Overview of biorefineries and current status

Tomorrow's biorefineries in Europe

Brussels , 11-12 February, 2014

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Agenda

- **IEA Bioenergy Task 42 on Biorefineries**
- Value added products from Biorefineries with emphasis on bulk chemicals
- Drop-in versus novel functionality
- Examples of European Biorefineries
- Conclusions

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Task 42 Biorefineries

Goal: To contribute to the development and implementation of sustainable biorefineries – as part of highly efficient, zero waste value chains – synergistically producing bio-based Food and Non-food

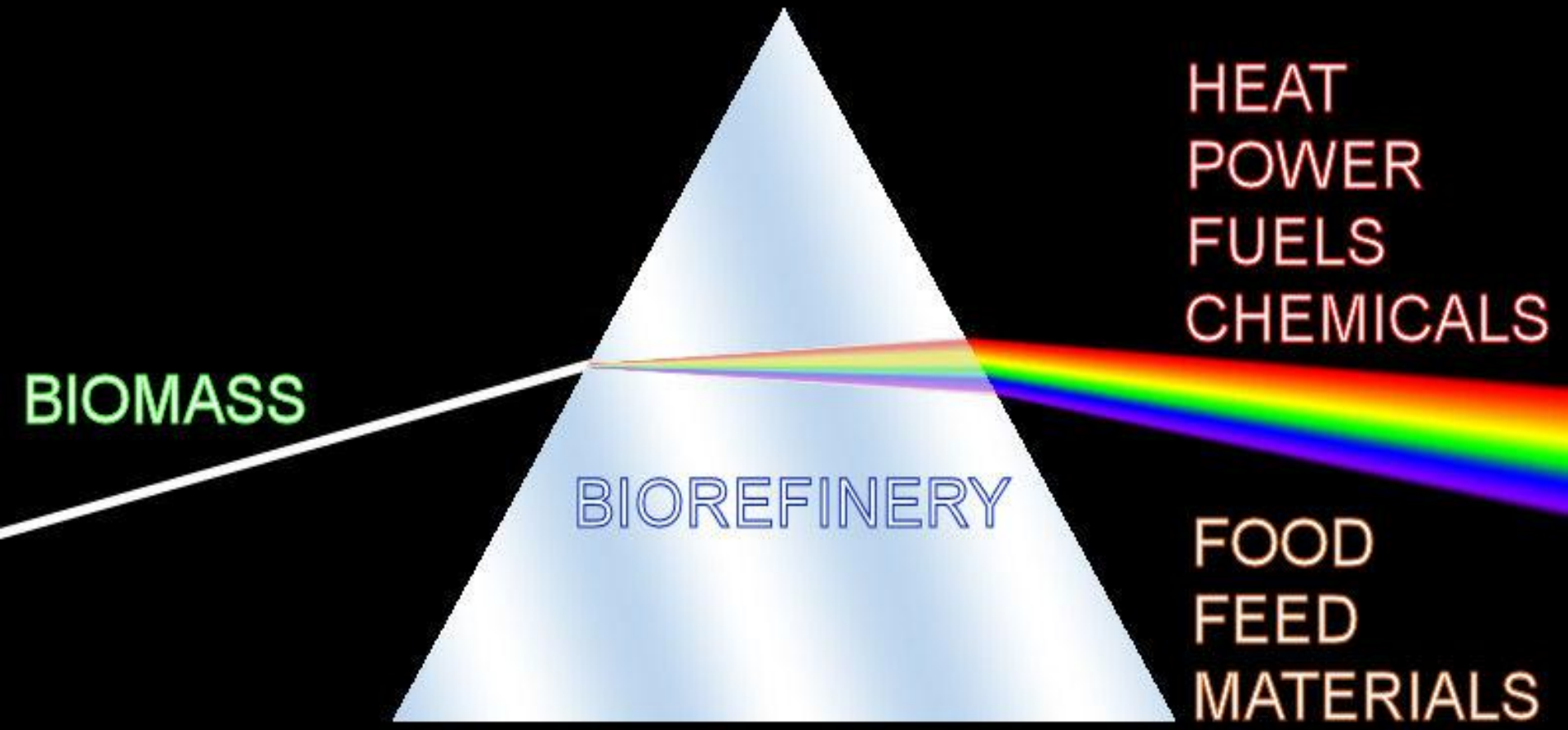
Products as base for a global BioEconomy.

- Led by Dr. Rene van Ree (Wageningen, NL)
- 11 Member countries

- Complement the other IEA Bioenergy Tasks
- Larger systems versus specific technologies
- Non-energy products: other bioproducts that make the biorefinery concept financially viable; co-existence with food

- http://www.iea-bioenergy.task42-biorefineries.com/en/ieabiorefinery.htm

Biorefining is the sustainable processing of biomass into a spectrum of marketable Bio-based Products and Bioenergy



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Task 42 Biorefineries

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Task 42 Biorefining

Energy (fuel) vs. Product (chemicals, materials) driven Biorefineries

- Energy (fuel) driven BRs

\+ Infrastructure (value chains) exists (power plants, digestion plants, biofuel plants)

\- Profitability questionable (often financial governmental support necessary and/or regulated market)

Upgrading of existing plants / value chains to multi-product BRs to improve full value chain sustainability

- Product (food/feed ingredients, chemicals, materials) driven BRs

\- Only limited new BBPs facilities in operation yet

\- Chain composing key technologies often still at R&D-phase

\+ High potential (interested stakeholders, advanced properties)

Deploying new high efficient sustainable biorefinery-based value chains co-producing BBPs & BE

Bioenergy will be the lubricating oil in a future circular BioEconomy

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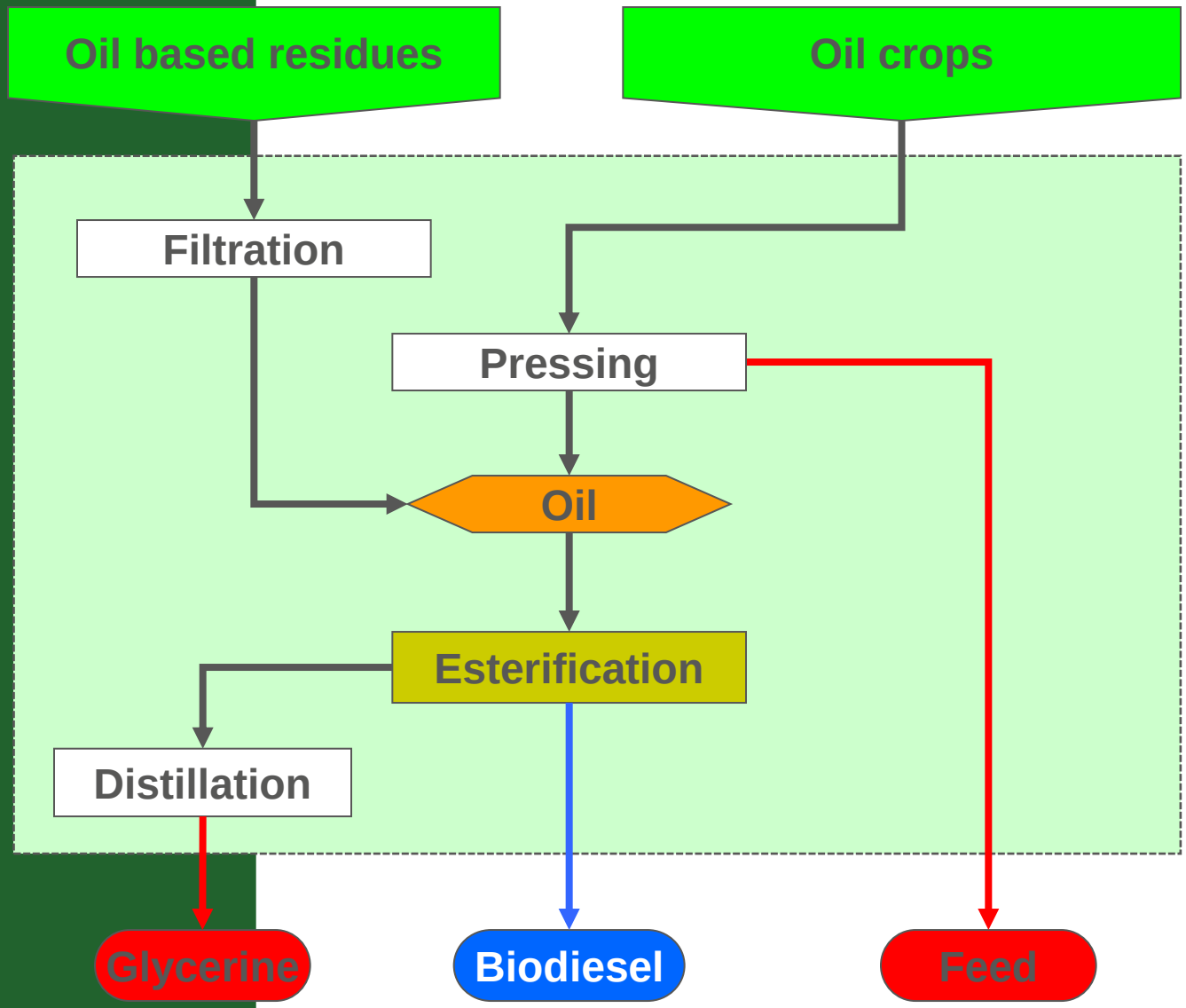
How to classify biorefineries?



Feedstocks

Platforms

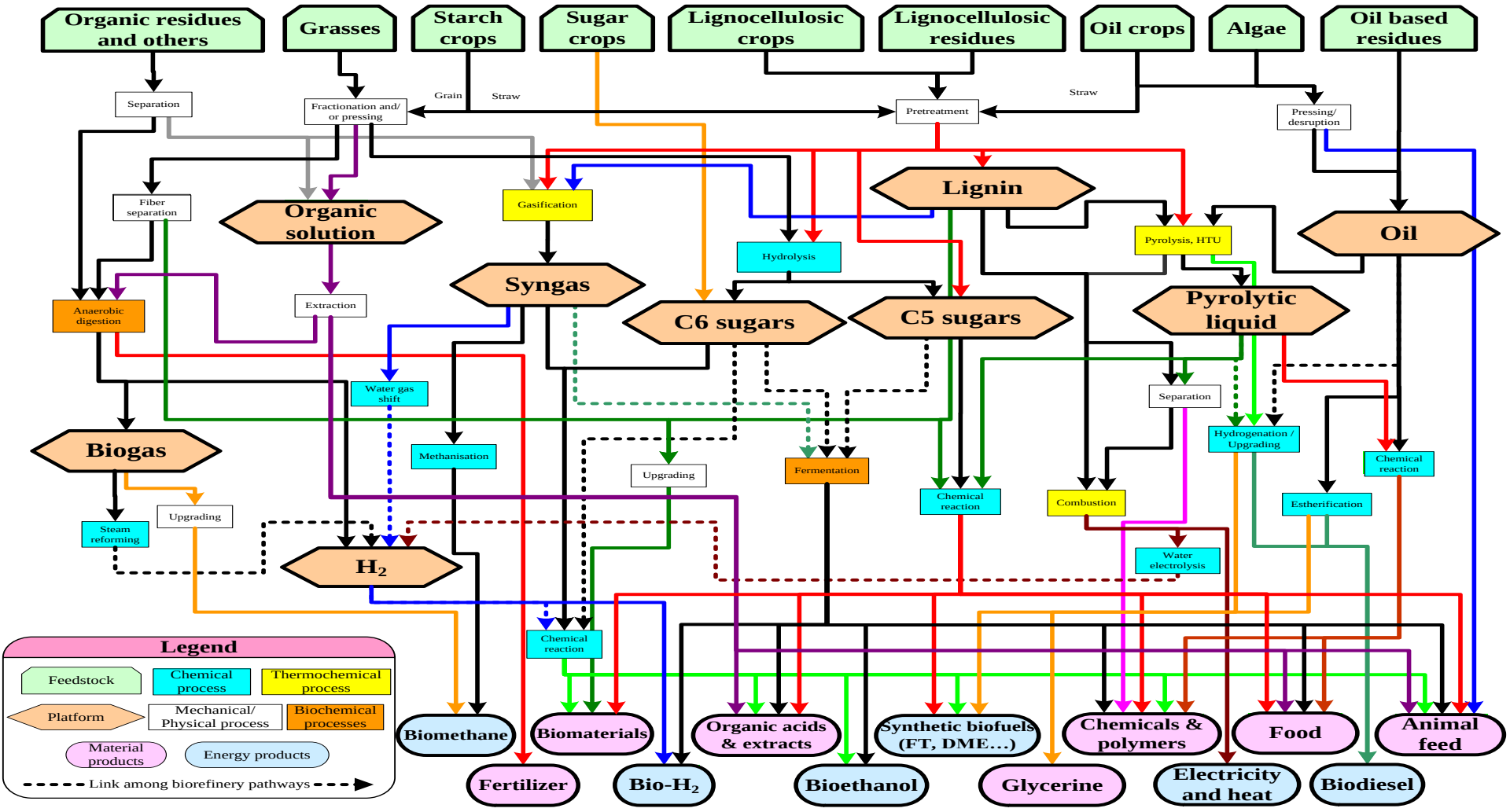
Processes

Products

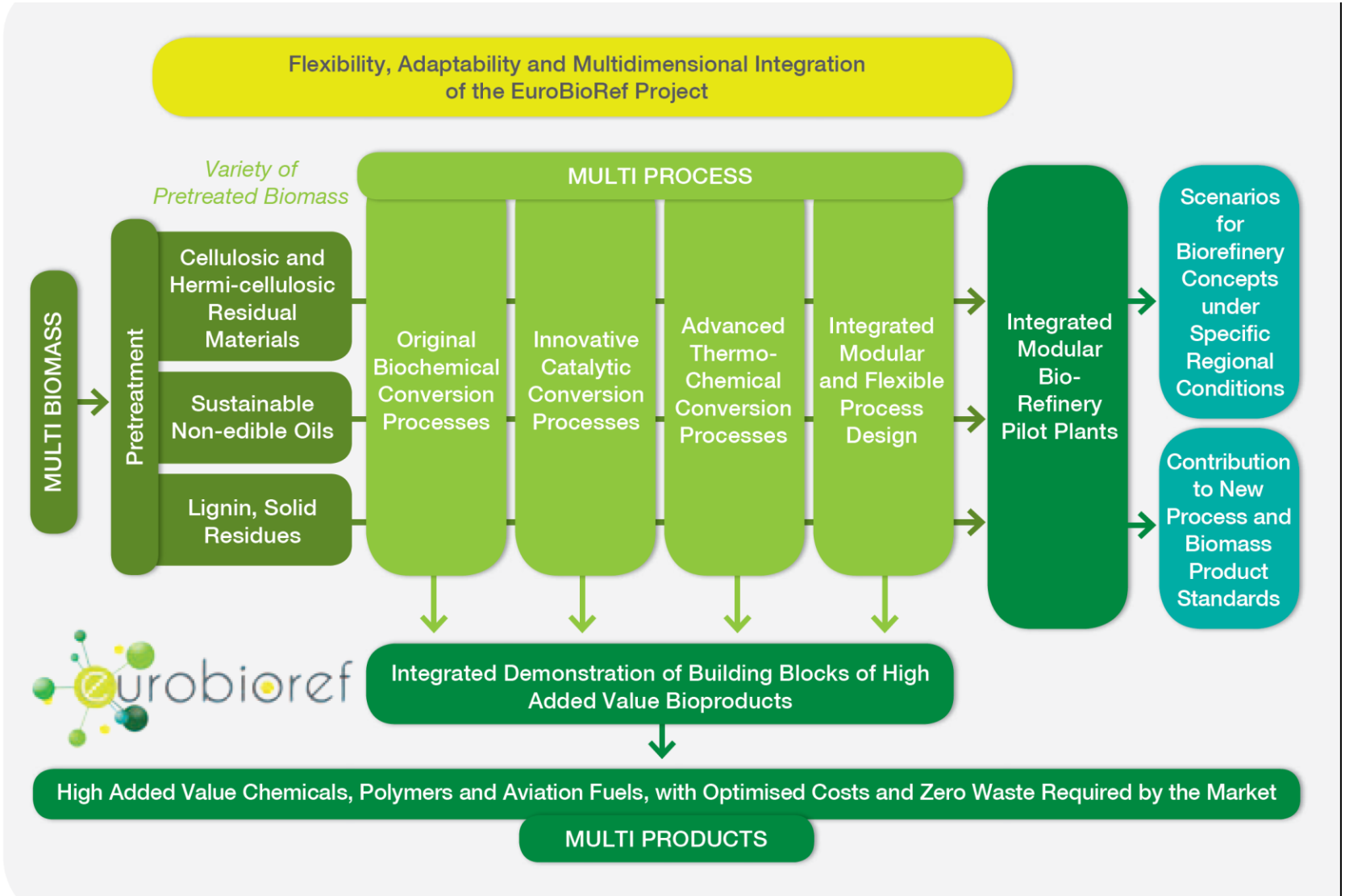
Cherubini et al. (2009). Toward a common classification approach for biorefinery systems.

Biofuels, Bioproducts & Biorefineries 3(5):534-546.

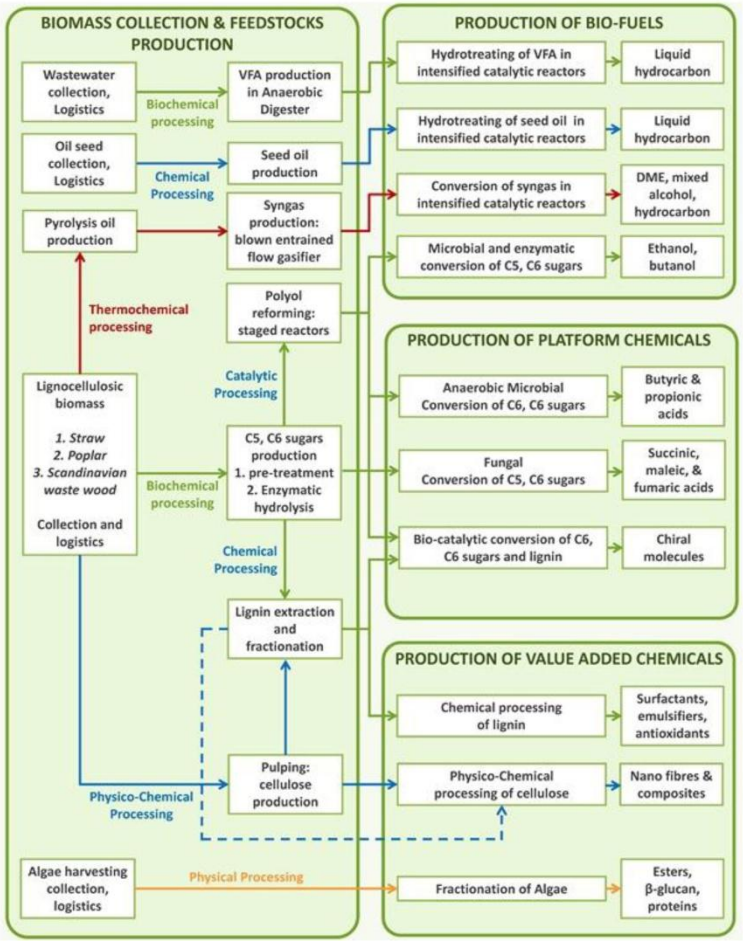
Classification system developed by IEA Bioenergy Task 42



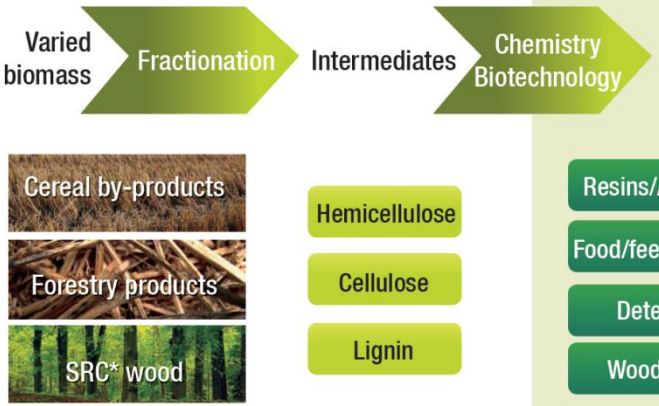
Lay-out of EuroBioref Project



Structure of the SupraBio, BioCore



The BIOCORE project aimed to use biomass to produce a range of products including bioethanol, several bulk and specialty chemicals and feed ingredients.



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Why value added products

- To improve the economics of bioenergy production
- To make scaling up easier (makes plant already commercial viable at smaller scales)
- Unique functionality
- Medium term CO_2 storage (depending on chemical)
- Reduction of NREU usage (both because of renewable product and less fossil fuel used in production)

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Current Market Size

Fossil based Chemicals:

330 million tonnes

Main molecules:

methanol, ethylene, propylene, butadiene, benzene, toluene and xylene

Biobased Chemicals & Materials

50 million tonnes

Main molecules:

Non-food starch, cellulose fibres/derivatives, tall oils, fatty acids and fermentation products

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Pull or Push ?

- Governmental – Legislative push
  - Sustainability
  - GHG/NREU usage
- Technological push
  - Biochemical / Chemical
  - Concepts versus applicability
- Market pull
  - Brand owners

What does the market think about this?

"We are working to completely eliminate the use of nonrenewable fossil fuels in our plastic bottles while maintaining quality and recyclability"

"Reducing the environmental impact of packaging: we will be developing partnerships with 2nd and 3rd generation bioplastics manufacturers"

"Using 100% renewable or recycled materials for all products and packaging"

"Reduce the carbon footprint of our operations"

"Halve the greenhouse gas impact of our products across the lifecycle by 2020"

"Leading in the development and use of packaging materials made from sustainably managed renewable resources such as bioplastics"

"Green. That's how we'd like the world to be. As an environmental leader, we do more than meet industry standards – we seek to raise them"

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Platforms

Syngas Platform
Biogas Platform
C6 sugar platform*
C6/C5 sugar platform
Plant-based Oil Platform*
Algae Oil Platform
Organic Solutions Platform
Lignin Platform
Pyrolysis Oil Platform

* Currently the dominant platforms for biobased chemicals

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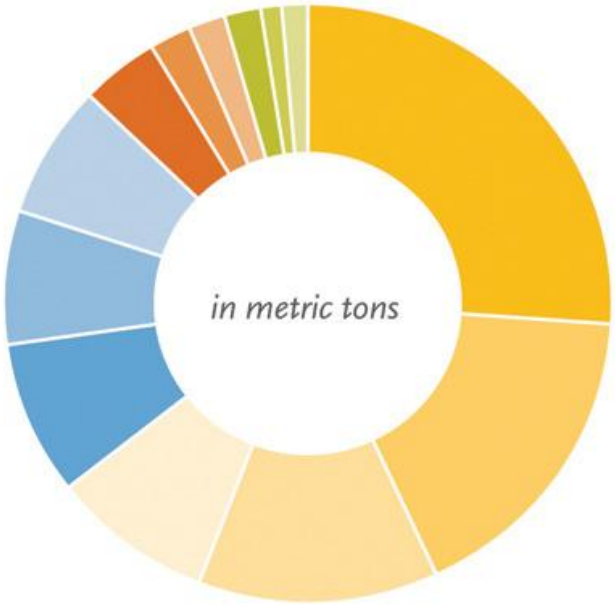
Biopolymer production capacity

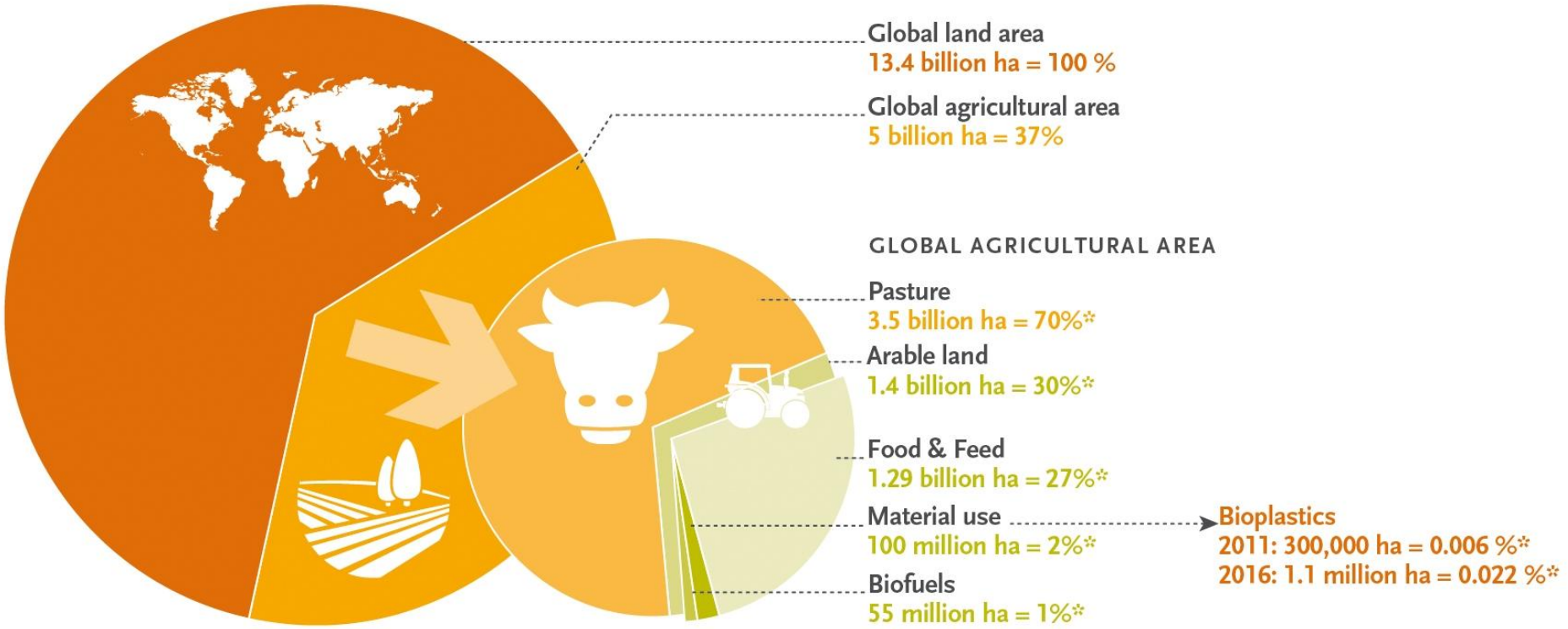
Biopolymers production capacity 2015 (by type)



Bio-PE	450.000	26 %
Bio-PET	290.000	17 %
PLA	216.000	13 %
PHA	147.100	9 %
Biodegradable Polyesters	143.500	8 %
Biodegradable Starch Blends	124.800	7 %
Bio-PVC	120.000	7 %
Bio-PA	75.000	5 %
Regenerated Cellulose[1]	36.000	2 %
PLA-Blends	35.000	2 %
Bio-PP	30.000	2 %
Bio-PC	20.000	1 %
Others	22.300	1 %
Total	**1.709.700**	100 %

Plastics Europe anticipated biopolymer production capacity (tonnes) by 2015

Global Land Use for Bioplastics (2011& 2016)



Source: European Bioplastics | Institute for Bioplastics and Biocomposites (October 2012) / FAO

** In relation to global agricultural area.*

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Biobased Chemicals Table

- Gives an overview of the biobased chemicals status in two categories
  - High growth potential
  - In the pipeline (Demonstration or pilot facility running)
- Organized from C1 (methanol, formic acid etc) to Cn (all molecules with more than 6 C atoms)
- Exhaustive list but certainly not complete
- Field is very dynamic at the moment so probably already some new changes / additions needed

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Biobased Chemicals

Cn	Products with strong growth potential		Bio-Based Chemicals in the pipeline	
	Chemical	Company	Chemical	Company
1	Methanol	BioMCN, Chemrec	Formic acid	Maine BioProducts
	Methane Syn gas	Many BioMCN, Chemrec		
2	Ethylene	Braskem, DOW/Mitsui, Songyuan Ji'an Biochemical	Ethyl acetate	Zeachem
	Ethanol	Many	Glycolic acid	Metabolix Explorer
	Ethyleneglycol	India Glycols Ltd, Greencol Taiwan	Acetic acid	Wacker
3	Lactic acid	Purac, NatureWorks, Galactic, Henan Jindan, BBCA	Acrylic acid	Cargill, Perstorp, OPXBio, DOW
	Glycerol	Many	Propylene	Braskem
	Epichlorohydrin	Solvay, DOW	3-Hydroxypropionic acid	Cargill
	1,3-Propanediol	DuPont/Tate&Lyle	n-Propanol	Braskem
	Ethyl lactate	Vertec BioSolvents	Isopropanol	Genomatica
	Propylene Glycol (1,2-Propanediol)	ADM		

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Biobased Chemicals

Cn	Products with strong growth potential		Bio-Based Chemicals in the pipeline	
	Chemical	Company	Chemical	Company
4	n-Butanol	Cathay Industrial Biotech, Cobalt/Rhodia	1,4-Butanediol	Genomatica/M&G
	iso-Butanol	Butamax, Gevo	Methyl methacrylate	Lucite
	Succinic acid	BioAmber, DSM/Roquette, Myriant, BASF/Purac		
5	Furfural	Many	Itaconic acid	a.o. Qingdao Kehai Biochemistry Co, Itaconix
	Xylitol	a.o. Danisco/Lenzing, Xylitol Canada	Isoprene/Farnesene	Goodyear/ Genencor, GlycosBio, Amyris
	Glutamic acid	a.o. Global Biotech, Meihua, Fufeng, Juhua	Levulinic acid	Maine BioProducts, Avantium, Segetis, Circa Group

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Biobased Chemicals

Cn	Products with strong growth potential		Bio-Based Chemicals in the pipeline	
	Chemical	Company	Chemical	Company
6	Sorbitol	a.o. Roquette, ADM	Adipic acid	Verdezyne, Rennovia, BioAmber, Genomatica
	Lysine	a.o. Global Biotech, Evonik/RusBiotech, BBCA, Draths, Ajinomoto	FDCA	Avantium, Corbion
	Isosorbide	Roquette	Glucaric acid	Rivertop renewables
	Citric acid	a.o. Cargill, DSM, BBCA, Ensign, TTCA, RZBC	Caprolactam	DSM
n	PHA	Telles, Meridian plastics (103)	*Para*-Xylene	Gevo, Draths*, UOP, Annellotech, Virent
	Dicarboxylic acids	Cathay Biotech, Evonik		
	Fatty Acid derivatives	Croda, Elevance		

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Product Commercialization

Key criteria

Market assessment

Market fundamentals (local, regional, global)
Feedstock availability and price
Product profitability
Competitive nature of market
Need for partnerships
Downstream development opportunities

Technology assessment

Commercial experience
Necessary capital investment
Process complexity
Access to technology
Environmental considerations

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Drop-in versus New Functionality

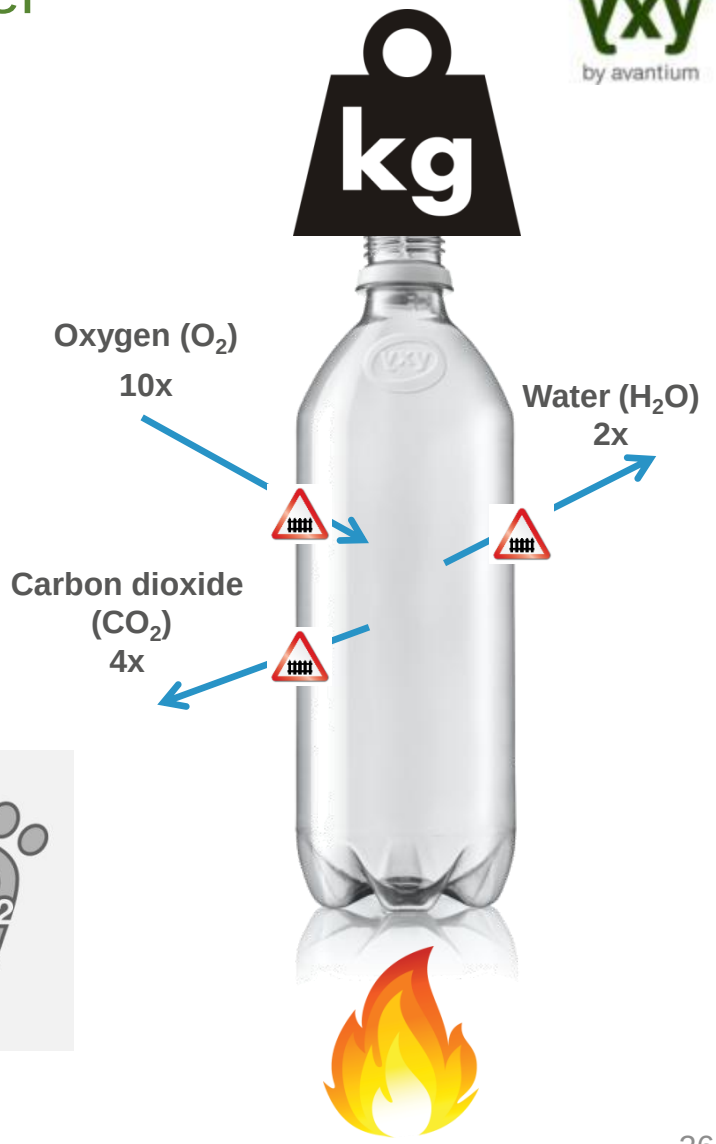
Bio-based chemicals	Reference petrochemicals
Ethyl lactate	Ethyl acetate
Ethylene	Ethylene
Adipic acid	Adipic acid
Acetic acid	Acetic acid
n-Butanol	n-Butanol
PTT	PTT & Nylon 6
PHA	HDPE
PLA	PET and PS
FDCA	Terephthalic acid
Succinic acid	Maleic anhydride

Drop-in versus Unique functionality

	Drop-in	Unique molecule
Market acceptance	↑↑	↓↓
Speed of introduction	↑↑	↓↓
Fit with existing infrastructure	↑↑ ↔	↔ ↓
Oil/Feedstock price sensitivity	↑↑↑	↑
Sustainability	↑ ↔ ↓	↑↑↑ ↔
Unique market space	↓↓↓↓	↑↑↑↑
Scalability	↑↑↑	↑ ↔ ↓
Legislation (e.a. REACH)	↑↑↑	↑↑↑↓↓↓

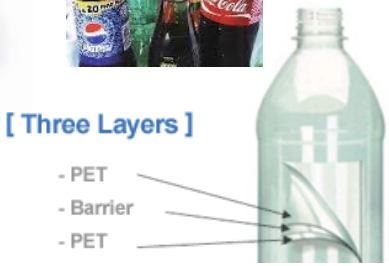
Example of novel functionality building block: PEF: the Next Generation Polyester

- Superior performance over PET:
  - O_2 barrier: 10x improvement
  - H_2O barrier: 2x improvement
  - CO_2 barrier: 4x improvement
- Improved Thermal Stability
  - Tg: ~88 C → 12 C higher than PET
- Excellent Mechanical Properties:
  - Tensile Modulus PEF : 1.6* PET
- Significant reduction in carbon footprint
  - 70% lower carbon emission
  - 65% lower NREU



Superior PEF Performance enables Penetration of Existing and New Markets

Simplification of existing packages



Existing markets penetration

Potential growth markets

New markets penetration

The Market Opportunity

PEF

- bottles — 18 mio ton per year
- fiber — 42 mio ton per year
- film — 5 mio ton per year

ALPLA

wifag//polytype
brilliance on top

Bottle Partners – Addressing all market segments

ALPLA

- Leading converter
- PEF bottles for: food, home care/ personal care, alcoholic beverages

The Coca-Cola Company

- #1 CSD company
- 1.8B servings per day
- PlantBottle™ in 2010

DANONE

(xy avantium

- #1 Water company in Europe
- Bouteille Végétale

- Creating a market pull
- De-risk supply chain for upstream partners: feedstock suppliers, resin companies, etc.

Safety

- Food Contact Safety studies being finalized:
  - All results up to today are good
  - All indications the polymer and monomer are safe
  - EFSA registration (2013) and FDA (2014)

- Safety studies FDCA monomer to support REACH registration:
  - Monomer is demonstrated to be safe
  - REACH registration to be completed 2013

Recycling

- Goal: find the optimal end-of-life solution for PEF polymer
  - Close collaboration with recycling community
- End goal: PEF to PEF recycling :
  - Mechanical recycling: demonstrated (similar to PET)
  - Chemical recycling: demonstrated PEF depolymerization to monomers
- Conducting sorting trials at waste separation & recycling sites
  - Sorting out PEF from PET for food grade bottles
- Transition period: PEF in PET recycle streams:
  - Conducting trials of potential effects of PEF in rPET streams and PET in rPEF streams

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Current status of Biorefineries in Europe (Examples)

- Expanding Agri-Food complexes
  - Borregaard
  - Roquette
- Adding value to biofuels plants
  - Abengoa
  - BTG
- 2nd generation pilot & demonstration plants
  - Biochemtex
  - Inbicon
  - CIMV
- Biobased chemicals
  - Avantium chemicals
  - Reverdia (DSM/Roquette)

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Task 42 Biorefining

Conclusions on Biorefining

- Biorefining (biocascading) co-producing food/feed, bio-based products & bioenergy is the way to go for large-scale sustainable use of biomass in a future BioEconomy
- Bioenergy will be the necessary lubricating oil (closing energy and mineral loops) within a future BioEconomy
- We need a clear international level-playing-field for optimal large-scale sustainable biomass production and valorisation (no subsidies for energy or regulations for fuels; or the same for all types of “bio-outlets”)
- Biorefining is not new, it is already used for some time in for example the food and paper sectors; now also in other market sectors commercial, demo and pilot facilities can be found

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Task 42 Biorefining

Conclusions on Biorefining

- Development and demonstration of chain composing technologies (separation, DSP) is still necessary to further increase the overall the efficiency and lower the costs of BRs
- Also some non-technical critical success factors need to be solved and encouraging policies have to developed for large-scale biomass implementation, incl. Biorefining
- Create Market-Pull
- Please use the international knowledge, technologies and available infrastructures available for short-term implementation to start off with the development of an efficient BioEconomy asap
- Biorefining needs a multi-stakeholder approach not only covering the full chain but also involving multiple markets; so please co-operate and talk to each other

Looking forward to hear the results of 3 exciting projects!!

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