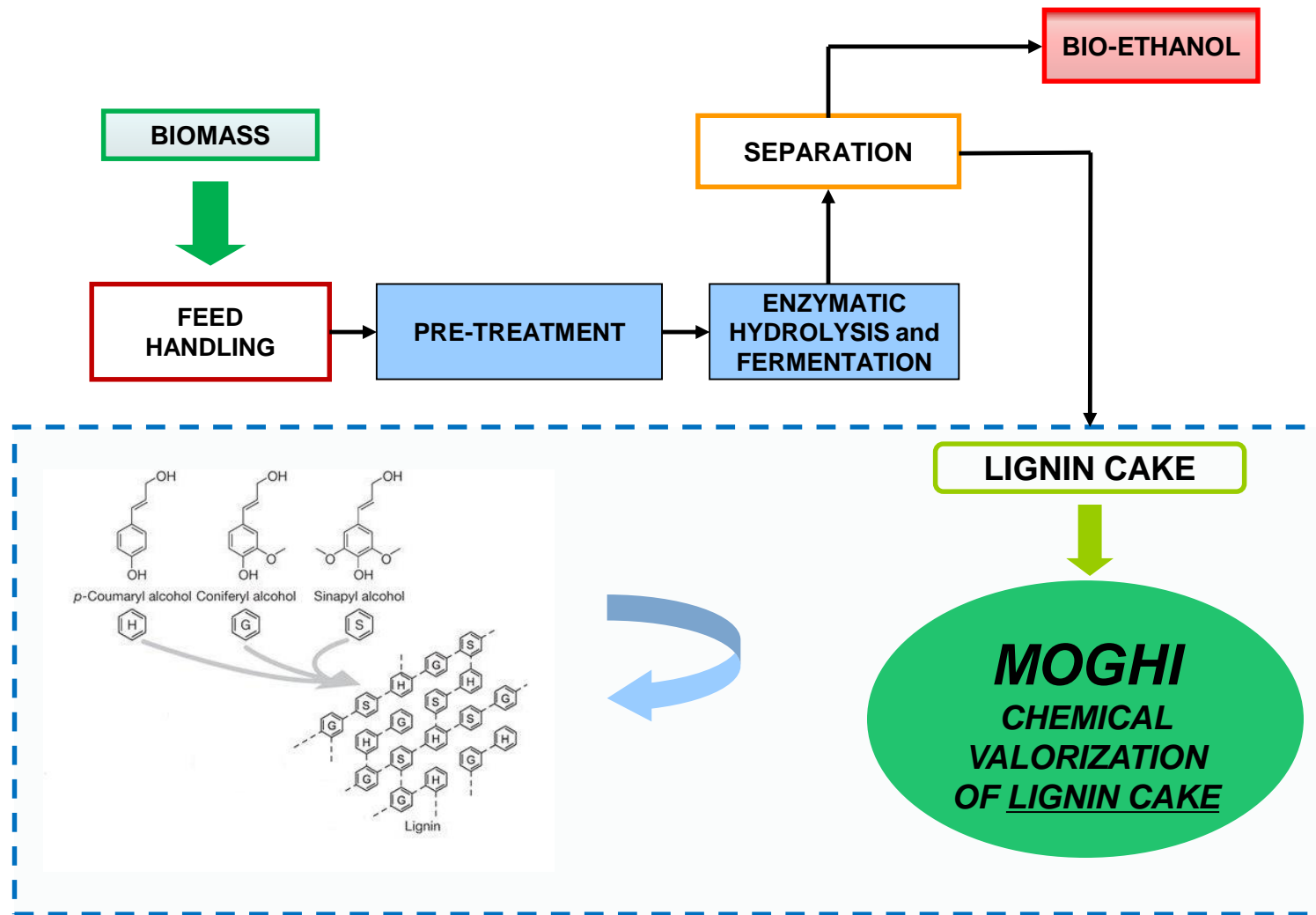


Issues with Lignin

- The chemical structure of the various lignin products is not completely well defined.
- Surprisingly little published research has been directed towards characterizing the mixtures beyond molecular weight distribution of the fragments, crude elemental analysis of the dried material and some quantification of the content of major functional groups.
- Most lignin up until today has undergone pulp & paper-type processing which deeply alters its original quality and reactivity. Lignin from bioethanol-focused processing such as steam explosion should be much less ruined and potentially more reactive.



Chemtex – Biochemicals from Lignin

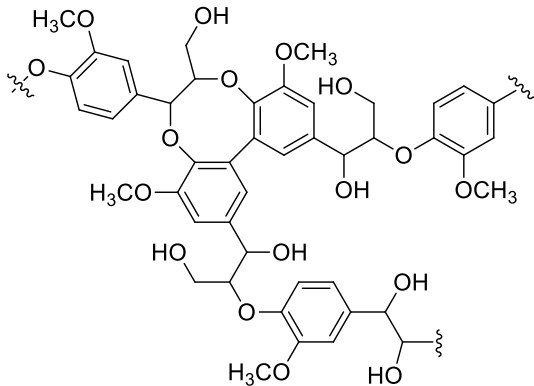


MOGHI - Lignin Conversion Process to Chemtex Bio-Reformate

Lignin

Chemtex Bio-Reformate
rich in BTX

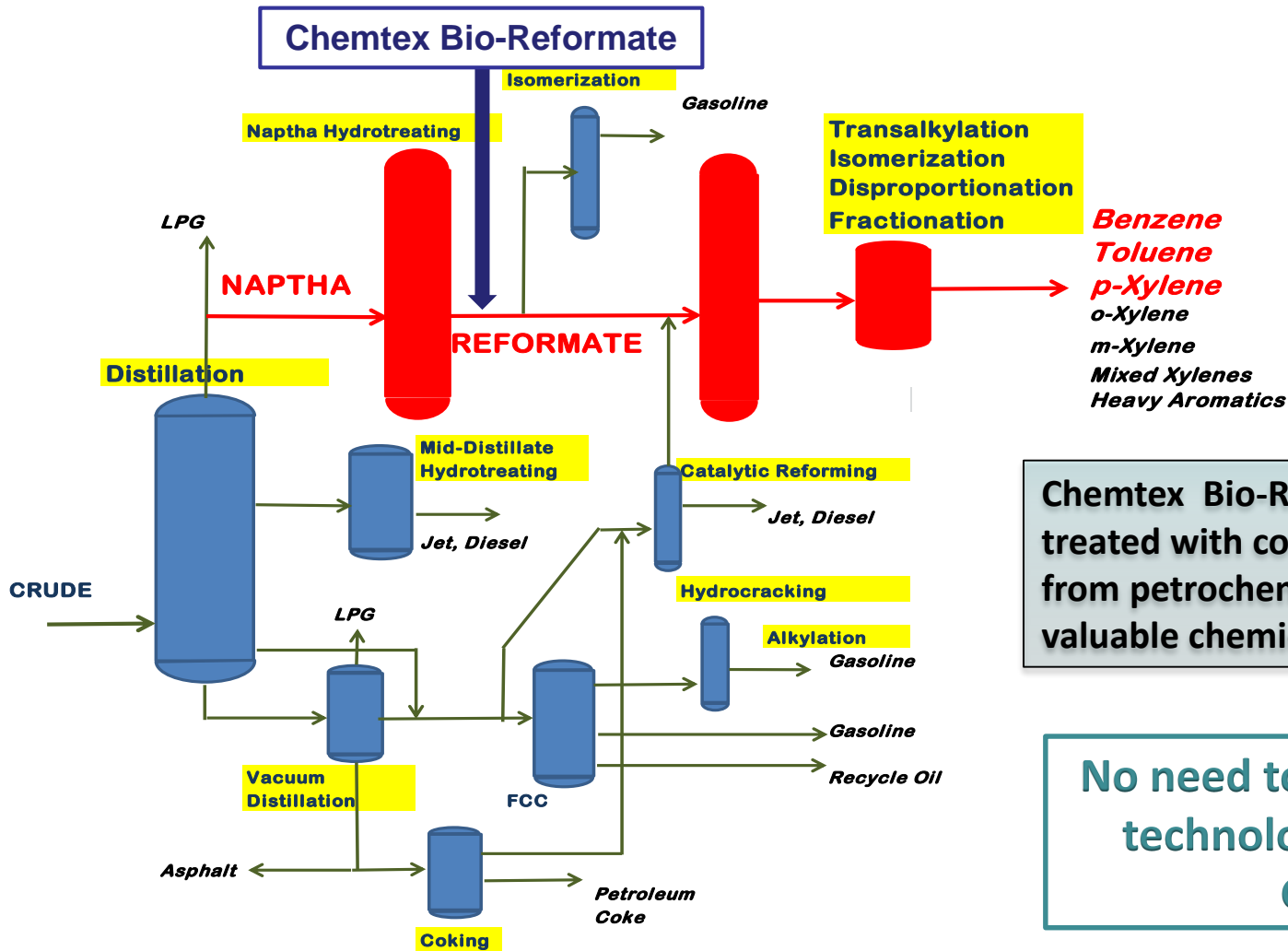
CHEMTEX
PROPRIETARY TECHNOLOGY



MOGHI



Chemtex Bio-Reformate – a “drop-in” product



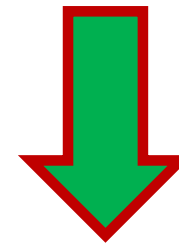
Chemtex Bio-Reformate will be treated with conventional process from petrochemical industry to valuable chemical products.

No need to change existing technology, just going GREEN

MOGHI - Lignin Conversion Process to Chemtex Bio-Reformat

	Petrochemical Reformat (Vol%)	Chemtex Bio-Reformat (Vol%)
Paraffins	22.5	<5
Naphthenes	0.7	10-15
Aromatics	60.8	75-85
Overall Totals	84.0	100

Chemtex Bio-Reformat
From Lignin



Available Petrochemical Technology

Aromatic chemicals, nylon intermediates, resins and many others

MOGHI – Raw material



Lignin from Proesa Demo Plant

After hydrolysis and fermentation of the biomass in the Proesa plant, the EtOH stream achieved is separated from the solid stream (lignin + ashes + residual sugars) by filtration in a rotary drum filter. The solid matter is a raw material with a very high lignin content.

Lignin range composition:

- 45-60% w/w pure lignin
- 25-35% w/w residual sugars
- 10-15% w/w ashes

Source of chemicals

MOGHI - Lignin Conversion Process

- Concept proven via continuous process using various high temperature and high pressure reactors.
- Operating conditions adjustment allows final product composition optimization (such as aromatic versus paraffinic fractions).
- Lignin from a variety of biomass sources successfully converted.
- More than 40 catalysts screened.
- More than 1000 experiments conducted.
- Aspen model for the Pilot Plant streams prediction.



Lignin Conversion Process

Sharon Center, Ohio, US

Bio-Lab

**Batch reactors:
50 cc, 8 L, 12 L**

**Continuous Reactors:
500 cc**



Lignin Pilot Plant

**Lignin to
Bio-Reformat
Pilot Plant**

2,5 kg/h Lignin Capacity

100 m²



**Modugno,
Apulia, Italy**

Demo Plant

**1000 ton/y
Bio-Reformat**

Demo Plant of MOGHI Technology will be built in Modugno

Its construction will start in 1st quarter of 2014

Lignin Conversion Process

Sharon Center, Ohio

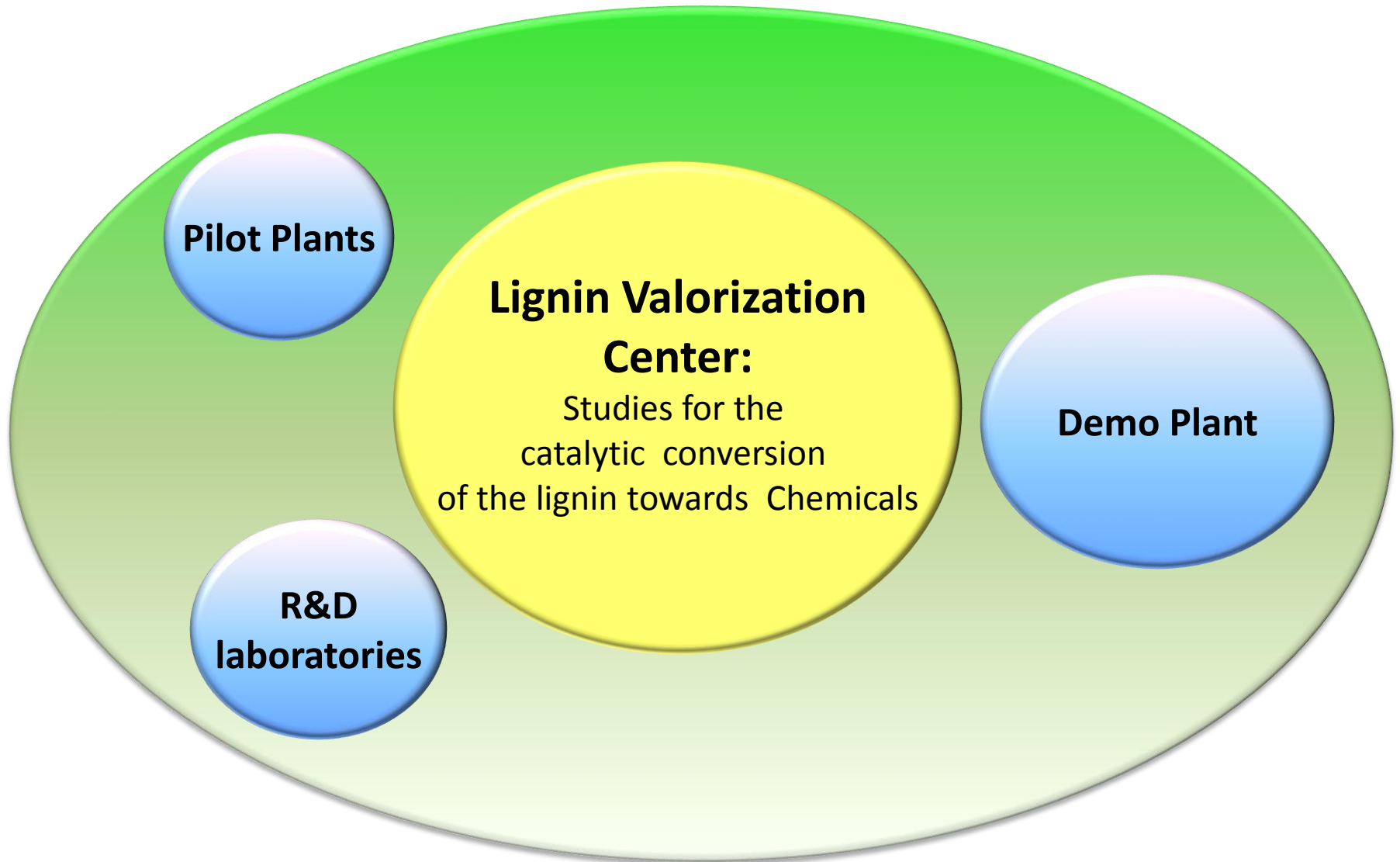
Lignin Pilot Plant

June 11th 2012, Lignin to Reformate Pilot Plant start up.

The Pilot Plant will help process improvement:

- Screening of new catalysts
- Reaction selectivity increase
- Final product yield increase
- Production costs reduction
- Operating conditions adjustment
- Final product composition optimization

Chemtex, Modugno Site



Demo Plant (Modugno, Puglia, Italy)

MOGHI Demo Plant construction:

- **Target: Bio-Reformate production, 1000 ton/y**
- **Raw material from Crescentino PROESA Plant**
- **Scale up from the Ohio Pilot Plant**
- **Will prove the technology on large scale**



PROESA® + MOGHI

PROESA® + MOGHI: the best way for going from PETROCHEMISTRY
to GREEN CHEMISTRY

