Biorefineries in Europe – Status quo and future perspectives



SMIBIO Workshop
Small-scale Biorefineries for Rural Development in Latin America and Europe

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Content

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- Biorefineries – concept and classification
- Commercial biorefineries in Europe
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WIP – Renewable Energies

…**founded in 1968** (48 years) to support infrastructure projects

…interdisciplinary private institute for the development and promotion of **renewable energy projects**

…**bridges the gap** between research and implementation of renewable energy systems

- Ranging between 15 and 20 employees
- More than 20 on-going (renewable energy) projects
- Overall portfolio: >300 international, multi-disciplinary projects
- WIP was ranked among the 25 most successful SMEs in FP7

Main Activity Fields – examples 2007 to 2016

Bioenergy

S2Biom · CORE-JetFuel · bioREFINE-2G · BioGRID · BioSTEP · BIO LYFE · Global-Bio-Fuel · Sweet Fuel · NEMO for bioethanol · BioTop Biofuels RTD-cooperation · COMPETE · URBAN BIOGAS www.urbanbiogas.eu · Solid Standards · SMIBIO · BIOREFLY · SRC+ www.srcplus.eu · BioTrade2020+ www.BioTrade2020plus.eu · sucellog · BIOGASHEAT · BIOGASIN · BABET REALS

Wind

7MW

RE Grid Integration

IndustRE · stoRE · Smart Build · ORPHEUS · GridTECH.EU

PV

PhotoVoltaic TECHNOLOGY PLATFORM · PVPARITY · PV employment · PV Enlargement · CROWDFUNDRES · SUNRISE · installRES www.resinstaller.eu

Energy and Water Nexus

RED HEAT TO POWER · REAPower · PRODES · Mediras

Development

bioregions.eu · AfriCAN climate · COMMUNITY POWER

Main Project Types – examples 2007 to 2016

Research

S2Biom, CORE-JetFuel, bioREFINE-2G, BioGRID, BioSTEP, HYDRO ACTION, Global-Bio-Tech, Sweet Fuel, NEMO for bioethanol, BioTop Biofuels RTD-cooperation, REAPower, RED HEAT TO POWER, ORPHEUS, SMIBIO, BABET REAL5

Market Development

CROWDFUNDRES, SRC+ www.srcplus.eu, BioTrade2020+ www.BioTrade2020plus.eu, sucellog, BIOGASHEAT, PhotoVoltaic TECHNOLOGY PLATFORM, stoRE, IndustRE, PVPARITY, COMMUNITY POWER, URBAN BIOGAS www.urbanbiogas.eu, SolidStandards, BIOGASIN, bioregions.eu, PRODES, GridTECH.EU

Demonstration

PV Enlargement, 7MW

Mediras, Qdrive, BIOLYFE, BIOREFLY, Smart Build

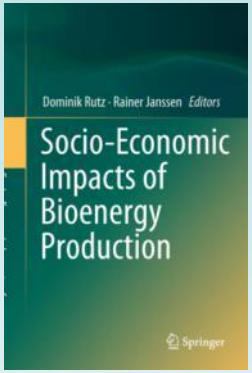
Social, economic & educational/training

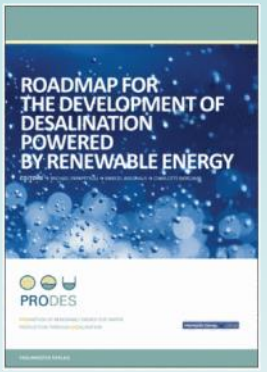
instalRES www.resinstaller.eu, SUNRISE, PV employment

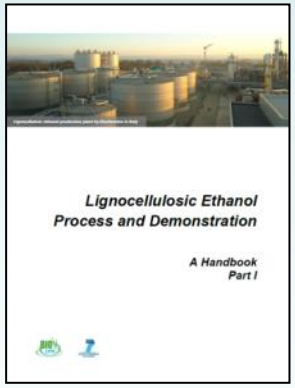
International Cooperation

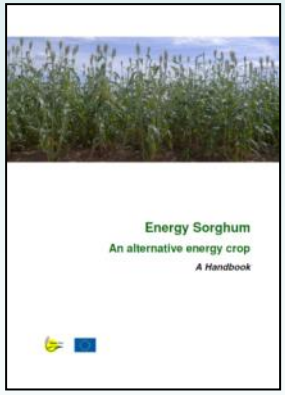
COMPETE, AfriCAN climate

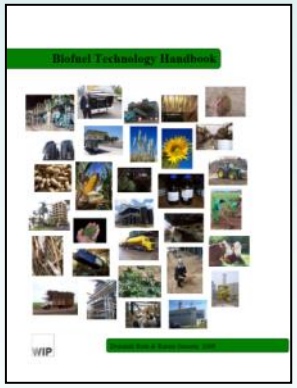
Books, Handbooks, Publications, Videos, Websites

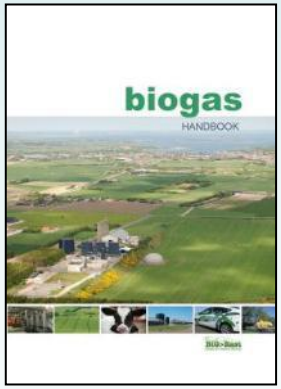


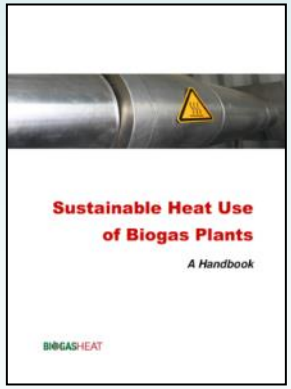




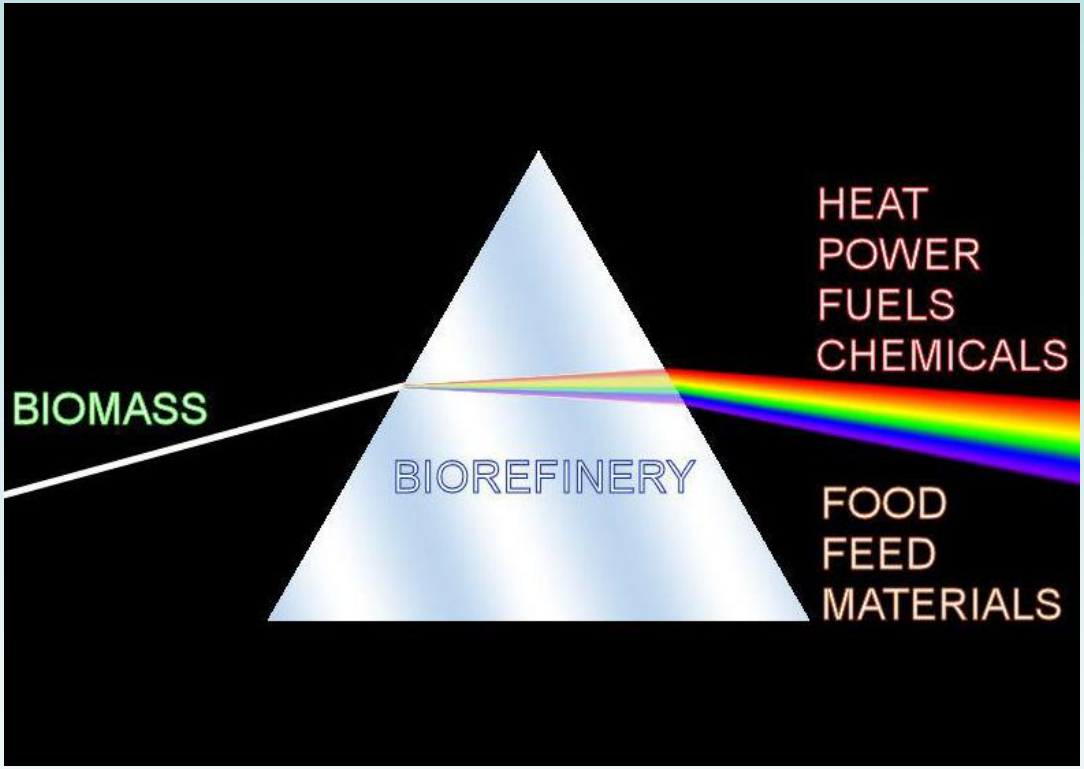








Biorefineries – concept and classification



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

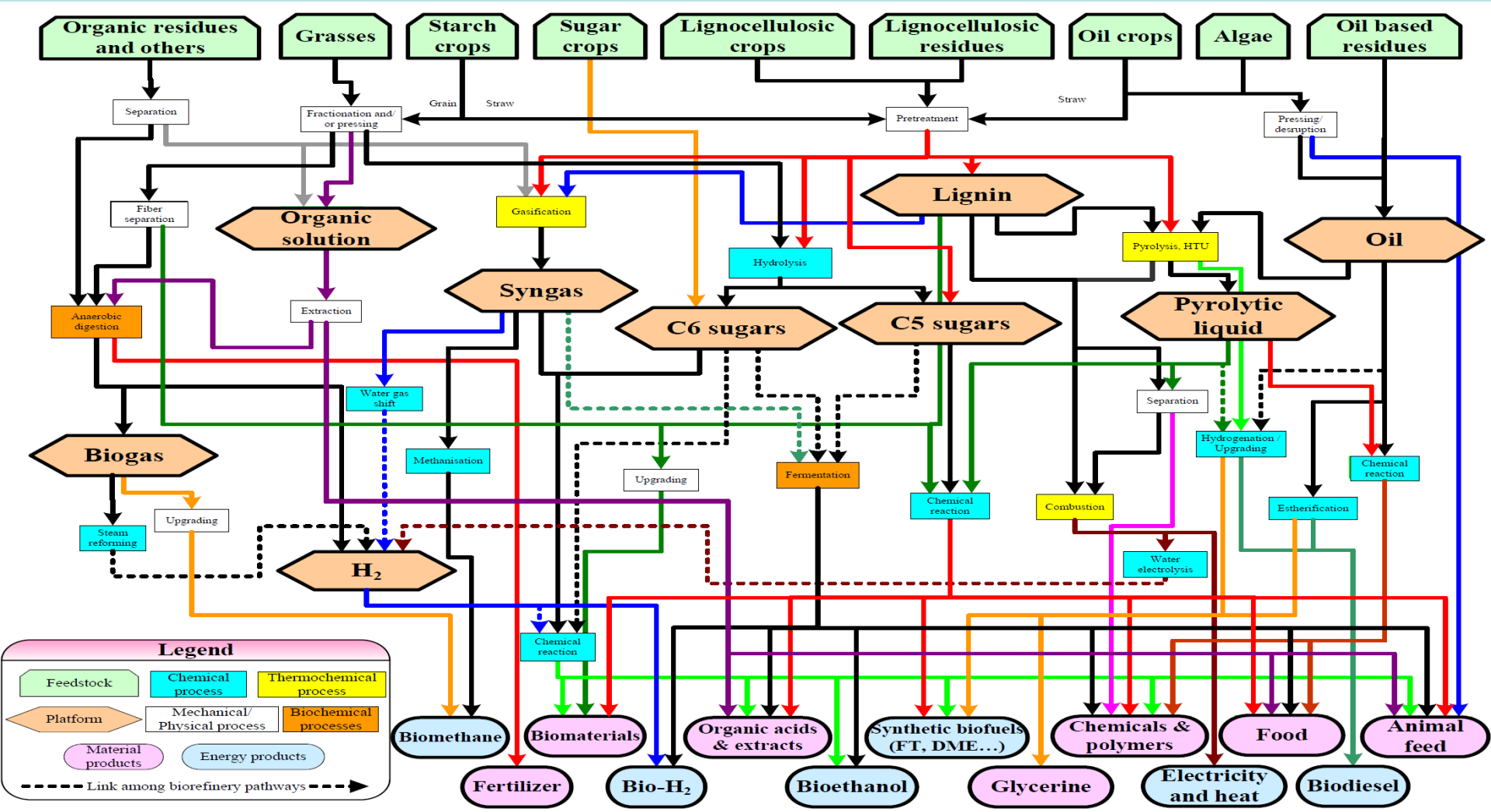
(Definition by IEA Bioenergy Task 42 Biorefineries)

Classification system - IEA Bioenergy Task 42

Four main features to classify biorefinery systems

- **Platforms** (e.g. C5/C6 sugars, syngas, biogas)
- **Product groups**: **Energy** (e.g. bioethanol, biodiesel, synthetic fuels) and **Products** (e.g. chemicals, materials, food and feed)
- **Feedstock groups** (e.g. energy crops, biomass residues from agriculture, forestry, trade and industry)
- **Conversion processes** (e.g. biochemical, thermo-chemical, chemical, mechanical)

Classification system - IEA Bioenergy Task 42



Energy vs. product driven biorefineries

Energy driven biorefineries

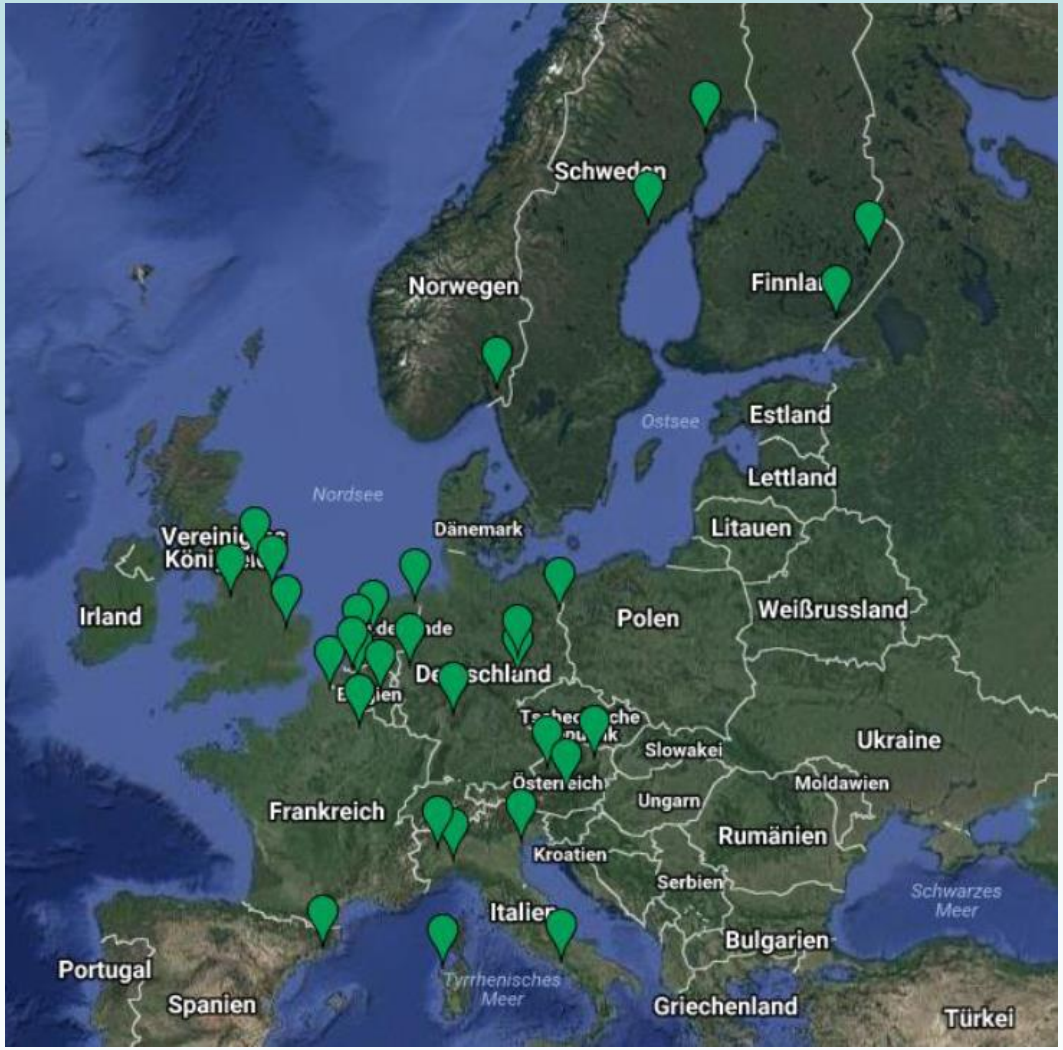
- Target: production of biofuels/energy; added value through co-products
- Infrastructure (value chains) exist
- Often (public) financial support required and/or regulated markets
- Up-grading of existing plants to multi-product biorefineries

Product driven biorefineries

- Target: production of chemicals, materials, food and feed; side-products used for energy (power/heat) production
- Only limited new facilities in operation yet
- Key technologies often still at R&D phase
- High potential (interested stakeholders, advanced properties)

Bioenergy will be the “lubricating oil” in a future circular BioEconomy

Commercial biorefineries in Europe



Source: https://biorrefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1

Commercial biofuel driven BR in Europe

Country	Name	Company	Platform	Products	Feedstock	Process	Model
Finland	Joensuu Bio-oil Plant	Fortum	Pyrolysis oil, power, heat	Bio-oil, power, heat	Forest residues, wood	Pyrolysis	
Finland	UPM Lappeeranta	UPM Biofuels	Oil	Biodiesel	Tall-oil	Pretreatm., hydrotreatm.	
Germany	Schwedt Biorefinery	Verbio	Starch, C5/C6 sugars	Bioethanol, biogas, fertiliser	Rye	Hydrolysis, fermentation	Convention. BR
Italy	Crescentino Bioethanol Plant	Beta Renewables	C5/C6 sugars, lignin, power, heat	Bioethanol, animal feed	Straws, giant reed	Hydrolysis, fermentation	Lignocellu. BR
Netherlands	Delfzijl Biomethanol Plant	BioMCN	Syngas	Biomethanol	Glycerin	Evaporation, reforming	
Netherlands	Rotterdam Biorefinery	Neste Oil	Oil	HVO	Vegetable oil, animal fat	Hydrotreat.	HVO BR

Source: https://biorrefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1

Commercial product driven BR in Europe

Country	Name	Company	Platform	Products	Feedstock	Process	Model
Finland	Metsä Bioproducts Mill	Metsä Fibre	Pulp, lignin, power, heat	Pulp, power, tall-oil, lignin, new prod.	Wood	Cooking, separation	Forest BR
France	Pomacle-Bezancourt BR	Soliance, Sugar ref., Cristanol, Air Liquid	Starch, C5/C6 sugars	Starch, glucose, feed, ethan., CO2	Sugar beet, wheat	Hydrolysis, fermentation	Integrated BR
Germany	Biowert Biorefinery	Biowert GmbH	Organic solutions, biogas	Cellulosic fibres, nutrients, biogas	Grass	Pressing, drying, separation	Green BR
Norway	Sarpsborg Biorefinery	Borregaard	C5/C6 sug., lignin, biogas, power, heat	Bioethanol, lignin, cellulose, vanillin	Lignocell. crops or residues	Cooking, fermentat., separation	Forest BR
Sweden	Domsjö Pulp Mill	Aditya Birla Group	C5/C6 sug., lignin, biogas	Bioethanol, lignin, cellulose	Lignocell. crops	Cooking, fermentat., separation	Forest BR

Source: https://biorrefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1

Biorefineries – incentives and tools

Biorefineries should be designed in a <u>flexible</u> way and aim for the integral use of feedstock

- Feedstock flexibility (new crops as potential substitution)
- Combine high volume/low quality with high quality/low volume products
- Integration with value chains (avoid mismatch with market volumes)
- Decentralised models to facilitate biomass transportation

<u>Sustainability</u> must be achieved and demonstrated

- GHG reduction potential for whole value chain (difficult to calculate)
- Development of standardised methodologies
- Important aspects: biodegradability, GHG emissions, biodiversity, soil quality
- Environmental footprint internalised in price (of any product)

Biorefineries – incentives and tools

Rather than subsidies…the need for a stable and coherent policy framework

- Stable (timeline 10-25 years) European and national policy and regulatory frameworks
- Loan guarantees for development and retrofitting of commercial-scale biorefinery facilities (cf. USDA Biorefinery Assistance Programme)
- Policies at various levels (local, regional, national) (cf. biorefinery roadmaps developed in Scotland and Germany)

Rather than subsidies…the need for markets

- Key priority: supporting market up-take for bio-based products
- Tools: production mandates (difficult for bio-chemicals), green public procurement

Challenges and opportunities

***Promising* technologies and products…**

- Lignin and hemicellulose valorisation (currently underutilised)
- Existing challenges on pre-treatment and conversion technologies
- Existing challenges on biomass (and product) fractionation and CCU

…to ensure that "the best goes to the best"

- Using high quality parts of biomass for high quality products
- Proteins should be first extracted for food and non-food use
- Biomass use in applications where it is only sustainable solution

…to increase the profitability of biorefinery business models

Hurdles from specific pieces of legislation

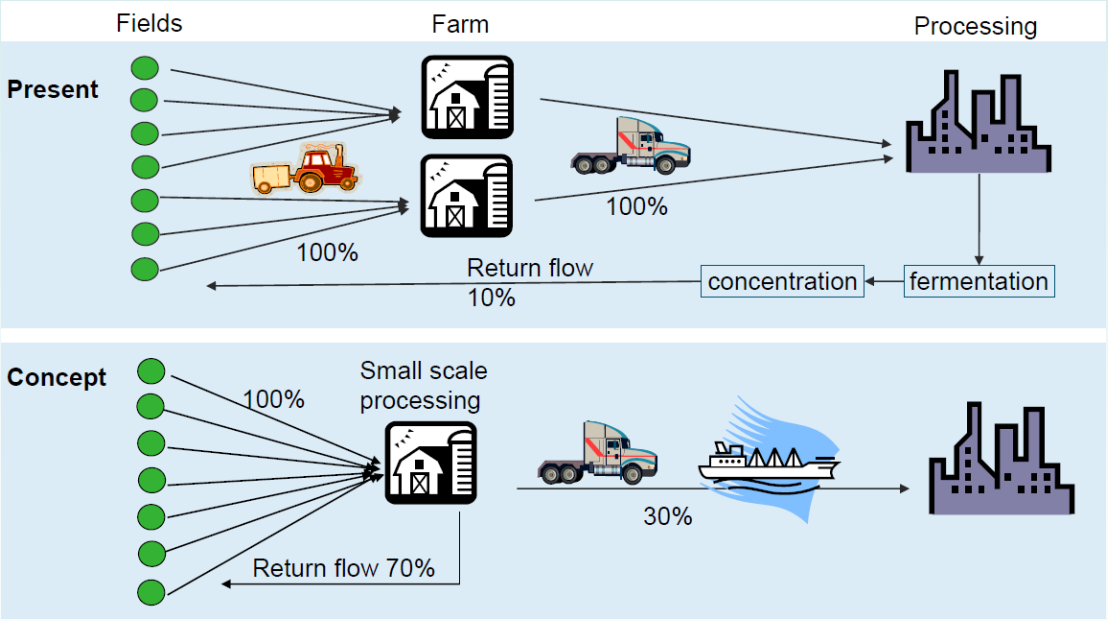
- Waste Framework Directive can hinder transport and valorisation

Address possible local resistance

- Open door policy, stakeholder involvement, local value chains

Small-scale biorefineries

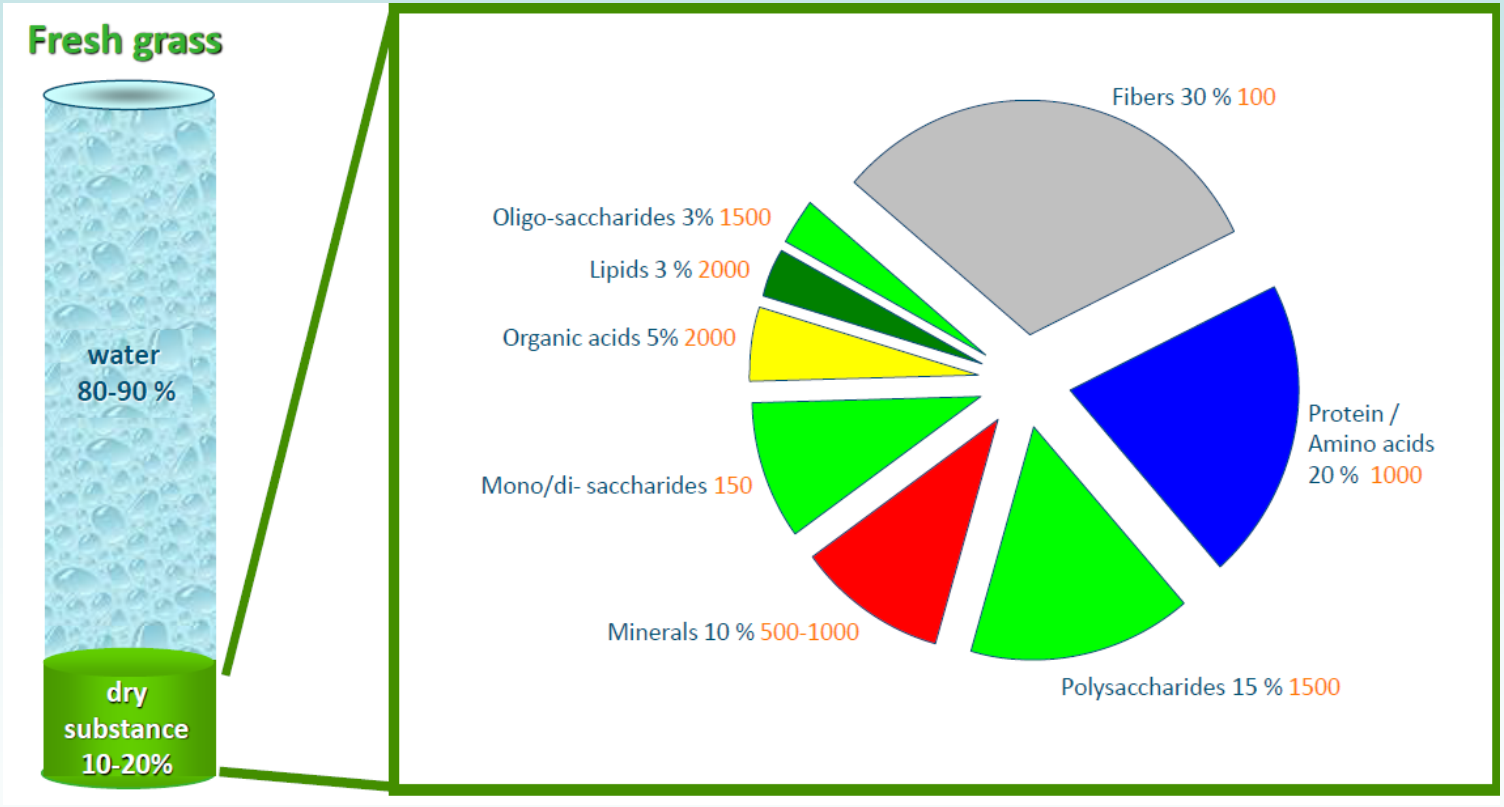
- Biorefineries for feed, materials and chemicals create income and employment in local agricultural sectors
- Small-scale processing reduces capital costs and costs for energy and transportation
- Challenge: cooperation of local actors (networks, clusters)



Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015

Mobile grass refinery unit Grassa (Netherlands)

- Separated components of grass value 700-800 EUR/ton, compared to 60 EUR/ton costs of raw material



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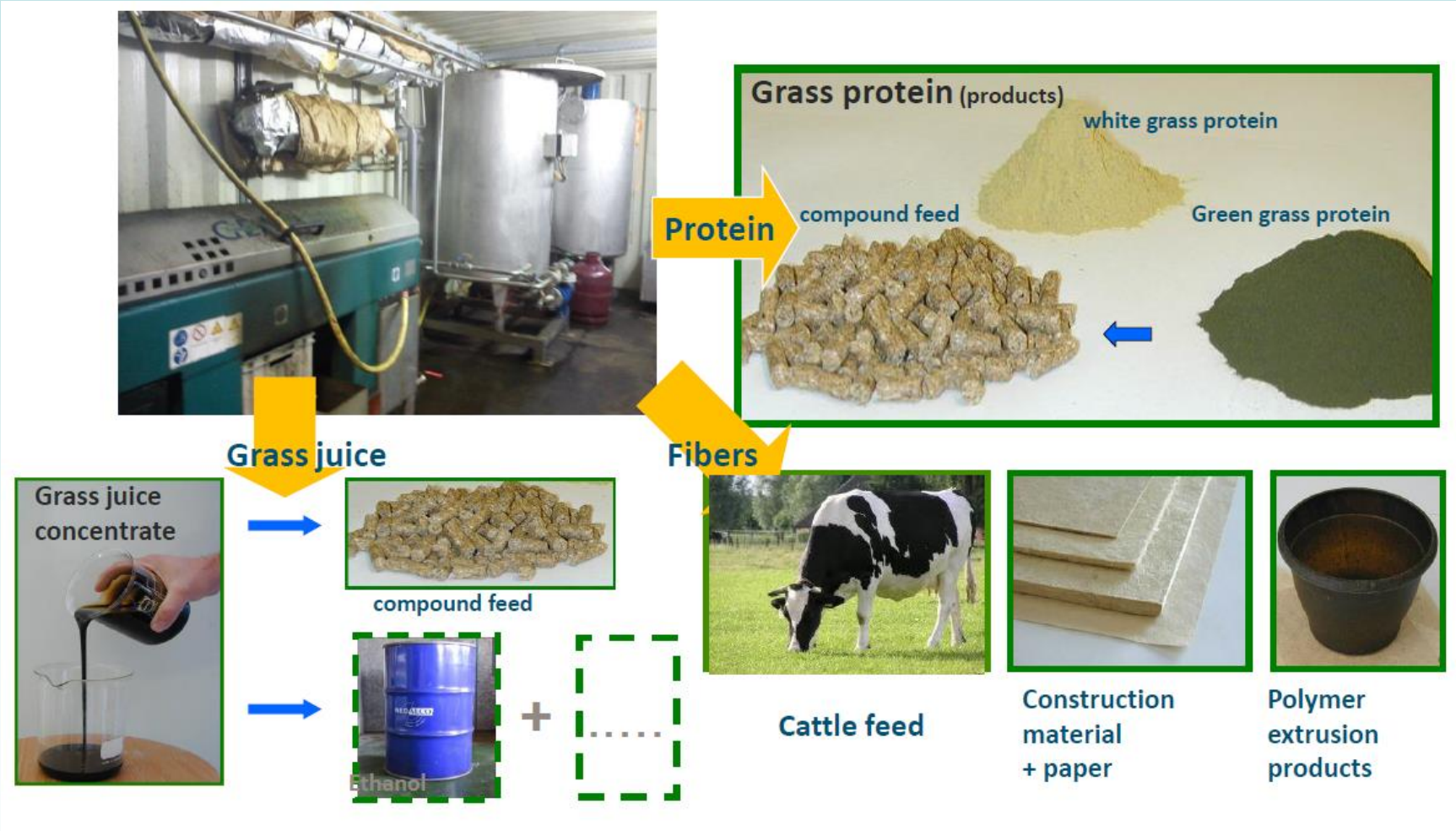
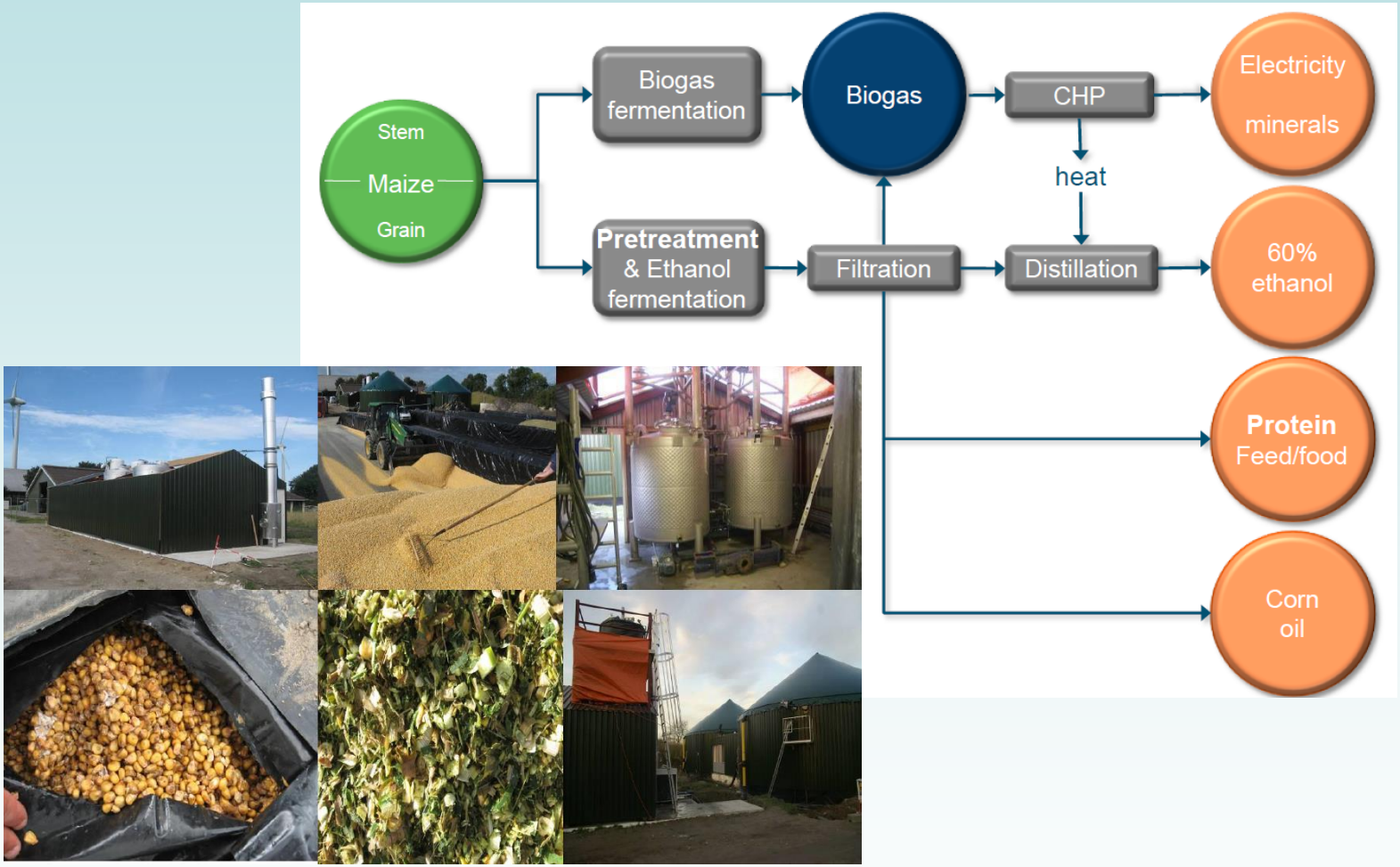


Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015

Small-scale corn biorefinery (Byosis, NL)



Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015

Future market perspectives – Advanced biofuels

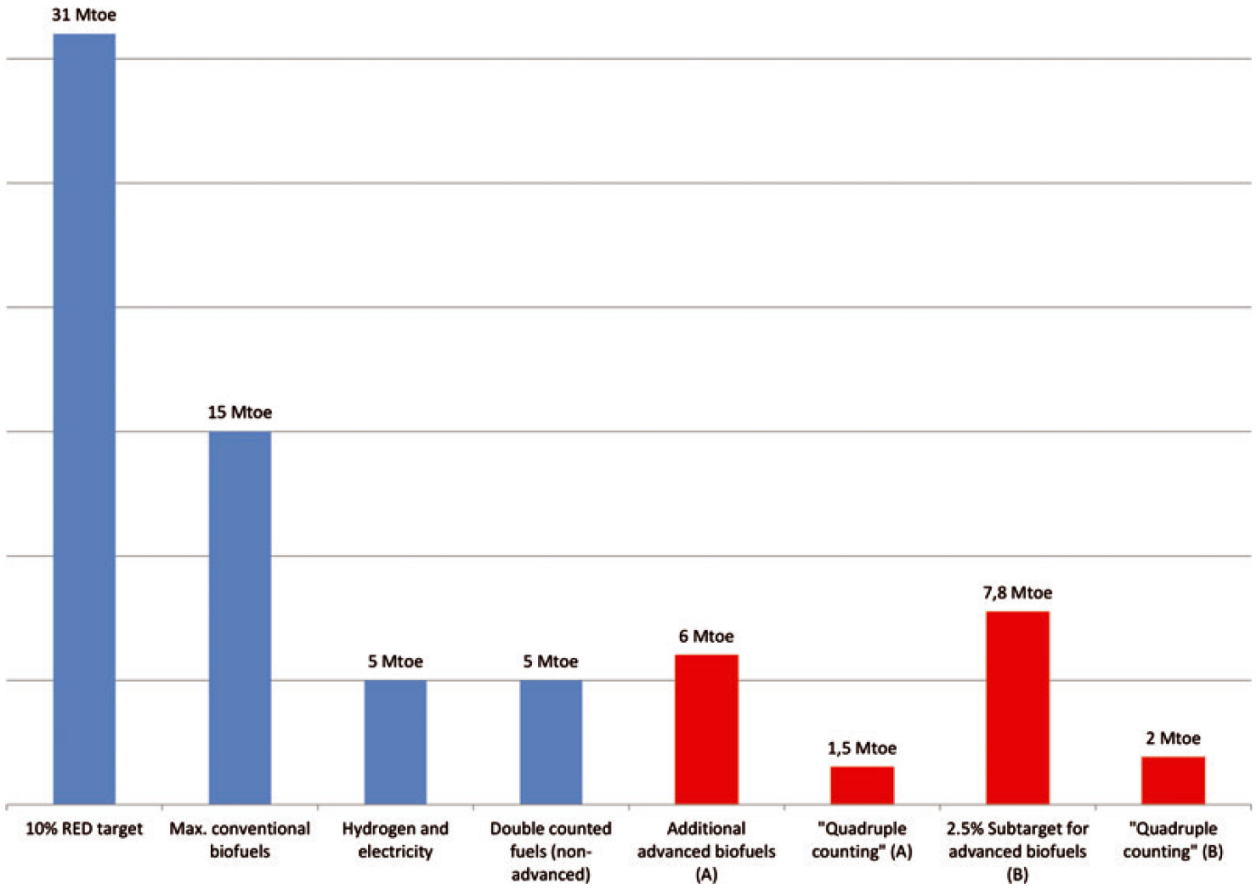
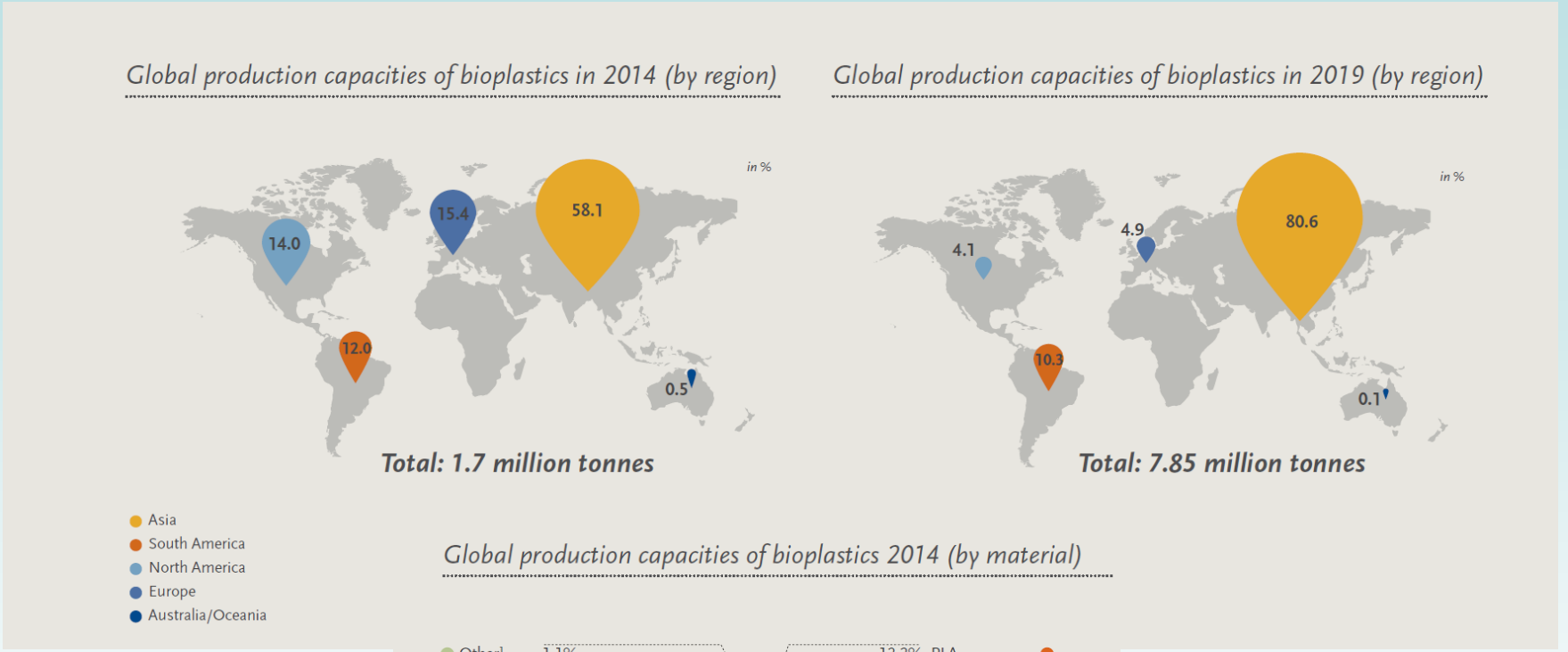


Figure 5. Potential additional demand for advanced biofuels triggered by the proposed revision of the RED (Option A: Current proposal, Option B: 2.5% subtarget for advanced biofuels).

Source: R. Janssen et al., Biofuels, Bioprod. Bioref. (2013); DOI: 10.1002/bbb

Future market perspectives – Bioplastics



Source: European Bioplastics, Bioplastics – facts and figures

Biomass-derived chemical building blocks

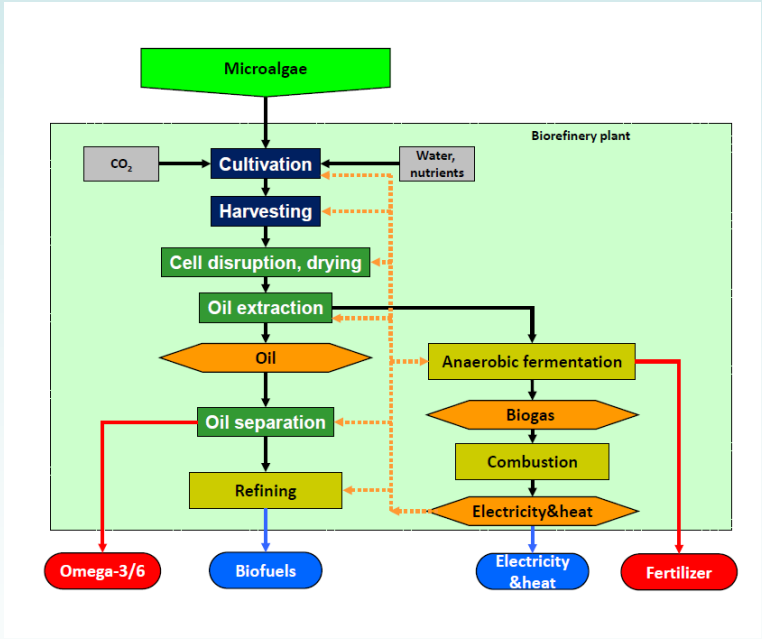
Cn	Chemical	Company	Potential
1	Methanol	BioMCN, Chemrec	Growth
	Formic acid	Maine BioProducts	Pipeline
	Methane	Many	Growth
	Syngas	BioMCN, Chemrec	Growth
2	Ethylene	Braskem, DOW/Mitsui, Songyuan Ji'an Biochemical	Growth
	Ethyl acetate	Zeachem	Pipeline
	Ethanol	Many	Growth
	Glycolic acid	Metabolic Explorer (Metex)	Pipeline
	Ethylene glycol	India Glycols Ltd, Greencol Taiwan	Growth
	Acetic acid	Wacker	Growth
3	Lactic acid	Purac, NatureWorks, Galactic, Henan Jindan, BBCA	Growth
	Acrylic acid	Cargill, Perstorp, OPXBio, DOW, Arkema	Pipeline
	Glycerol	Many	Growth
	3-Hydroxy propionic acid	Cargill	Pipeline
	Propylene	Braskem/Toyota Tsusho, Mitsubishi Chemical, Mitsui Chemicals	Pipeline
	Epichlorohydrin	Solvay, DOW	Growth
	1,3-Propanediol	DuPont/Tate & Lyle	Growth
	n-Propanol	Braskem	Pipeline
	Ethyl lactate	Vertec BioSolvents	Growth
	Isopropanol	Genomatica, Mitsui Chemicals	Pipeline
	Propylene Glycol (1,2-Propanediol)	ADM	Growth
4	n-Butanol	Cathay Industrial Biotech, Butamax, Butalco, Cobalt/Rhodia	Growth
	1,4-Butanediol	Genomatica/M&G, Genomatica/Mitsubishi , Genomatica /Tate & Lyle	Pipeline
	iso-Butanol	Butamax, Gevo	Growth
	Iso-butene	Gevo/Lanxess	Pipeline
	Methyl methacrylate	Lucite/Mitsubishi Rayon, Evonik/Arkema	Pipeline
	Succinic acid	BioAmber, Myriant, BASF /Purac, Reverdia (DSM/Roquette), PTT Chem / Mitsubishi CC	Growth
5	Furfural	Many	Growth
	Itaconic acid	a.o. Qingdao Kehai Biochemistry Co, Itaconix	Pipeline
	Xylitol	a.o. Danisco/Lenzing, Xylitol Canada	Growth
	Isoprene/ Farnesene	Goodyear/ Genencor, GlycosBio, Amyris	Pipeline
	Glutamic acid	a.o. Global Biotech, Meihua, Fufeng, Juhua	Growth
	Levulinic acid	Maine BioProducts, Avantium, Segetis, Circa Group	Pipeline
6	Sorbitol	a.o. Roquette, ADM	Growth
	Adipic acid	Verdezyne, Rennovia, BioAmber, Genomatica	Pipeline
	Lysine	a.o. Global Biotech, Evonik/RusBiotech, BBCA, Draths, Ajinomoto	Growth
	FDCA	Avantium	Pipeline
	Isosorbide	Roquette	Growth
	Glucaric acid	Rivertop renewables	Pipeline
	Citric acid	a.o. Cargill, DSM, BBCA, Ensign, TTCA, RZBC	Growth
	Caprolactam	DSM	Pipeline
n	PHA	Metabolic Explorer (Metex), Meridian plastics (103), Tianjin Green Biosience Co.	Growth
	Para-Xylene	Gevo, Draths*, UOP, Annellotech, Virent	Pipeline
	Dicarboxylic acids	Cathay Biotech, Evonik	Growth
	Fatty Acid derivatives	Croda, Elevance	Growth

* Draths is recently acquired by Amyris.

Source: IEA Bioenergy Task 42

Ecoduna Algae Biorefinery, Austria

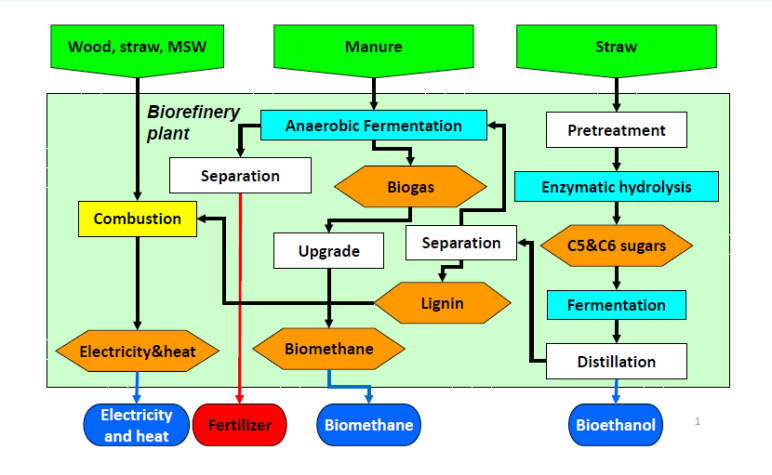
- **State-of-the-art:** Demonstration Plant
- **Type of biorefinery:** 3-platform biorefinery
- **Location:** Bruck an der Leitha, Austria
- **Owner:** Ecoduna produktions-GmbH
- **Feedstocks:** Microalgae
- **Outputs:** Biofuels, electricity & heat, omega-3/6 fatty acids and Fertilizer



Source: IEA Bioenergy Task 42 Biorefining, August 2014

Maabjerg Energy, Denmark

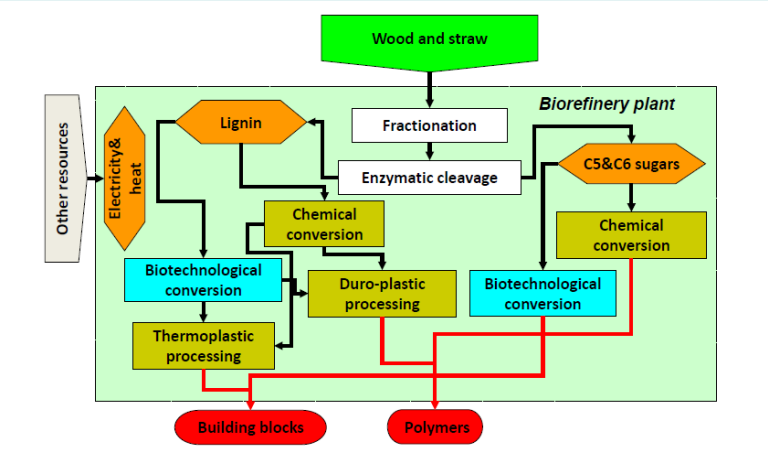
- **State-of-the-art**: Commercial Scale (project)
- **Type of biorefinery**: A 5-platform (C5&C6 sugar, lignin, biogas, bio-methane, electricity&heat) biorefinery
- **Location**: Maabjerg, Denmark
- **Owner**: Vestforsyning A/S, Struer Forsyning A/S, Nomi I/S, DONG Energy A/S, Novozymes A/S
- **Feedstocks**: Wood chips, straw, manure, sewage sludge and MSW
- **Outputs**: Bio-methane, bioethanol, fertilizer, electricity and heat



Source: IEA Bioenergy Task 42 Biorefining, August 2014

LEUNA, Germany

- **State-of-the-art**: Pilot Plant
- **Type of biorefinery**: A 2-platform (C5&C6 sugars, lignin)
- **Location**: Leuna, Germany
- **Owner**: Fraunhofer Center for Chemical-Biotechnological Processes CBP
- **Feedstocks**: Ligno-cellulosic residues (wood, straw)
- **Outputs**: Bio-based synthesized building blocks and polymers



Source: IEA Bioenergy Task 42 Biorefining, August 2014

BTG Bioliquids Refinery, Netherlands

- **State-of-the-art**: Commercial Scale, start-up 2015
- **Type of biorefinery**: 1-platform (pyrolysis-oil) biorefinery
- **Location**: Hengelo, the Netherlands
- **Owner**: Empyro BV
- **Feedstocks**: Wood
- **Outputs**: Pyrolysis-oil, power, heat

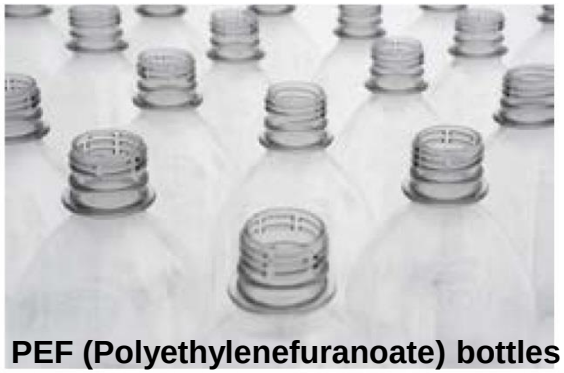
Source: IEA Bioenergy Task 42 Biorefining, August 2014

Avantium YXY Fuels & Chemicals, Netherlands

- **State-of-the-art**: Pilot Plant
- **Type of biorefinery**: 3-platform (C5, C6 sugars and lignin)
- **Location**: Furanics, Amsterdam/Geleen, the Netherlands
- **Owner**: Avantium Chemicals B.V.
- **Feedstocks**: Cellulose, hemi-cellulose, starch, sucrose
- **Outputs**: Furan-based biofuels, monomers for polymers (furan dicarboxylic acid, furan diamine), fine and specialty chemicals (organic acids, solvents, flavors & fragrances), solid fuels (humins and lignin residues)

PEF: superior performance over PET (gas barrier), improved thermal stability, excellent mechanical properties, reduced carbon footprint

Figure 28. Pilot-plant in Geleen, the Netherlands [Avantium]



PEF (Polyethylenefuranoate) bottles

Figure 29. 100% PEF-bottles [Avantium]

Source: IEA Bioenergy Task 42 Biorefining, August 2014

Conclusions

- Biorefining (co-production of food/feed, bio-based products and bioenergy) can **maximise value** for sustainable biomass use
- Bioenergy will be the “lubricating oil” in a future circular BioEconomy
- Multitude of commercial, demonstration and pilot biorefinery concepts exist in Europe and globally (long experience in food and paper sector)
- **Development and demonstration of (new/innovative) technologies** is still needed to further increase efficiency and reduce costs
- **Small-scale biorefineries** may create additional income and employment in local agricultural sectors
- **Stable policy and regulatory frameworks** needed (level playing field)
- Key priority: **supporting market up-take** for bio-based products

Thanks for your attention!

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