Industrial Energy-Related Technologies and Systems
An Implementing Agreement established under the auspices of the International Energy Agency

Laboratório Nacional de Energia e Geologia, I. P.

Unit of BIOENERGY

INDUSTRY-BASED BIOREFINERIES

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GOVERNO DE PORTUGAL
MINISTÉRIO DA ECONOMIA E DO EMPREGO

Seminar on Heat Integration and Biorefineries, IST 2013 July15th

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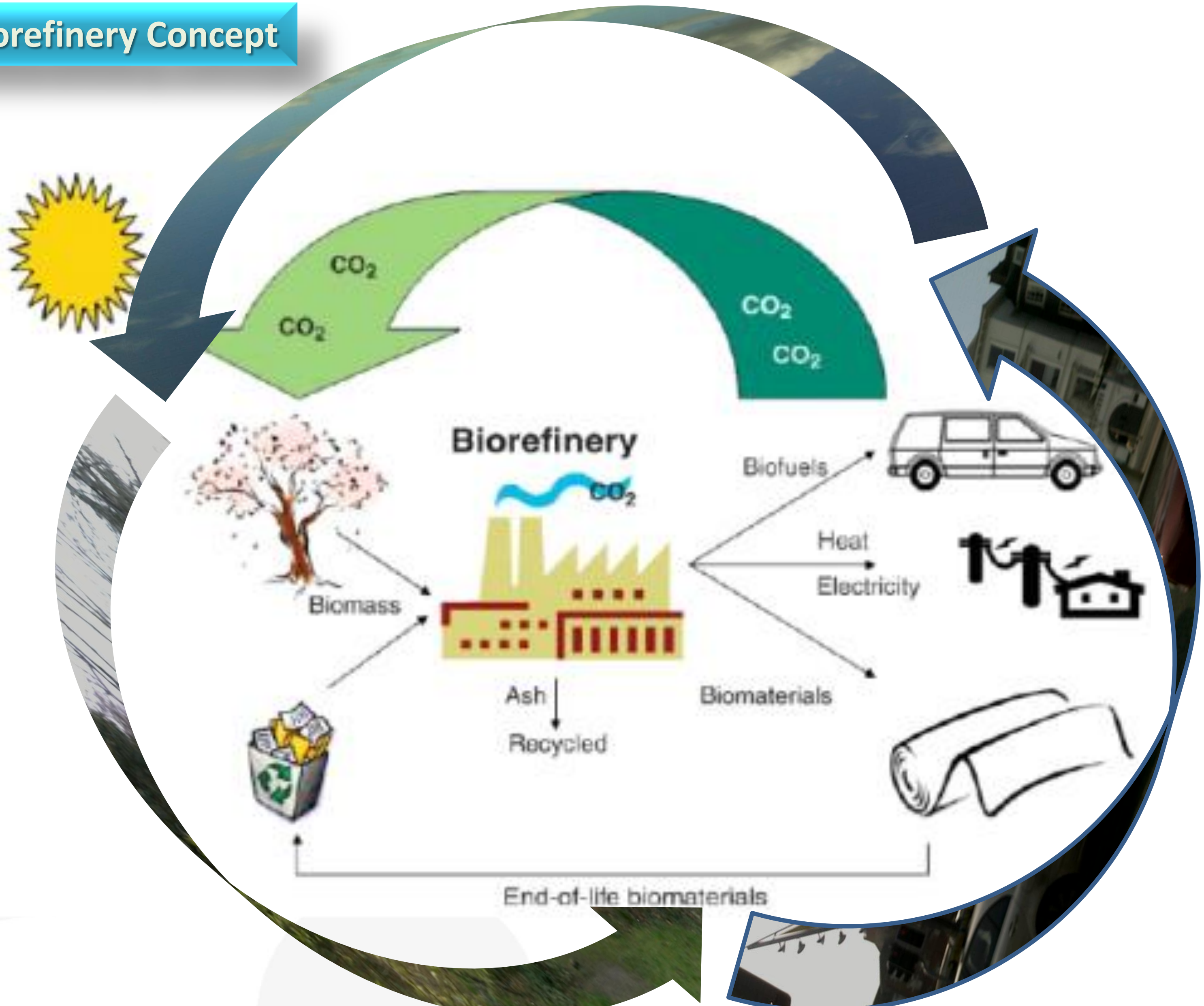
Biorefinery Concept

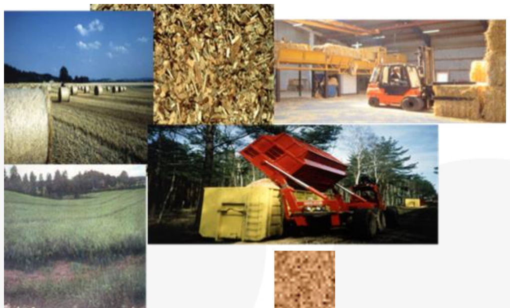


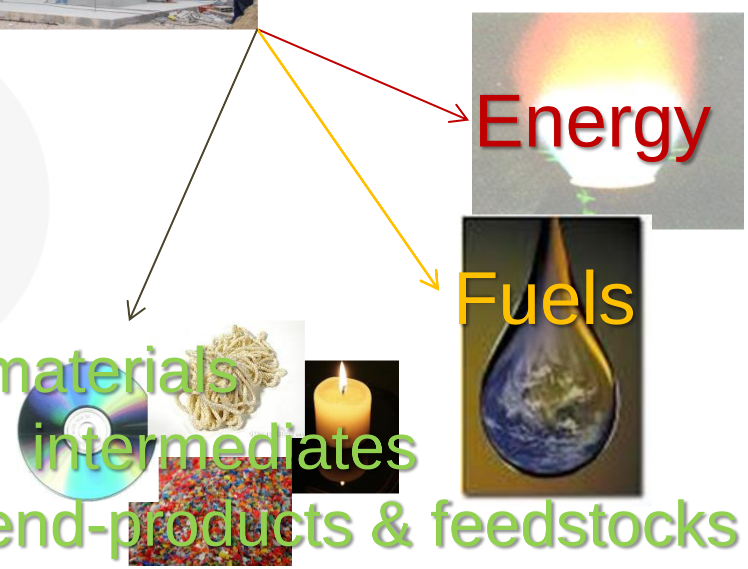
Biorefinery Concept

Similar to an oil refinery

an industrial plant that converts Renewable Resources - BIOMASS (instead of fossil petroleum) into

valuable products

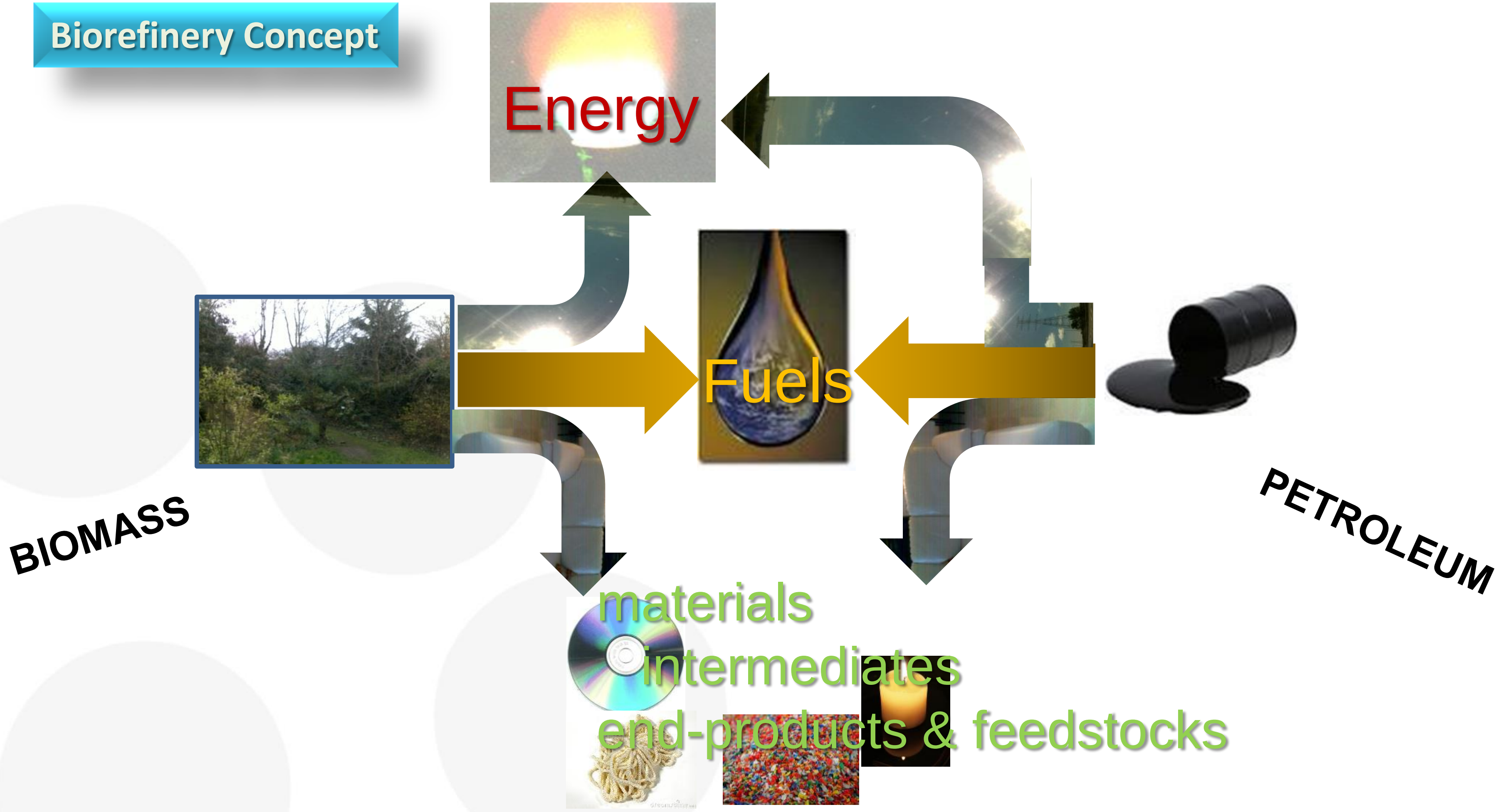




The biorefinery industrial concept

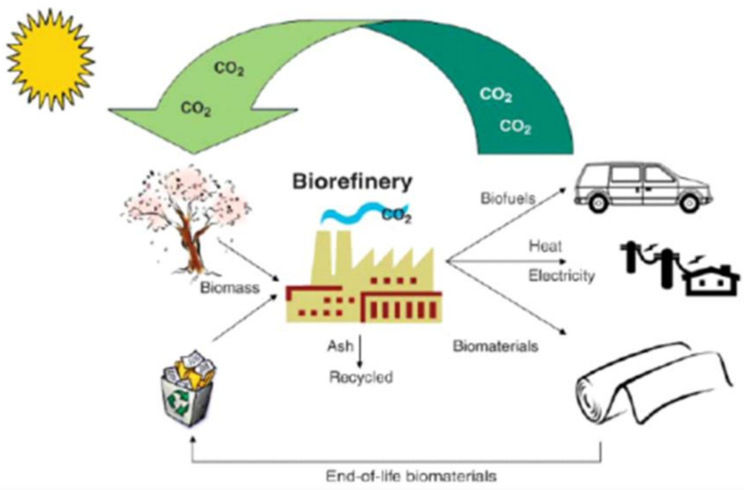
- an integrated process converting biomass available related to the industrial complex into valuable products

Biorefinery Concept



KEY FACTOR: Sustainability of the RESOURCE supply

Biorefinery Concept



Ideal Concept ?

- Wide range of valuable products
  - Competitiveness
  - Market
- Ability to process different biomass feedstocks
  - Resources
  - Flexibility
  - Economics
- Efficient integration with minimum impacts
  - Energy
  - Waste
  - Emissions
  - Sustainability

Biorefinery Concept
Conversion routes...

BIOCHEMICAL PLATFORM

THERMOCHEMICAL PLATFORM

3rd Generation Biofuels?

EU Biofuels Technology Platform Roadmap

2005

2010

2020

2050

Integrated Biorefinery Complexes

"2nd Generation"
Lignocellulosic Biomass & Energy Crops

"1st Generation"
Improving existing technologies

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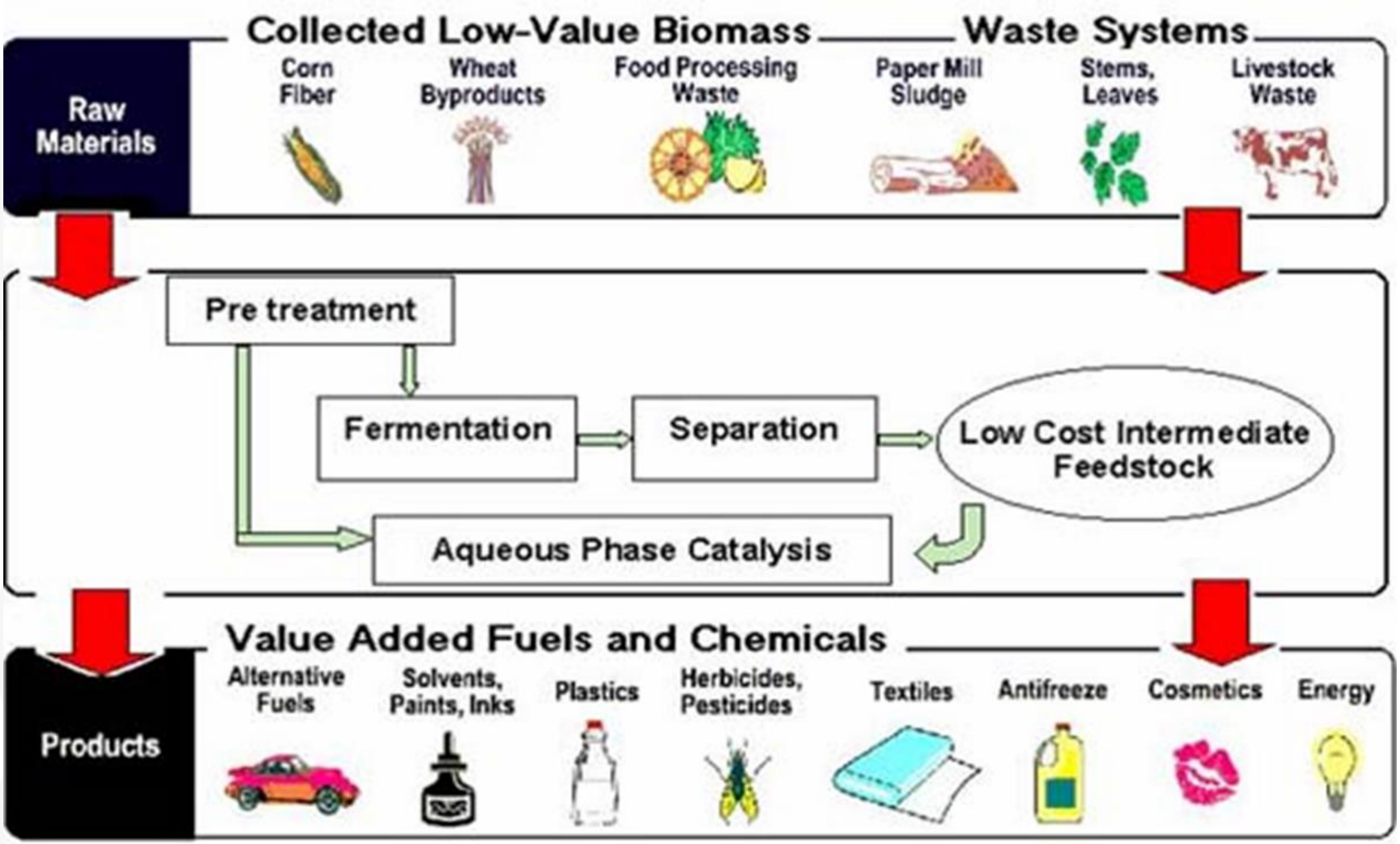
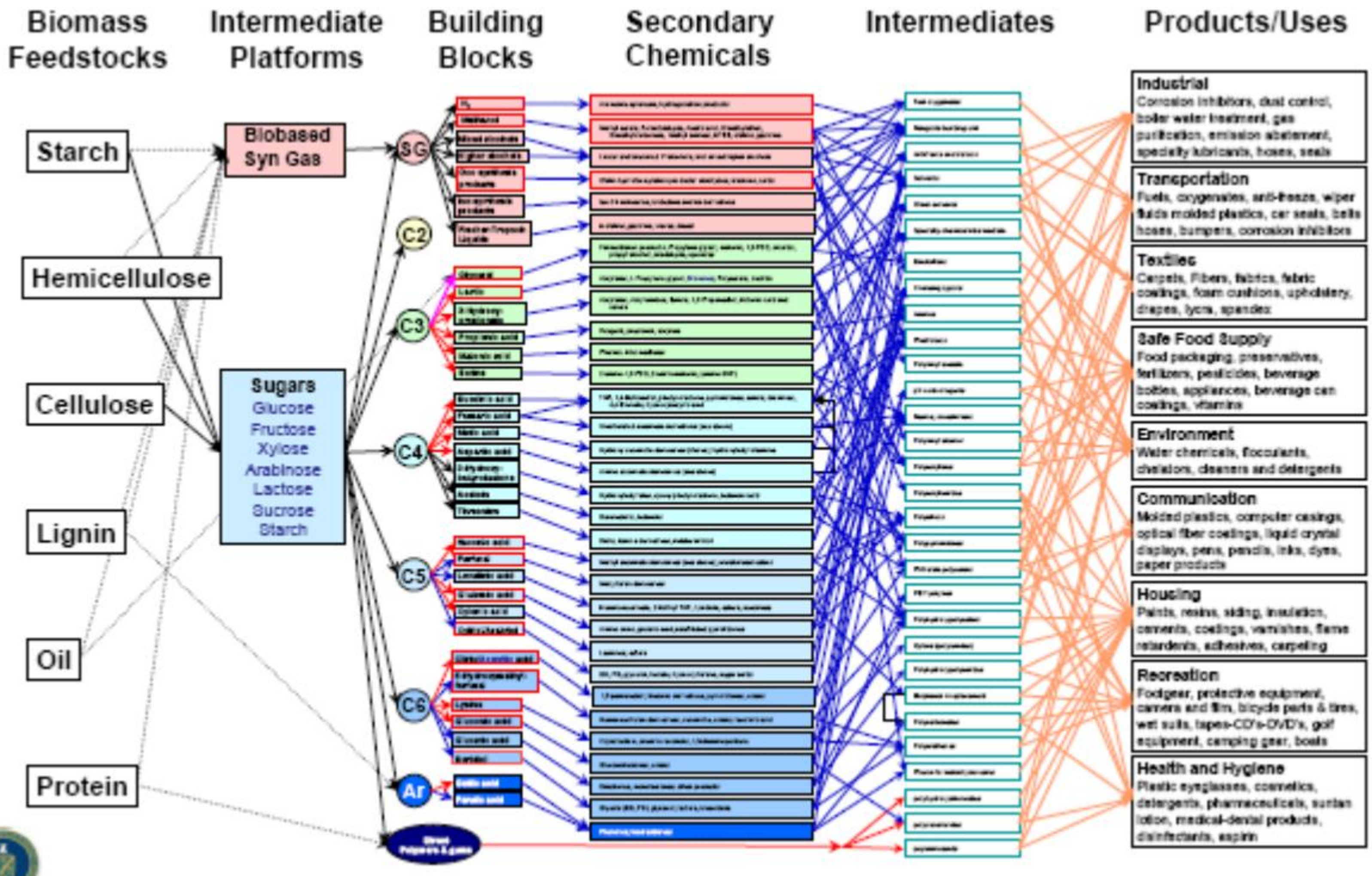
BIOREFINERY CONCEPT
The traditional biochemical path...



BIOREFINERY CONCEPT
The traditional biochemical path…

Building blocks



Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks

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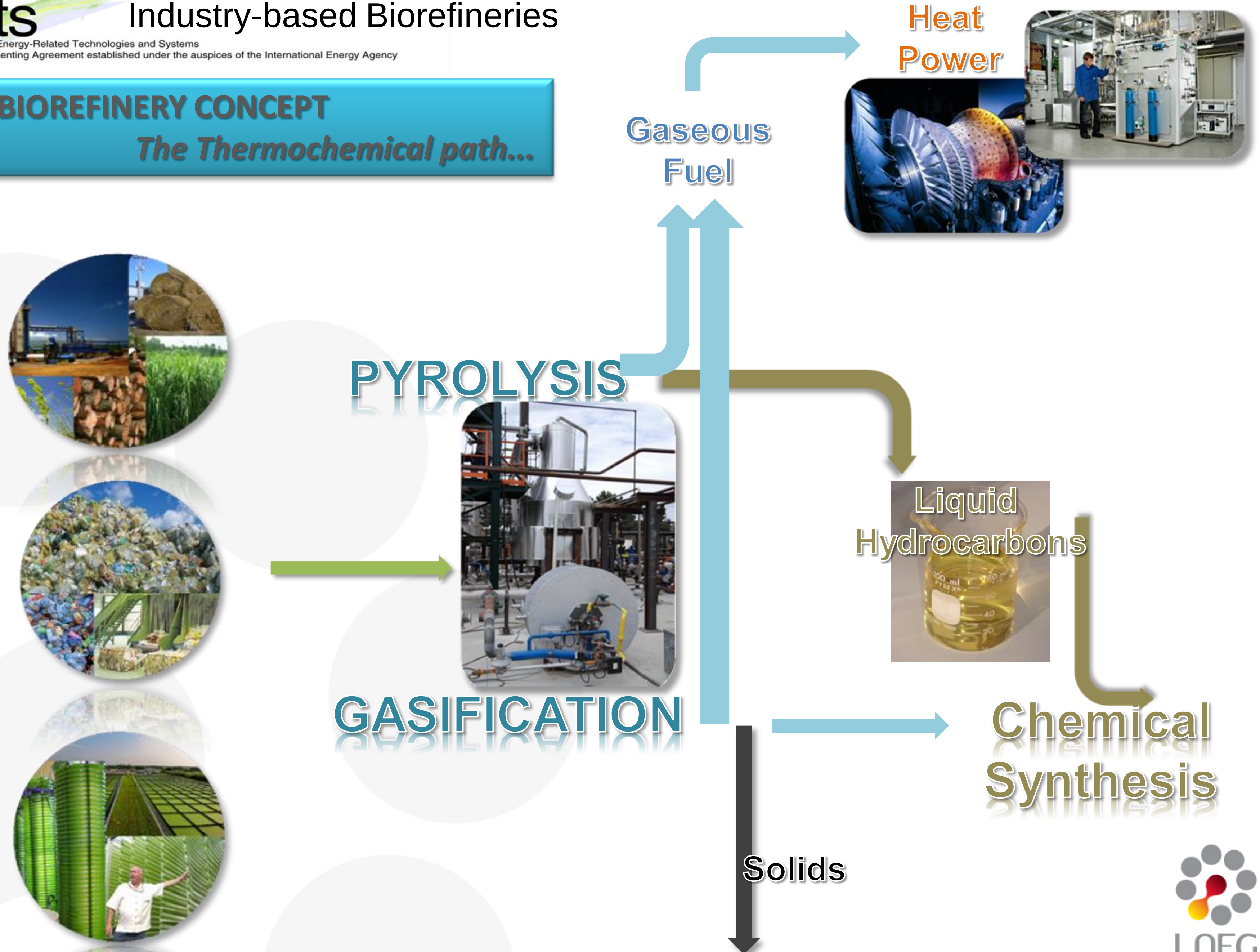
Industry-based Biorefineries

BIOREFINERY CONCEPT
The Thermochemical path…



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BIOREFINERY CONCEPT
Integration

Biochemical Platform

Sugar Feedstocks

Combustible residues

Heat & Power

Fuels, Chemicals & Materials

Combustible streams

Thermochemical Platform

Hydrocarbons & Carbonaceous Materials

CLASSIFICATION OF BIOREFINERIES

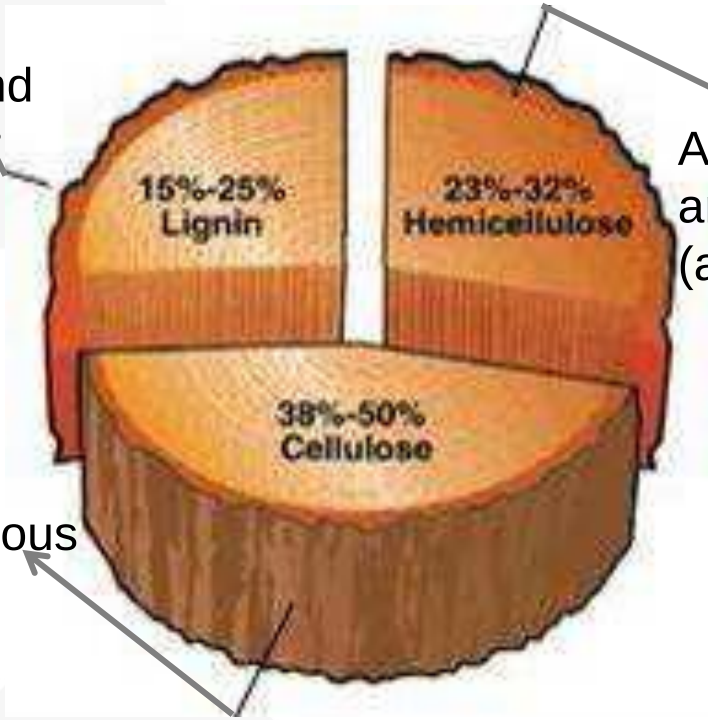
- Classification of biorefineries depends on complexity and commercial viability
  - Biorefinery systems depend on the nature of feedstock and type of conversion process
    - Lignocellulosic Feedstock Biorefinery (LCF - Biorefinery)
    - Whole Crop Biorefinery (WCB)
    - Green Biorefinery (GBR)
    - Two Platform Biorefinery (TPB) to Multi-Platform Biorefinery (MPB)

CLASSIFICATION OF BIOREFINERIES

Lignocellulosic Feedstock Biorefinery

Combination of agro-forestry technologies transforming the feedstock to fuels, chemicals and energy.

Amorphous polymer of phenyl-propene units via co-polymerisation of alcohols (coumaryl, coniferyl and sinapyl alcohols)



Amorphous polymer of C5 (xylose) and C6 sugars, and side chains (acetic and uronic acids)

Polymer of glucose (C6-sugar) with both crystalline and amorphous regions

J.H. Reith *et. Al.*, *Lignocellulosic feedstock biorefinery for co-production of chemicals, transportation fuels, electricity and heat – IP BIOSYNERGY and Beyond*, Biorefinery Training Course, 12 June 2009, Ghent.

CLASSIFICATION OF BIOREFINERIES
Lignocellulosic Feedstock Biorefinery

	Woody feedstock	Non-woody feedstock
Cellulose	38-50	30-45
Hemicellulose	23-32	20-35
Lignin	15-25	10-25
Extractives	2-5	5-15
Protein	<0.5	5-10
Inorganics	0.1-1	0.5-10
SiO_2	<0.1	0.5-7

Hemicellulose and lignin are very significant biomass fractions

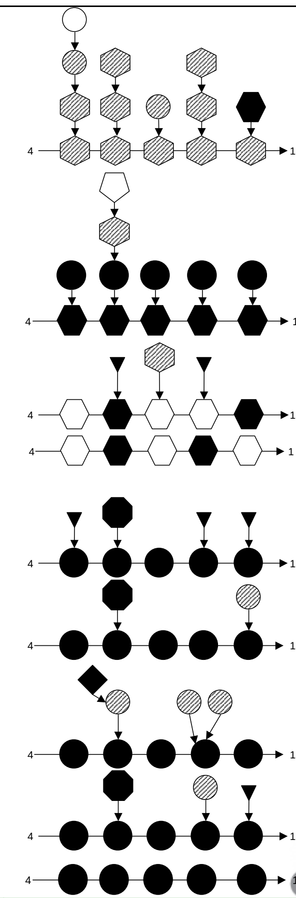
Hemicelluloses

Gírio FM, Fonseca C, Carvalheiro F, Duarte LC, Marques S & Bogel-Łukasik R (2010), "Hemicelluloses for fuel ethanol: a review", *Bioresource Technology* **101**.

CLASSIFICATION OF BIOREFINERIES

Lignocellulosic Feedstock Biorefinery

Polysaccharide type	Biological origin	Abrev.	Amount[a]	Units			DP	Schematic representation
				Backbone	Side chains	Linkage		
Arabinogalactan	Softwoods	AG	1-3;35*	β-D-Gal*p*	β-D-Gal*p* α-L-Ara*f* β-L-Ara*p*	β-(1→6) α-(1→3) β-(1→3)	100-600	
Xyloglucan	Hardwoods, grasses	XG	2-25	β-D-Glc*p* β-D-Xyl*p*	β-D-Xyl*p* β-D-Gal*p* α-L-Ara*f* α-L-Fuc*p* Acetyl	β-(1→4) α-(1→3) β- (1→2) α-(1→2) α-(1→2)		
Galactoglucomannan	Softwoods	GGM	10–25	β-D-Man*p* β-D-Glc*p*	β-D-Gal*p* Acetyl	α-(1→6)	40-100	
Glucomannan	Softwoods and Hardwoods	GM	2–5	β-D-Man*p* β-D-Glc*p*			40-70	
Glucuronoxylan	Hardwoods	GX	15–30	β-D-Xyl*p*	4-O-Me-α-D-Glc*p*A Acetyl	α-(1→2)	100-200	
Arabinoglucuronoxylan	Grasses and cereals, softwoods	AGX	5–10	β-D-Xyl*p*	4-O-Me-α-D-Glc*p*A β-L-Ara*f*	α-(1→2) α-(1→3)	50-185	
Arabinoxylans	Cereals	AX	0.15-30	β-D-Xyl*p*	α-L-Ara*f* Feruloy	α-(1→2) α-(1→3)		
Glucuronoarabinoxylans	Grasses and cereals	GAX	15-30	β-D-Xyl*p*	α-L-Ara*f* 4-O-Me-α-D-Glc*p*A Acetyl	α-(1→2) α-(1→3)		
Homoxylans	Algae	X		β-D-Xyl*p*[b]				

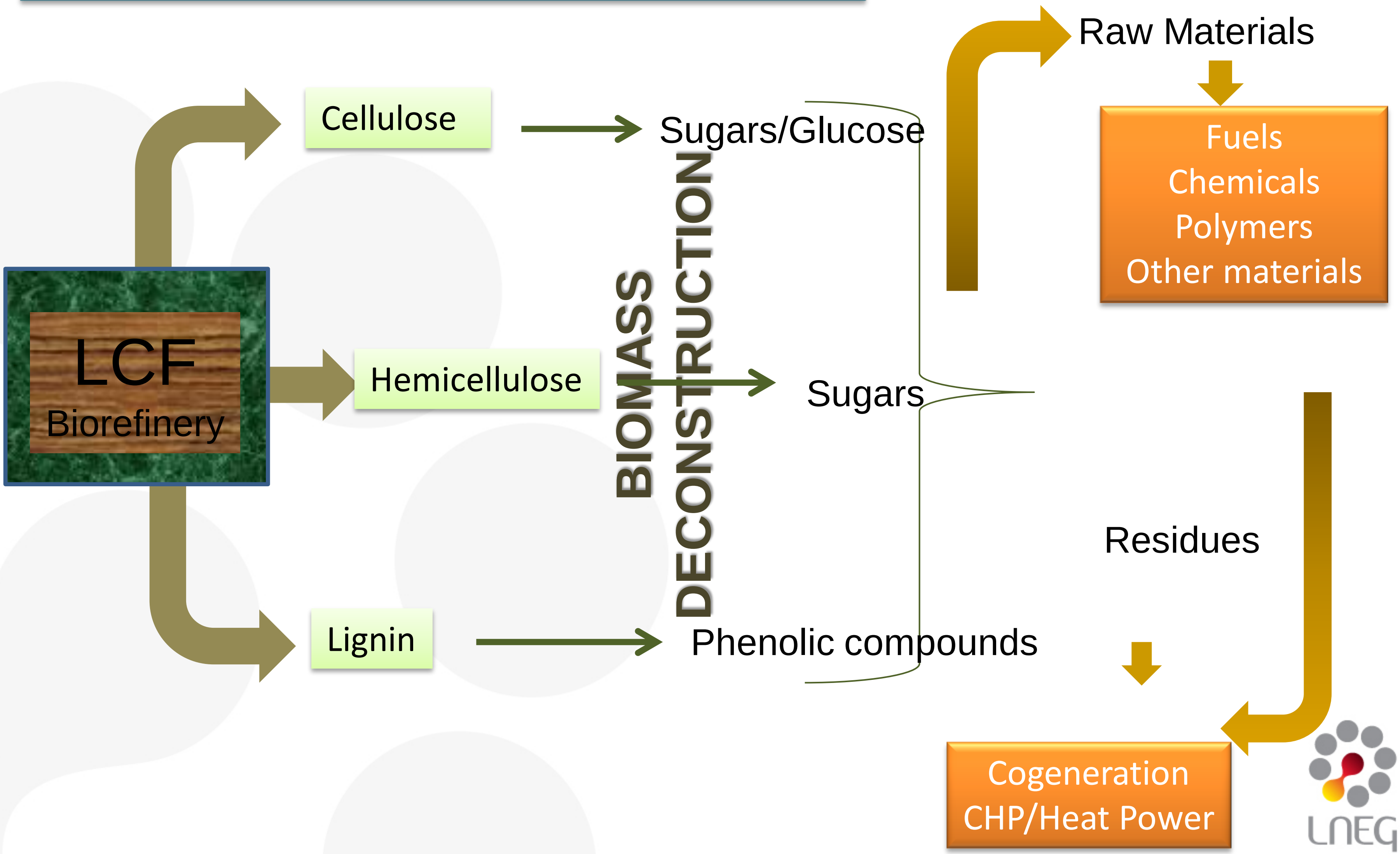


[a]% on dry biomass; [b] may also present β-(1→3) linkages on the backbone; * (up to) in the heartwood of larches

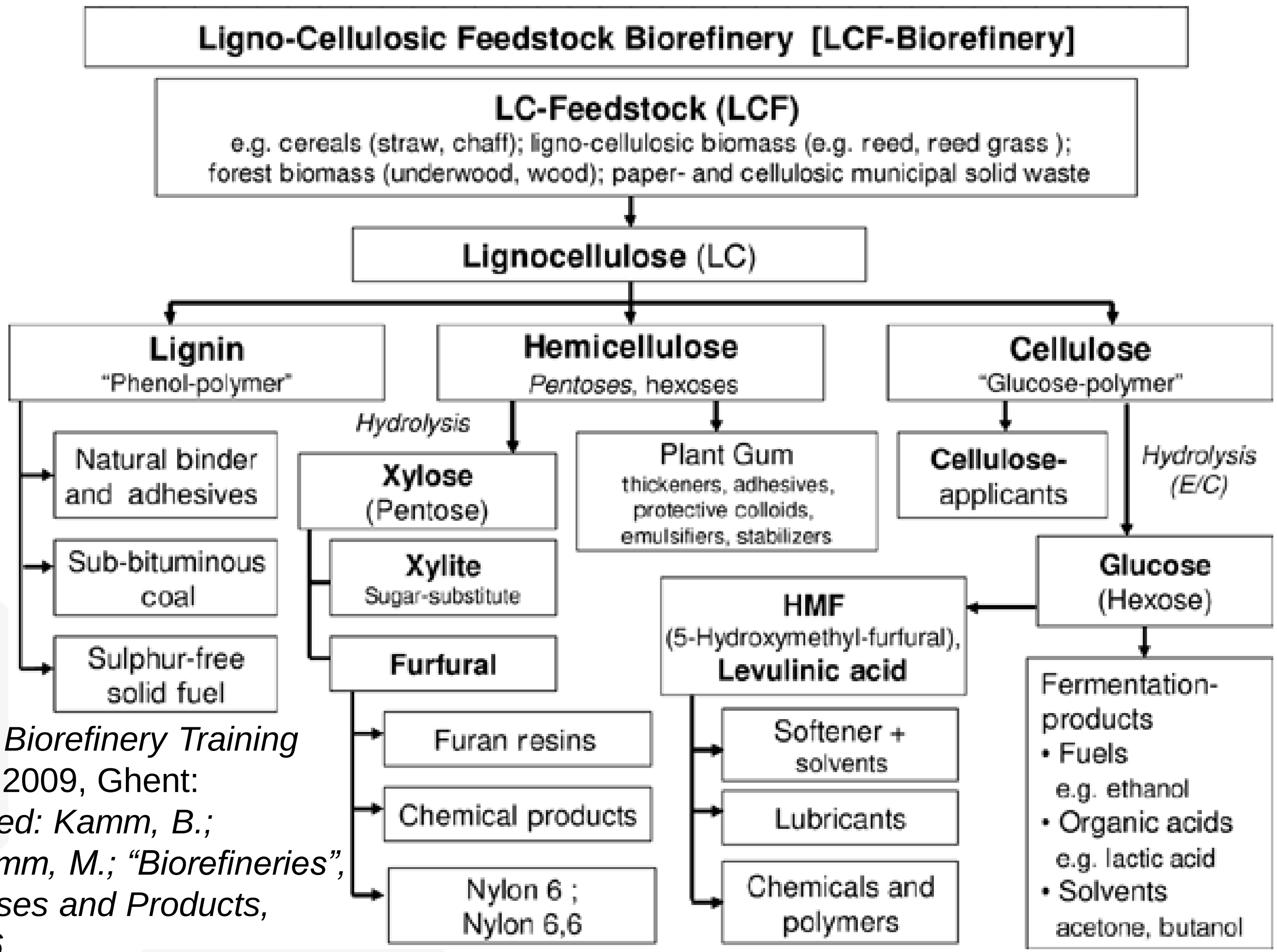
β-D-Gal*p*; β-D-Glc*p*; β-D-Man*p*; β-D-Xyl*p*; β-L-Ara*f*; β-L-Ara*p*; α-L-Fuc*p*;
4-O-Me-α-D-Glc*p*A; Acetyl; Feruloyl

CLASSIFICATION OF BIOREFINERIES

Lignocellulosic Feedstock Biorefinery



CLASSIFICATION OF BIOREFINERIES
Lignocellulosic Feedstock Biorefinery



J.H. Reith *et. al.*, *Biorefinery Training Course*, 12 June 2009, Ghent:
- *Reference quoted: Kamm, B.; Gruber, B.R.; Kamm, M.; "Biorefineries", Industrial Processes and Products, Wiley-VCH, 2006*.

CLASSIFICATION OF BIOREFINERIES
Lignocellulosic Feedstock Biorefinery

LIGNIN origin Potencial products

Syngas products	Hydrocarbons	Phenols	Oxidised products	Macromolecules
•Methanol •DME •Ethanol •Mixed alcohols •Fischer-Tropsch •Liquids •C1-C7 gasses	•Benzene •Toluene •Xylene •Cyclohexane •Styrenes •Biphenyls	•Phenol •Substituted phenols •Cathecols •Cresols •Resorcinols •Eugenol •Syringols •Coniferols •Guaiacols	•Vanillin •Vanilic acid •DMSO •Aromatic acids •Aliphatic acids •Syringaldyde •Aldehydes •Quinones •Cyclohexanol •ß-keto adipate	•Carbon fibre fillers •Polymer extenders •Substituted lignins •Thermoset resins • Composites •Adhesives •Binders •Preservatives •Pharmaceuticals •Polyols

IEA Bioenergy- Task 42 Biorefinery (2012), *Bio-based chemicals: value added products from biorefineries*.

CLASSIFICATION OF BIOREFINERIES
Whole Crop Biorefinery

CROPS
are plants grown in substantial quantities and harvested for food and other purposes.

Residues

Food

Energy Plantations

Other products

Residues

BIOREFINERY FEEDSTOCKS

CLASSIFICATION OF BIOREFINERIES
Whole Crop Biorefinery

Biorefinery Feedstocks	→	Products
Selective Crops Starch, Sugar Crops, Proteins Oil, Starch, Sugar Crops, Straw Oil, Starch, Sugar Crops, Straw Various Oil Crops Mostly Starch, & Sugar Crops Lignocellulosic Crops, Residues, Grasses		Pharmaceuticals Bulk Chemicals Fine Chemicals Solvents Surfactants Lubricants Polymers Fibres

J. W. A. Langeveld, J. Dixon & J. F. Jaworski, “Development Perspectives Of The Biobased Economy: A Review”, *Crop Science*, Vol. 50, No. Supplement 1, 2010, pp. S-142-S-151; doi: 10.2135/cropsci2009.09.0529

CLASSIFICATION OF BIOREFINERIES

Whole Crop Biorefinery

Raw Materials

Fuels
Chemicals
Polymers
Other materials

Residues

Cogeneration
CHP/Heat Power

Grain → Oil; Starch, sugars

Flour (Meal)

Straw → Lignocellulosic materials

BIOMASS DECONSTRUCTION

- Cellulose
- Hemicellulose
- Lignin

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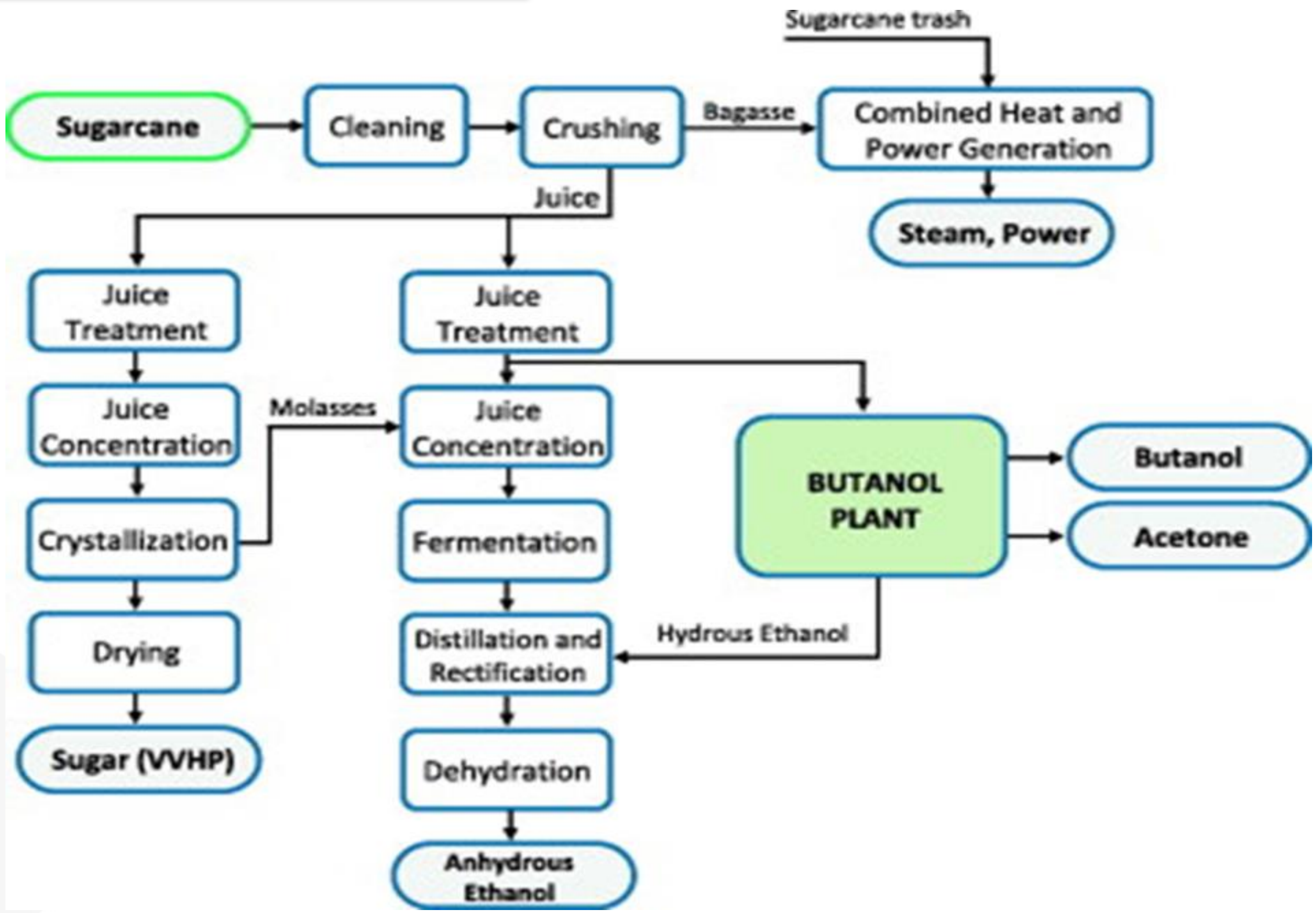
CLASSIFICATION OF BIOREFINERIES
Whole Crop Biorefinery



A. P. Mariano, M.O.S. Dias, T. L. Junqueira, M. P. Cunha, A. Bonomi & R. M. Filho, "Butanol production in a first-generation Brazilian sugarcane biorefinery: Technical aspects and economics of greenfield projects", *Bioresource Technology,* vol.135, 2013, pp. 316-323; http://dx.doi.org/10.1016/j.biortech.2012.09.109

CLASSIFICATION OF BIOREFINERIES
Green Biorefinery

Technological combination to process grass and other immature green biomass into valuable products.

Juice extraction

Proteins
Amino acids’ mixtures
Sugars
Lactic Acid

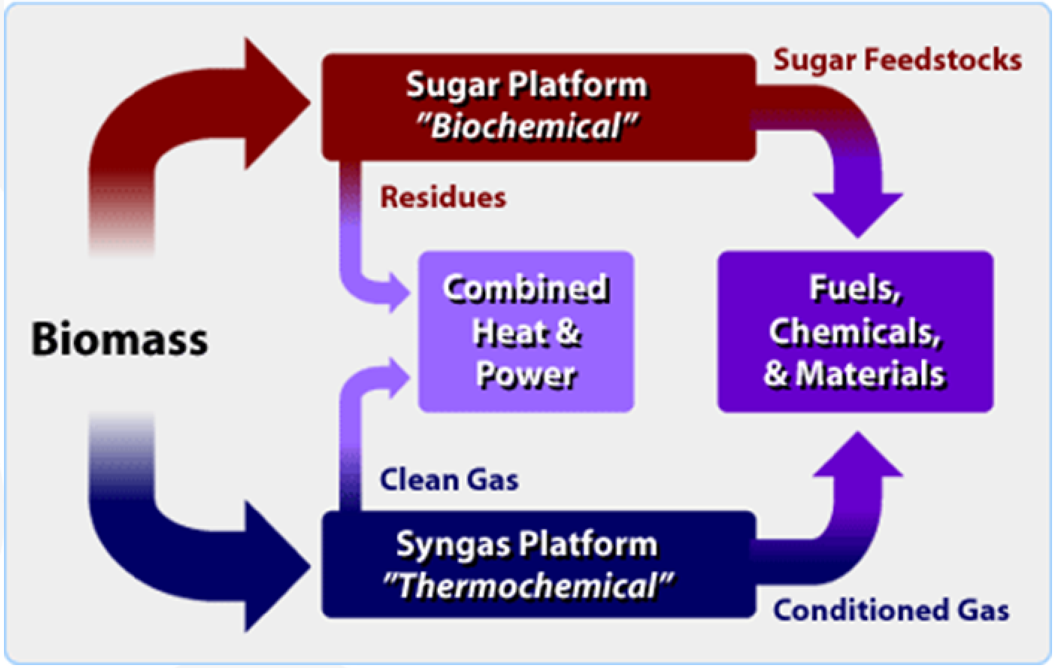
Solid fraction

Biogas/Bio-methane
Fibre materials
Lignocellulosic material

CLASSIFICATION OF BIOREFINERIES
Two Platform Biorefinery

Biorefinery Platform has been defined as the CONVERSION PATH from raw materials to end-products.

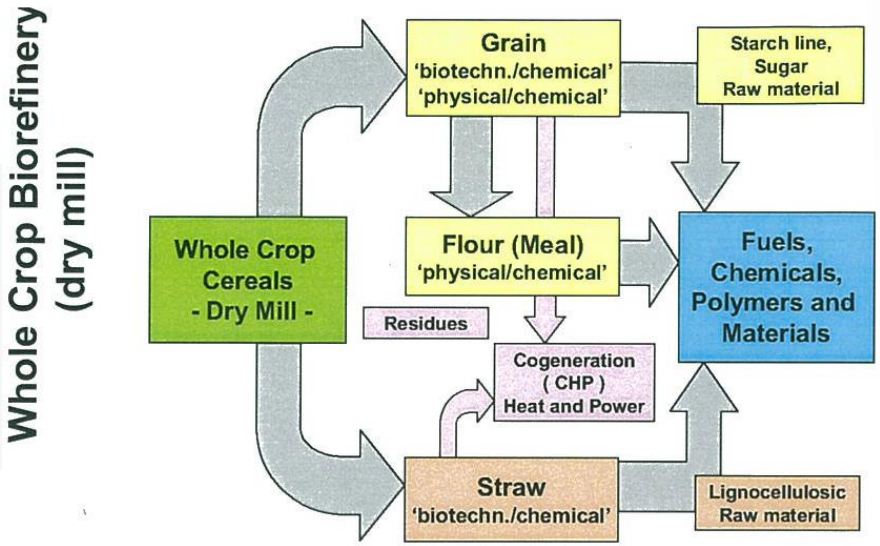
Biorefinery Concept

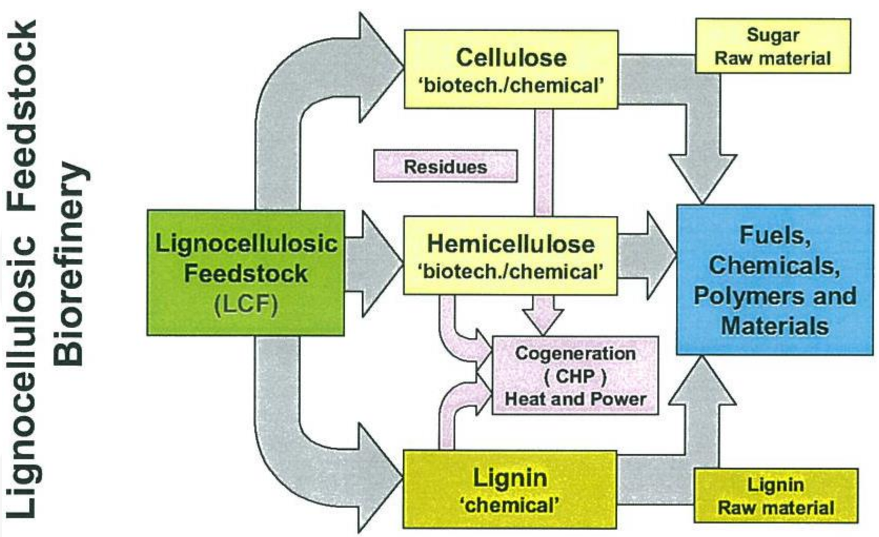


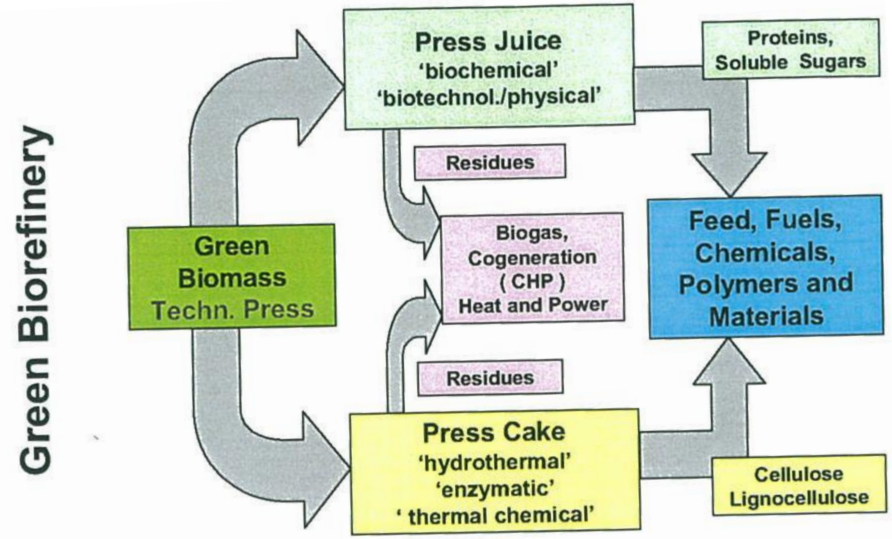
http://www.nrel.gov./biomass/biorefinery.html

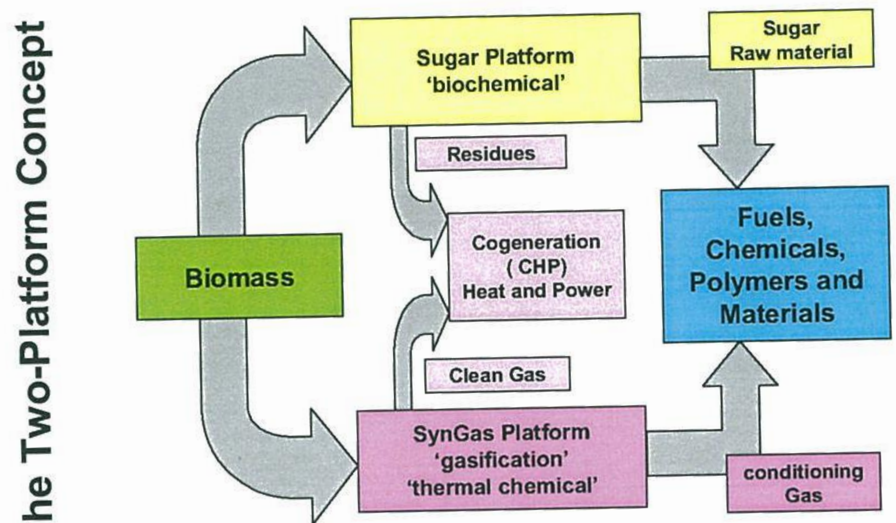
Industry-based Biorefineries

CLASSIFICATION OF BIOREFINERIES









Birgit Kamm, "Technical description of Green and Whole Crop Biorefineries", *BioreFuture- Biopol Meeting,* 2009, Brussels March 30;
- *Reference quoted: Kamm, B.; Gruber, B.R.; Kamm, M.; "Biorefineries", Industrial Processes and Products, Wiley-VCH, 2006*.

CLASSIFICATION OF BIOREFINERIES

Evolving in the Concept of Platform…

Platform could also be associated with:
- Intermediates from raw materials to products;
- Linkages between biorefinery concepts;
- Final Products.

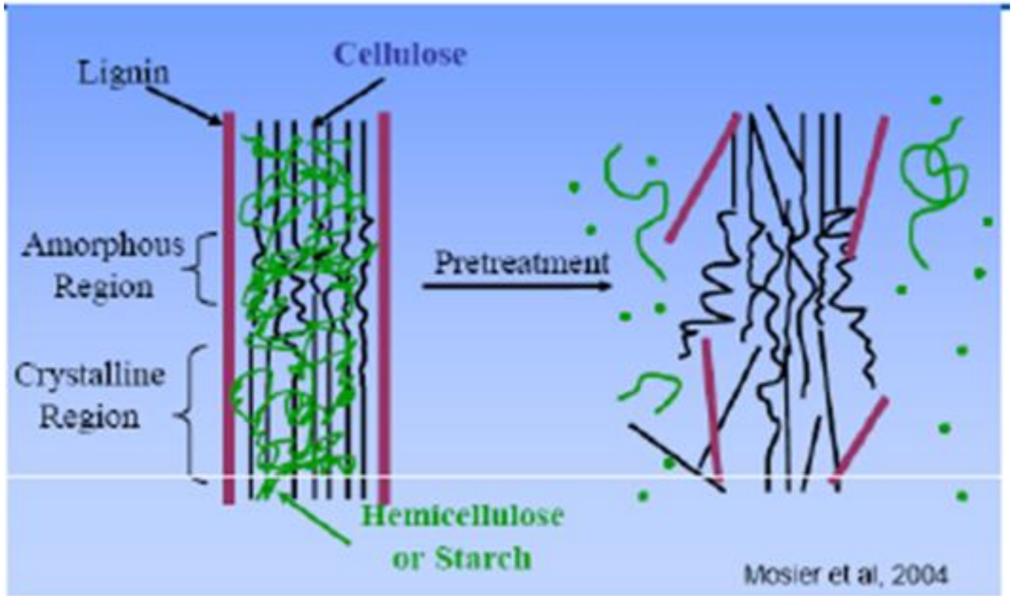
Multi-Platform Concept

Source: G. Jungmeier & F. Cherubini *et. al.*, "Definition and Classification of Biorefinery Systems - The Approach in IEA Bioenergy Task 42 "Biorefineries", *Biorefinery Course "Adding Value to the Sustainable Utilisation of Biomass",* RRB5 satellite event, Ghent, Belgium, 12 June 2009.

FEEDSTOCK PRE-TREATMENT

Objectives

- Overcome the natural resistance of lignocellulosic feedstocks to microbial degradation
- Reduce the recalcitrance of cellulose and hemicellulose to better enable conversion of the carbohydrates to soluble sugars



Mosier, N., Wyman C., Dale B., Elander R, Lee YY, Holtzapple & Ladisch M, “Features of promising technologies for pretreatment of lignocellulosic biomass”, *(2005), Bioresour. Technol.*, April (96)6: 673-86.

Limitations

- One of the **most expensive processing steps in cellulosic biomass-to-fermentable sugars conversion**
- Insufficient separation of cellulose and lignin
- Formation of byproducts (fermentation inhibitors)
- High use of chemicals and/or energy

FEEDSTOCK PRE-TREATMENT

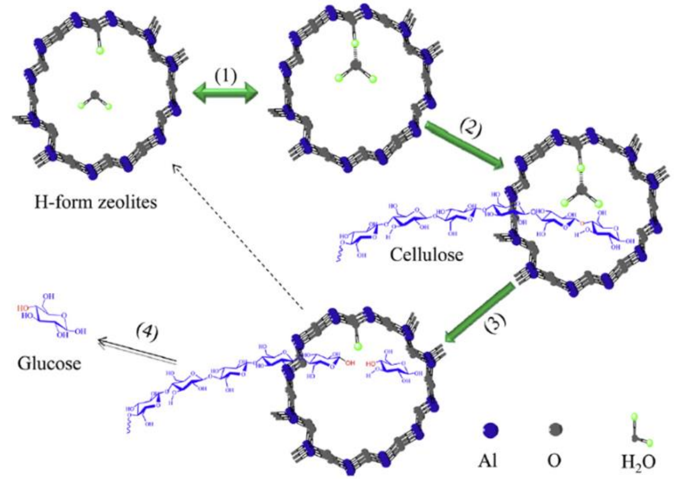
Main Pre-treatment Options:

Physical	Chemical	Physico-chemical	Biological
Milling	**Acid processes/ Solid (Super) Acids**	**Autohydrolysis/ Liquid hot water**	Brown-, white- and soft-rot fungi
Grinding	**Alkaline processes**	**Steam explosion**	
Ultrasound	Wet Oxidation	**Sub- and supercritical fluids**	
Irradiation (microwaves, ɣ-irradiation)	**Organosolv**		
	Ozonolysis		
	Ionic liquids		
	Inorganic salts		

Carvalheiro, F.; Duarte, L.C.; Moniz, P.; Gírio, F.M.; Bogel-Lukasik, R., “Emerging Biomass fractionation processes and their potential role in the biorefineries”, (2012), *Proceedings 1-CIAB:1st Iberoamerican Congress on Biorefineries*, Mexico.

LNEG

FEEDSTOCK PRE-TREATMENT
Novel Chemical processes



➢ Solid (Super) Acids

Solids which can donate protons or accept electrons during reactions

"acids stronger than 100% sulphuric acid" (Brønsted superacids), "acids stronger than anhydrous aluminum trichloride" (Lewis superacids)

Main classes

- **H-FORM ZEOLITES** *(microporous aluminosilicates minerals)*
  - H-mordenite, H-ZSM-5, …, but also bentonite, kaolin
- **TRANSITION-METAL OXIDES** *(mesoporous Single or Mixed metal oxides)*
  - Nb_2O_5, Zr-TMS, TiO_2, CeO_2, $HNbMoO_6$, Ta_2O_5-$W0_3$, Zn-Ca-Fe oxide, …
- **CATION-EXCHANGE RESINS**
  - Amberlyst-15 (polystyrene-based cation-exchange resin with SO_3H), Dowex 50wx8-100, NKC-9, Nafion® NR50 (perfluorosulfonated ionomer)

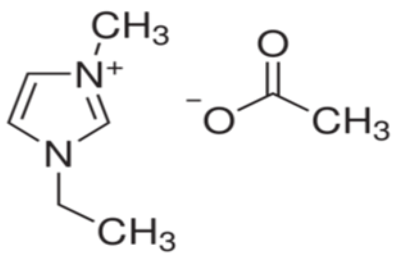
FEEDSTOCK PRE-TREATMENT
Novel Chemical processes

- **Solid (Super) Acids**

Compared to liquid catalysts:

- ✓ **Limited problems associated to equipment corrosion, safety and waste generation**
- ✓ **Easy separation/recovery without loss of activity**
- ✓ **Long catalyst life**
- ✓ **High Selectivity**
- ✘ Costs
- ✘ Reaction time
- ✘ Thermal stability
- ✘ Water presence can decrease catalytic activity
- ✘ **Solid-solid interaction required (mass transfer limitations, pore diameters can limit accessibility, …)**

FEEDSTOCK PRE-TREATMENT
Novel Chemical processes



[emim][Ac]

➢ Ionic Liquids (ILS)

- ILs organic salts (melting point < 100ºC)
- High thermal stability, great solvent power, negligible vapour pressure
- Particularly useful in dissolution of cellulose.

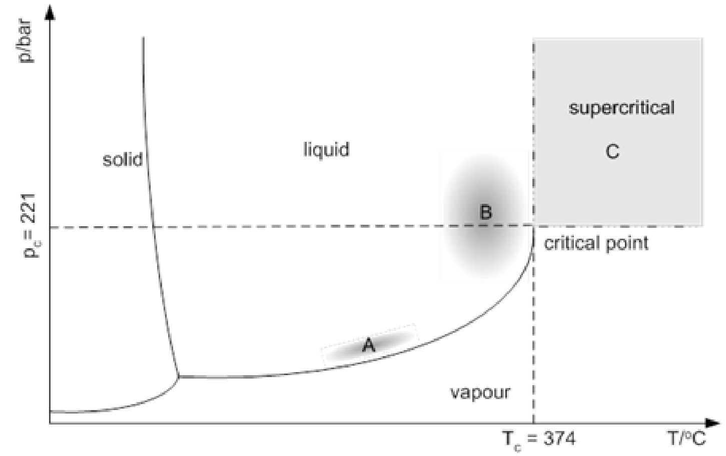
Imidazolium ILs dissolve up to 25% of **cellulose** (Zakrzewska et al., *Energ. Fuel*, 2010, **24**, 737-745), breaking the extensive hydrogen bonding network

- **Chlorine ILs**; (Cl^- strong proton acceptor in the interaction between IL and hydroxyl groups of the carbohydrate). High melting point/viscosity
- **Newly designed ILs** (1-ethyl-3-methylimidazolium dimethylphosphate ([emim][$(MeO)_2PO_2$]) , ILs containing dialkylimidazolium cation and dicyanamide anion)
- Two possible **approaches**: **complete dissolution** of biomass followed by **selective fractionation (e.g. precipitation) and hydrolysis**

FEEDSTOCK PRE-TREATMENT
Physico-Chemical processes

➢ Hydrothermal processes

- **Liquid hot water (LHW) (A)**
- **Steam (A)**
- **Steam explosion (A)**
- **Subcritical water (B)**
- **Supercritical water (C)**



Gírio, F.M., Fonseca, C., Carvalheiro, F., Duarte, L.C., Marques, S., Bogel-Lukasic, R. (2010) *Biores. Technol.*, **101**, 4775-4800.

Water (T_c=374.0°C, p_c=221.0 bar), **CO_2** (T_c=31.0°C, p_c=73.8 bar)

Supercritical Fluids (SCF)

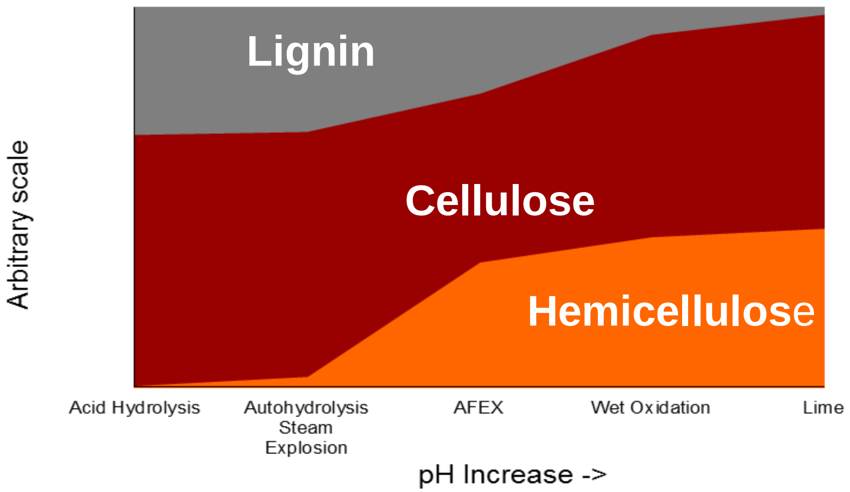
- **SC water**

  Hemicellulose can be completely separated and **digestibility** of **cellulose** significantly increased (220ºC, K_w=6.34*10^{-12}, pH =5.5)

- **SC CO_2**

  Significantly increase the **digestibility of cellulose** (any significant change in microscopic morphology of LCM of biomass). Yield can be enhanced by addition of organic acids (and with SC CO_2 the addition of acids is lower)

FEEDSTOCK PRE-TREATMENT



Carvalheiro, F., Duarte, L.C., Gírio, F. M. (2008). *J. Scientific & Ind. Res.*, **67,** 849-864

- **There is no single method that can fulfill all the requirements for the effective biomass fractionation**
- **Future: increase in the study of combined/sequential processes targeting separately different fractions**
- **Milder processes targeting the separation and recovery of hemicellulose and high quality lignin may be advantageous**
- ***Novel processes* such as the ones based on ILs, can also be effective, as they may be able to convey the two goals in a single process**

FEEDSTOCK PRE-TREATMENT

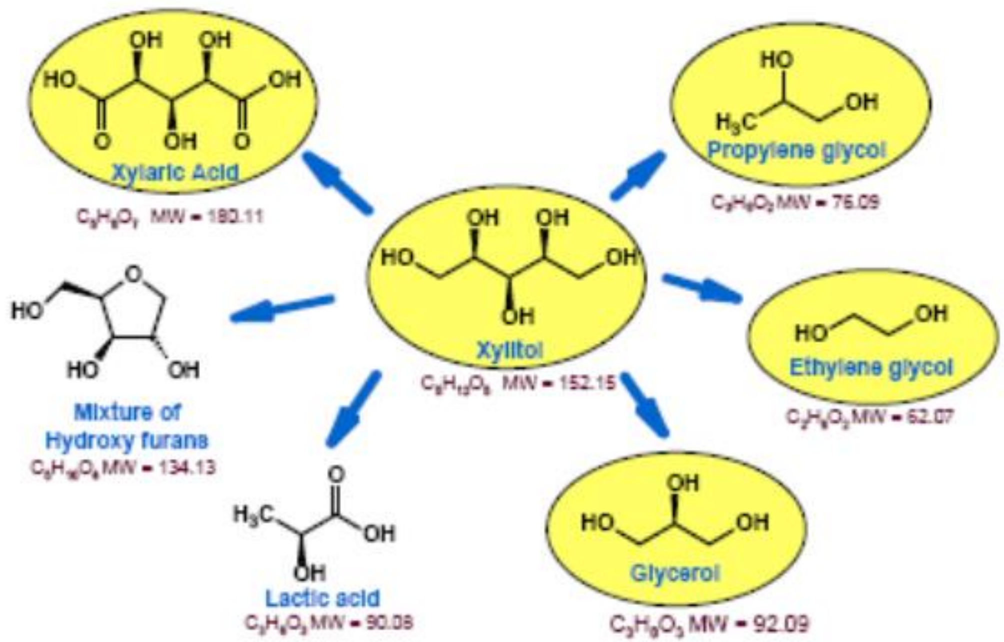
Desirable features	Concentrated acid	Dilute acid	Steam explosion	Autohydrolysis	Organosolv	Solid Superacids	Alkaline	Ionic liquids	Supercritical fluids
High hemicellulose solubilisation	++	++	++	++	+	+	+	++	+
High hemicellulosic monosaccharides production	++	++	0	-	-/0	+	-/0	0/+	-
Low hemicellulosic oligosaccharides production	+	+	0	-	-/0	+	-/0	0/+	-
High cellulose recovery	++	++	++	++	-	++	+	+	++
High cellulose digestibility	++	++	+	+	-	+	++	+	0/+
High lignin quality	-	-	0/+	+	+	-/0	-	+	+
High chemicals recycling	--	-	0	n.r.	--	+	-/0/+	+	n.r./+
Low inhibitors formation	-	-	0	0	+	0	+	-	0
Low corrosion problems	--	-	0	0	-	0	-	-/0	-/0
Low need for chemicals	--	-	0	++	--	0/+	-/0	+	++
Low neutralisation requirements	--	-	0	n.r.	+	-/0	-/0	0	n.r.
Low investment costs	+	+	-	+	0	0	0/+	+	-
Low operational costs	-	0	++	+	-	0	- / 0	-	-
Low energy use	0	-	0	0	0	+	+	++	+

Gírio FM, Fonseca C, Carvalheiro F, Duarte LC, Marques S & Bogel-Łukasik R (2010), "Hemicelluloses for fuel ethanol: a review", *Bioresource Technology* **101**.

LNEG

Top 12 sugar-derived value-added chemicals (“building blocks”) from biomass

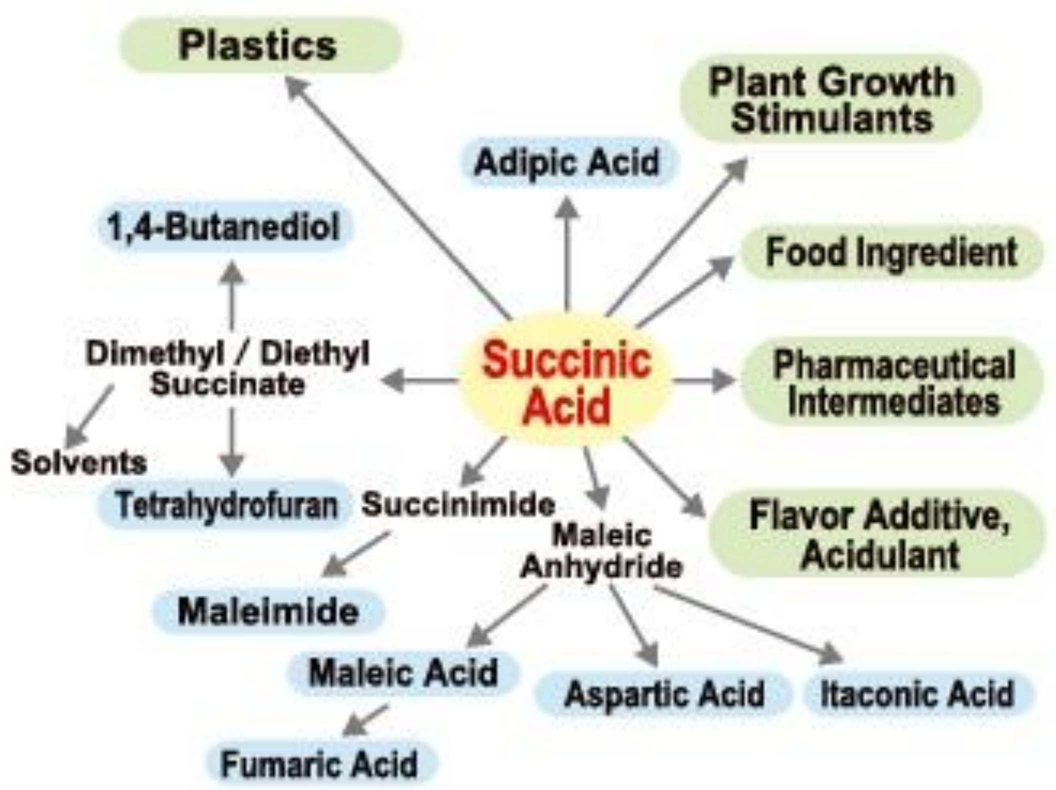
1,4 diacids: succinic, fumaric, malic (C4)
2,5 furan dicarboxylic acid (C6)
3- hydroxy propionic acid (C3)
Glucaric acid (C6)
Itaconic acid (C5)
Levulinic acid (C5)
3-hydroxybutyrolactone (C4)
Aspartic acid (C4)
Glutamic acid (C5)
Glycerol (C3)
Sorbitol (C6)
Xylitol/arabinitol (C5)



Chemistry to Derivatives of Xylitol and Arabinitol

T. Werpy & G. Petersen, “Top Value Added Chemicals From Biomass”, Volume I: *Results of Screening for Potential Candidates from Sugars and Synthesis Gas*, August 2004, USDOE.

Focus on optimization of the production of intermediates

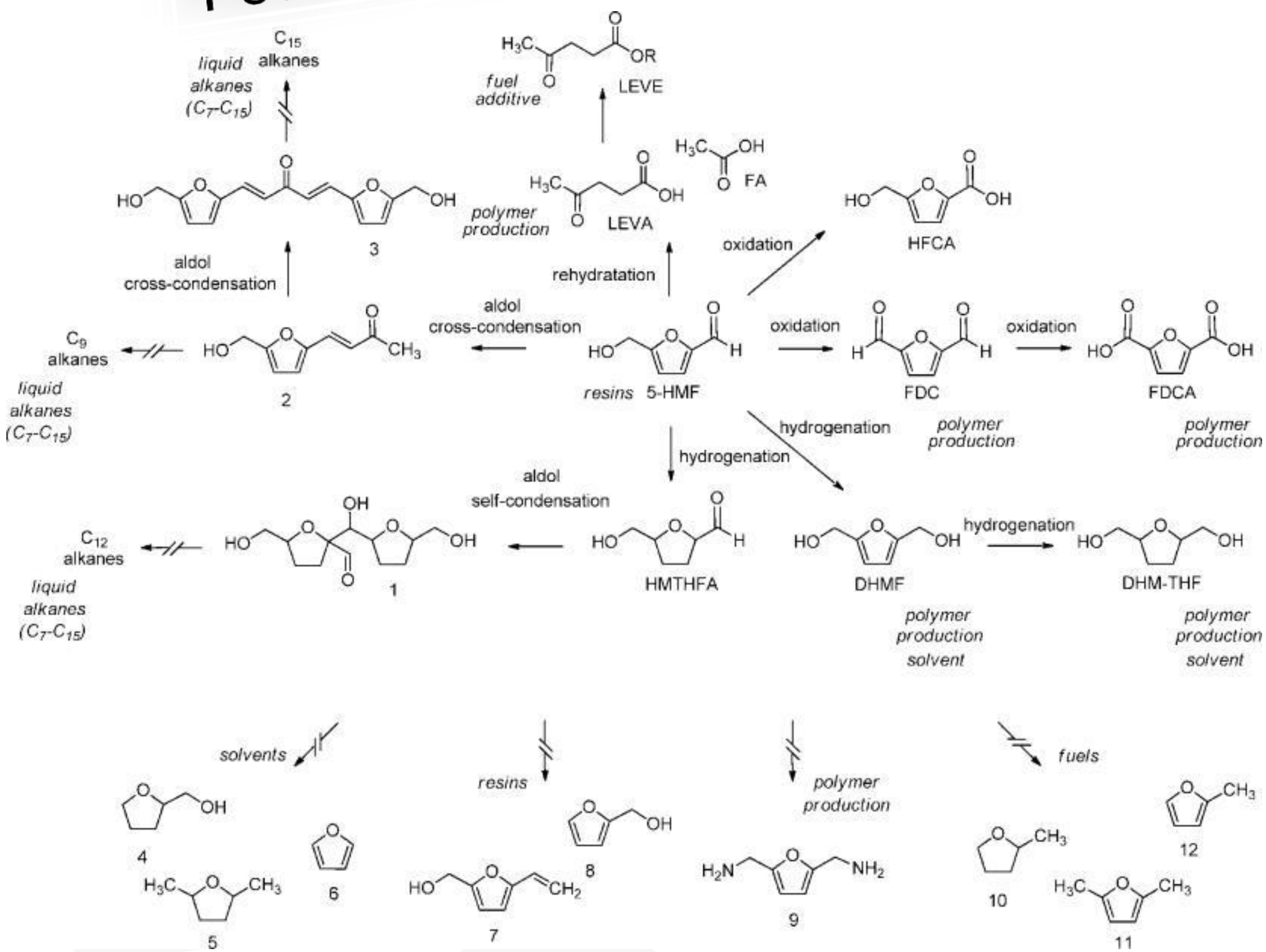


Succinic acid is being increasingly viewed as an Intermediate that could lead to various chemicals. Succinic acid is currently manufactured from petroleum through chemical synthesis; it is also possible to produce succinic acid from sugar derived from the hydrolysis of biomass.

Considered from the standpoint of raw material manufacture, it is strongly desired that an economical bioprocess of this type be developed and practically applied.

R&D WORK & INNOVATION

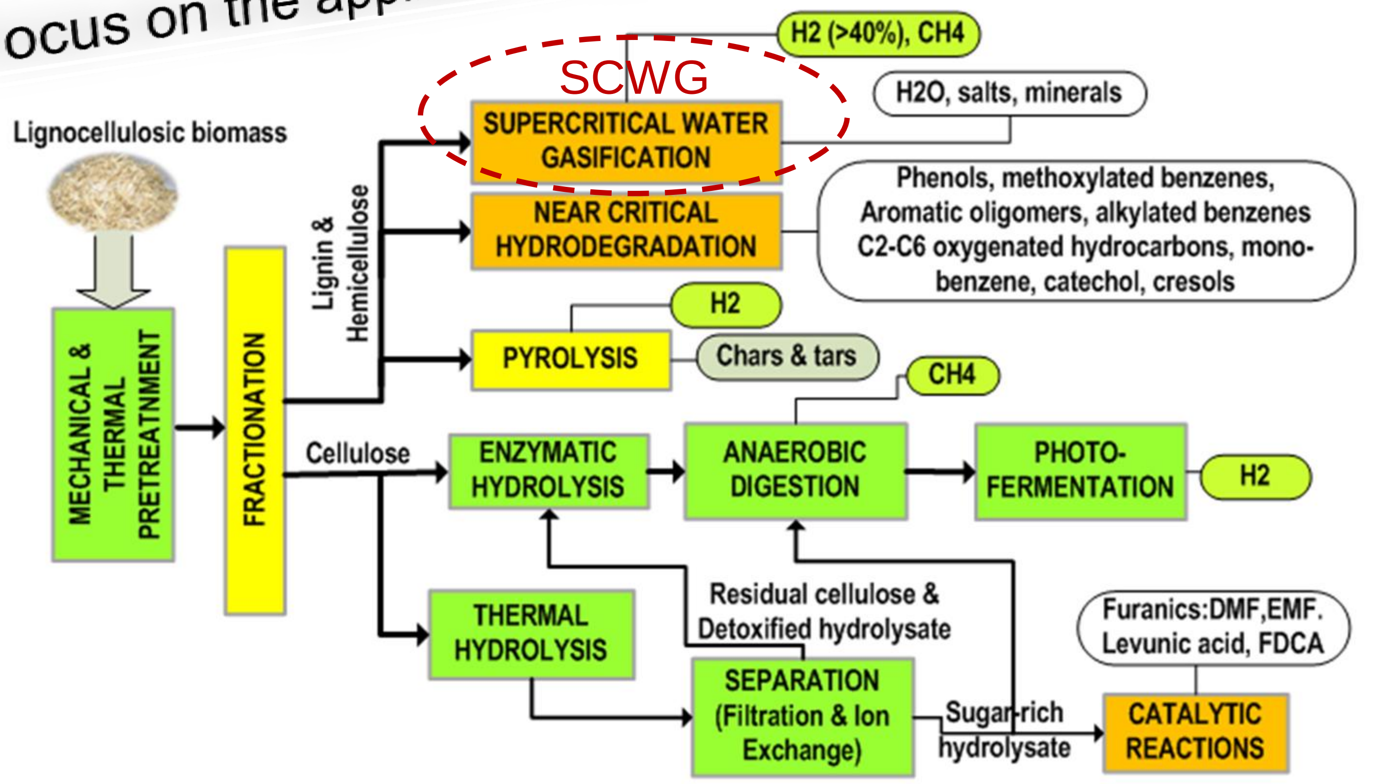
Focus on novel pre-treatment processes, e.g. Application of Ils to produce 5-HMF



M.E. Zakrzewska, E. Bogel-Lukasik & R. Bogel-Lukasic, “Ionic Liquid-mediated formation of 5- Hydroxylmethylfurfural-A promising Biomass-derived Building Block, *Chem Review,* 2011, **111**.

R&D WORK & INNOVATION

Focus on the application of supercritical conditions for liquid biomass conversion



- SCWG
  - Ideal for wet biomass saving much cost and energy associated with drying.
  - It eliminates the formation of chars and tars, due to <u>different reaction pathway compared to thermal gasification;</u> in favour of H_2-rich gas.
  - Reactions in SCW medium have the advantage of *zero* NO_x and dioxins emission (which characterise incineration reactions).

Bushra Al-Duri, "The Biorefinery Concept: on-Route to waste utilization & H2 Production", *University of Birmingham Reader; presentedin 9th International Conference on Fuel Cells and Hydrogen, March 2013, NEC Birmingham (UK).*

R&D WORK & INNOVATION

Focus on Lignin Studies

Focus on the production of single products with development of efficient separation technologies

Focus on the developmen of selective robust catalytic processes for lignin conversion

J.E. Holladay, J.J. Bozell, J.F. White & D. Johnson, “Top Value-added Chemicals from Biomass”, *Volume II: Results from screening fro Potential Candidates from Biorefinery Lignin*, PNNL-16983, October 2007, USDOE.

R&D WORK & INNOVATION

Focus on Thermochemical Processes - gasification/pyrolysis for Fuels diversification

Fluidised Bed Gasification Installation at LNEG

Main characteristics of the installation

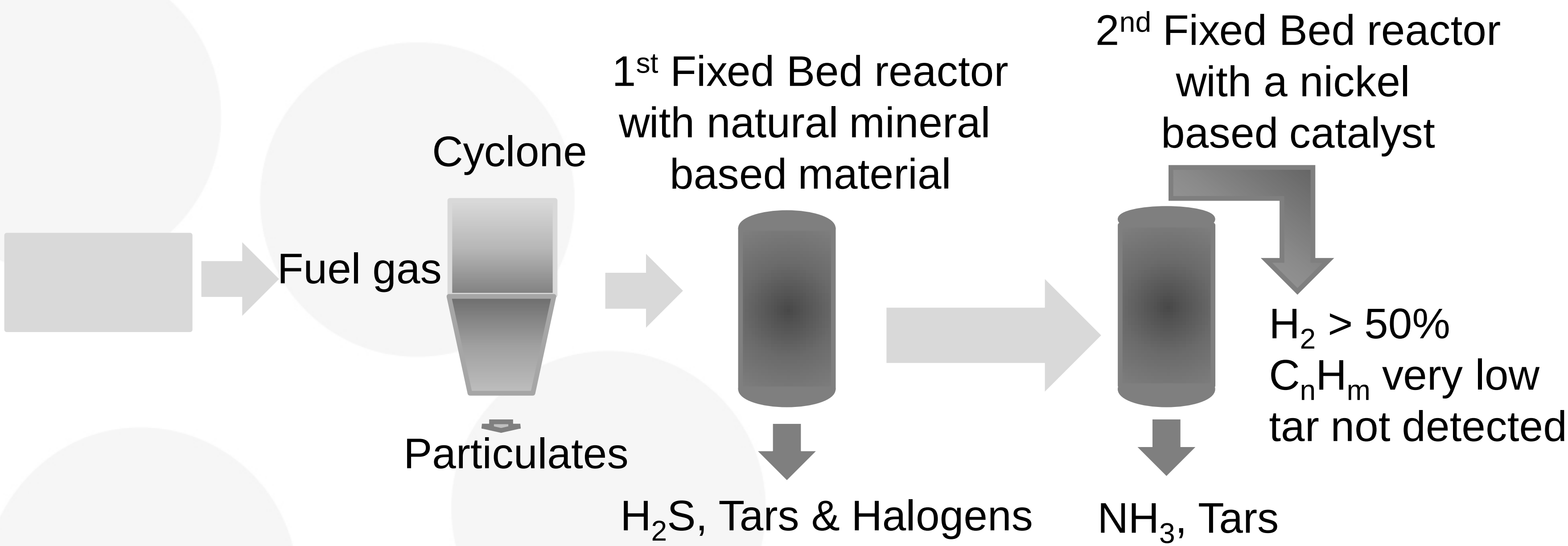
- FB gasifier
  with a square cross sectional area, each side being 0.2 m long and the height 3.7m
- Bed inert material
  sand
- Gasification medium
  air/steam; oxygen/steam
- Gasification Temperature
  800ºC – 900ºC
- Catalytic hot gas cleaning system

Feedstocks
Various types of biomass - lignocellulosic wastes, urban wastes, olive bagasse
Mixtures of coal and wastes

LNEG

R&D WORK & INNOVATION

Focus on Efficiency Optimization of Hot Gas Cleaning Technologies



F. Pinto, C. Franco, R. N. André, H. Lopes, I. Gulyurtlu, I. Cabrita, "Co-gasification of coal and wastes in a pilot-scale installation 1: Effect of catalysts in syngas treatment to achieve tar abatement", Fuel 88 (2009).

F. Pinto, R. Neto André, C. Franco, H. Lopes, C. Carolino, R. Costa, I. Gulyurtlu, "Co-gasification of coal and wastes in a pilot-scale installation. 2: Effect of catalysts in syngas treatment to achieve sulphur and nitrogen compounds abatement", Fuel 89 (2010).

INTERNATIONAL COOPERATION

International Cooperation and with other Implementing Agreements, namely the Bioenergy, aim at combining the knowledge of industrial technologies with energy efficiency, and the biomass conversion processes...

- Providing a global forum to exchange information, disseminate knowledge gained and lessons learned in an atmosphere that promotes interaction and collaboration
- Encouraging participants to engage in truly collaborative, value-adding research and development of activities and to promote demonstrations
- Focusing the research efforts by regularly updating a prioritized list of research needs and knowledge gaps
- Involving industry and communicating progress apart from industry, government representatives and other appropriate people

INTERNATIONAL COOPERATION

ANNEX XI of the IEA Implementing Agreement

INDUSTRY Based BIOREFINERIES
Annex Leader
Isabel Cabrita

FOCUS AREAS

AREA I
Bioenergy
Biofuels
Area Leader: Isabel Cabrita
LNEG

AREA II
Biochemicals
New Fibre Materials
Area Leader: Alexandre Gaspar
RAIZ

AREA III
Sustainability
Integrated Systems
Area Leader: Henrique Matos
IST/UTL

ANNEX XI
Active Participating countries

- Sweden
- Belgium
- Portugal

Participating Entities

- Belgium
  - VITO (Project ALGAECASCAD)
  - WETLANDS (Project Bugworkers)
- Portugal
  - GNIP (Portuguese Group for Process Integration, more directly IST, LNEG and RAIZ)

    (Task management/Projects Bugworkers, ALGAECASCAD, PI in gasification based biorefineries and Sustainability mehodologies)
  - University of Coimbra (Project on Sustainability methodologies)
  - BIOTREND (Bugworkers)
- Sweden
  - Chalmers University (project PI og gasification based biorefineries)

Technologies

- Biomass gasification, including waste and black liquor gasification
- Pyrolysis
- Biogas production and integration
- Biological conversion
- Combustion
- Gas clean-up processes, including CCS techniques (e.g. using microalgae for CO_2 fixation producing hydrocarbons and/or hydrogen)
- Fuels and chemicals synthesis

Programme of Work of Annex XI

- Evaluation of technological and economical options focusing on industry integrated biorefineries
- R&D projects on technology specific areas
- Biorefinery concept with the integration of the capture of CO_2 for enhancing the growth of microalgae and/or other biomass species through process integration
- Sustainability and life cycle analysis

ANNEX XI of the IEA Implementing Agreement

Ongoing Projects

Project XI/1- BUGWORKERS - New tailor-made PHB-based nano-composites for high performance applications produced from environmentally friendly production routes

ProjectXI/2 - ALGAECASCAD - The biorefinery of Algae

ProjectXI/4 - Integrated Biofuel Production Processes Based on Systematic Optimization Methodologies

ProjectXI/5- Process Integration of Gasification-based Biorefineries

VISION OF THE FUTURE

BIOENERGY A competitive sustainable component of the World Economy

- International cooperation should be strengthened by governments
  - complementarities in targeted actions
  - information management and exchange

- Governments should consider priorities and roadmaps built upon targeted technology or on a mix of technologies
  - integrated multi-disciplinary teams, both of national expertise and foreign identified groups with relevant knowledge on specific needed competences
  - technology transfer
  - incentives for adoption of new technologies

- R&D budgets need to consider a multi-year scheme, with concrete targets

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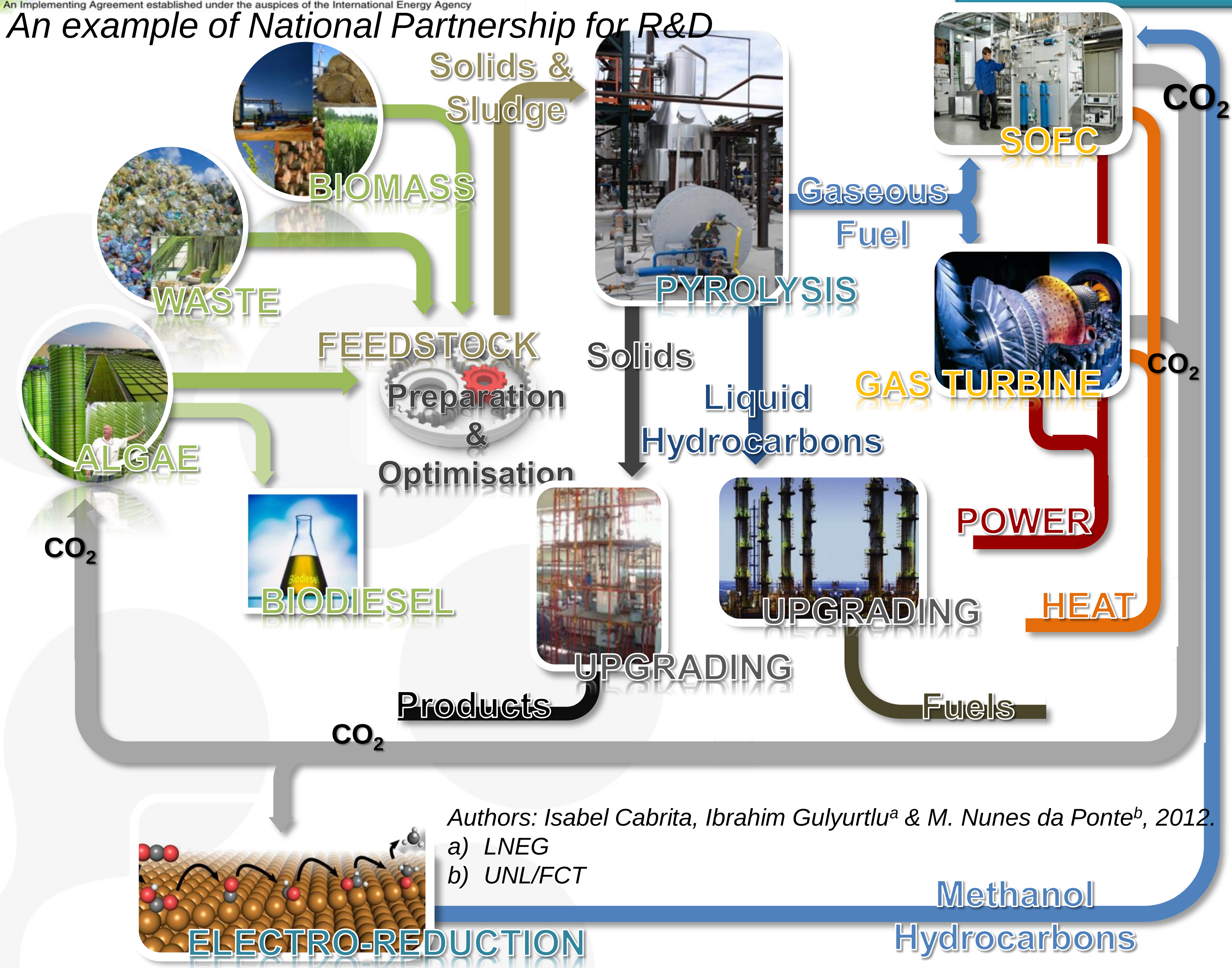
Industry-based Biorefineries

VISION OF THE FUTURE

An example of National Partnership for R&D



Authors: Isabel Cabrita, Ibrahim Gulyurtlu[a] & M. Nunes da Ponte[b], 2012.
a) LNEG
b) UNL/FCT

LNEG

VISION OF THE FUTURE

IEA Bioenergy

Joint Workshop

System and Integration Aspects of Biomass-based Gasification

Discussion on future projects and international collaboration

- System integration and optimization aspects of pre-treatment, gasification, downstream treatment and end product processing for different technology concepts and products,
- Integration of biomass gasification systems with process industries, district heating systems, industrial clusters, etc.
- Methodologies for assessing technical and economic performance (incl. selection of data) of industrial gasification technologies and systems for different future scenarios regarding energy costs and policy instruments,
- Methodologies for assessing the green house and sustainability impact of products and systems (incl. the generation and selection of data), and
- Case studies

Thank you for your attention

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MINISTÉRIO DA ECONOMIA E DO EMPREGO