IEA Bioenergy

Task 42
Biorefineries in a future BioEconomy
Activities and results update

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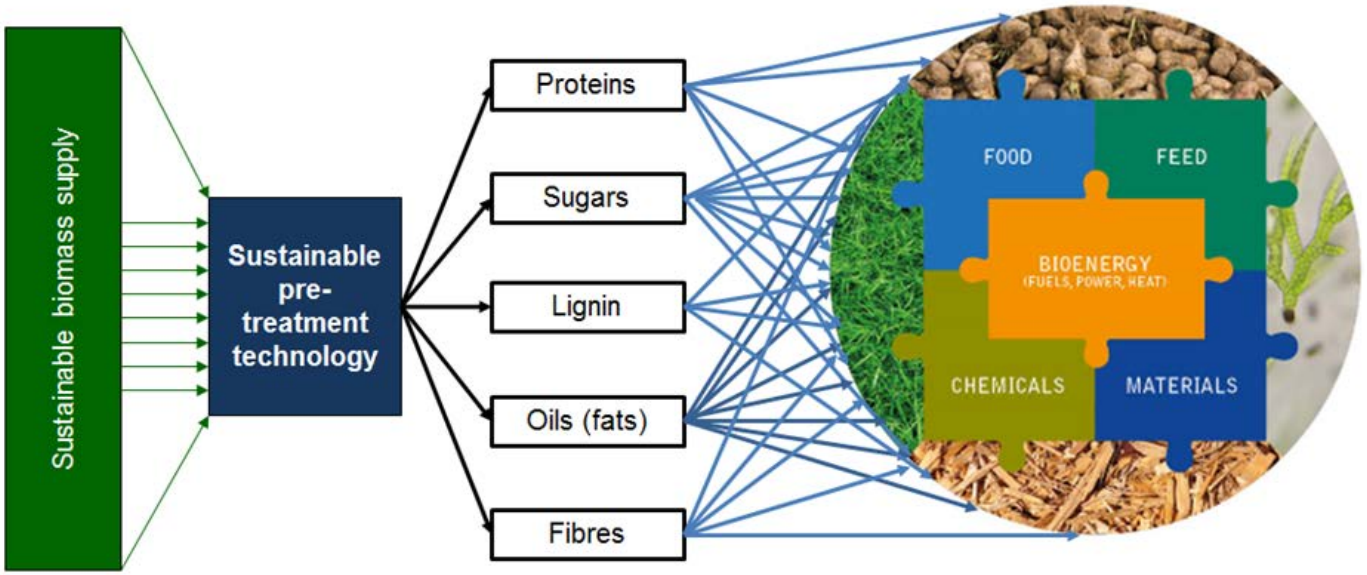
IEA Vernetzungstreffen 2018,
10th Oct 2018, bmvit, Vienna

Biorefining

Definition IEA Bioenergy Task42

Sustainable processing of biomass into a portfolio of marketable biobased products (food and feed ingredients, chemicals, materials, fuels, energy, minerals, CO_2) and bioenergy (fuels, power, heat)



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Biorefineries in a future BioEconomy

Task 42

Vision

Biorefining is the optimal strategy for large-scale **sustainable use of biomass in the BioEconomy** resulting in cost-competitive co-production of food/feed ingredients, biobased products and bioenergy with optimal socio-economic and environmental impacts, viz.

-> efficient use of resources

-> reduced GHG emissions

Mission

To **facilitate the commercialisation and market deployment** of environmentally sound, socially acceptable, and cost-competitive **biorefinery** systems & **technologies**, and to advise policy and industrial decision makers.

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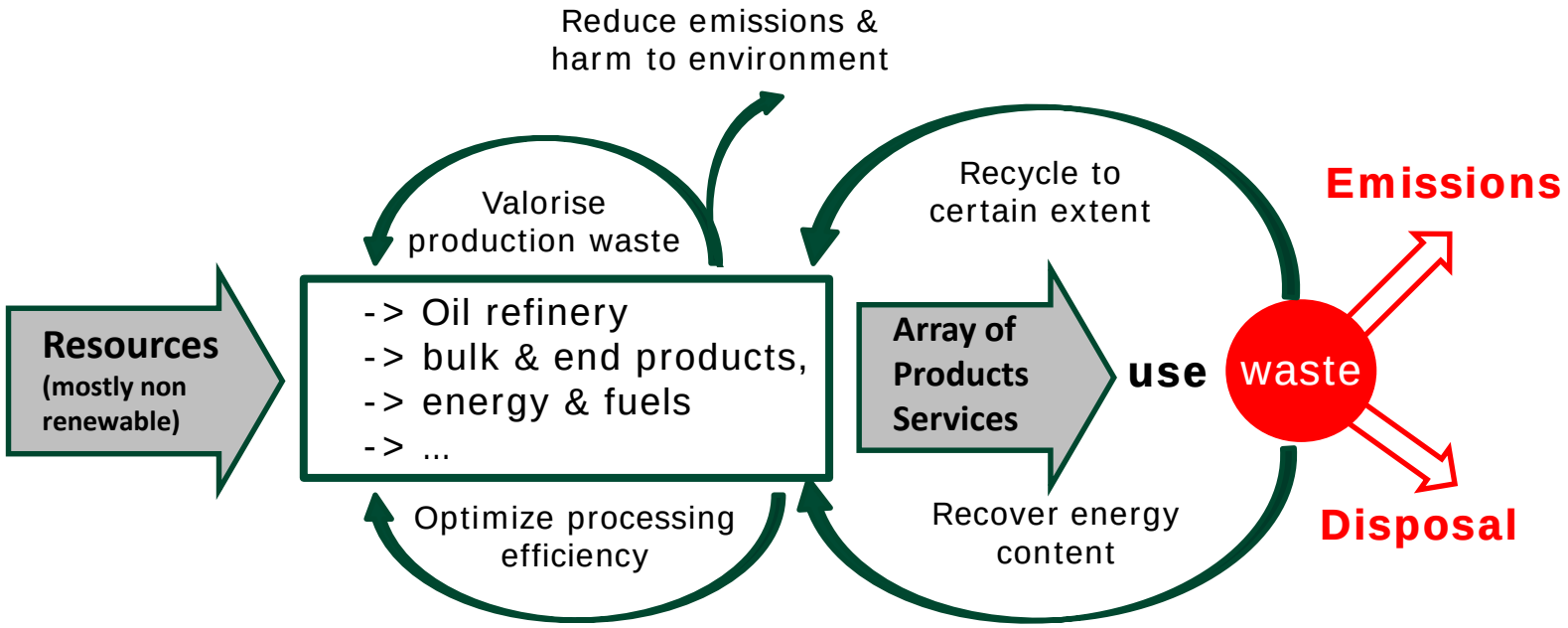
Concept of current Economy

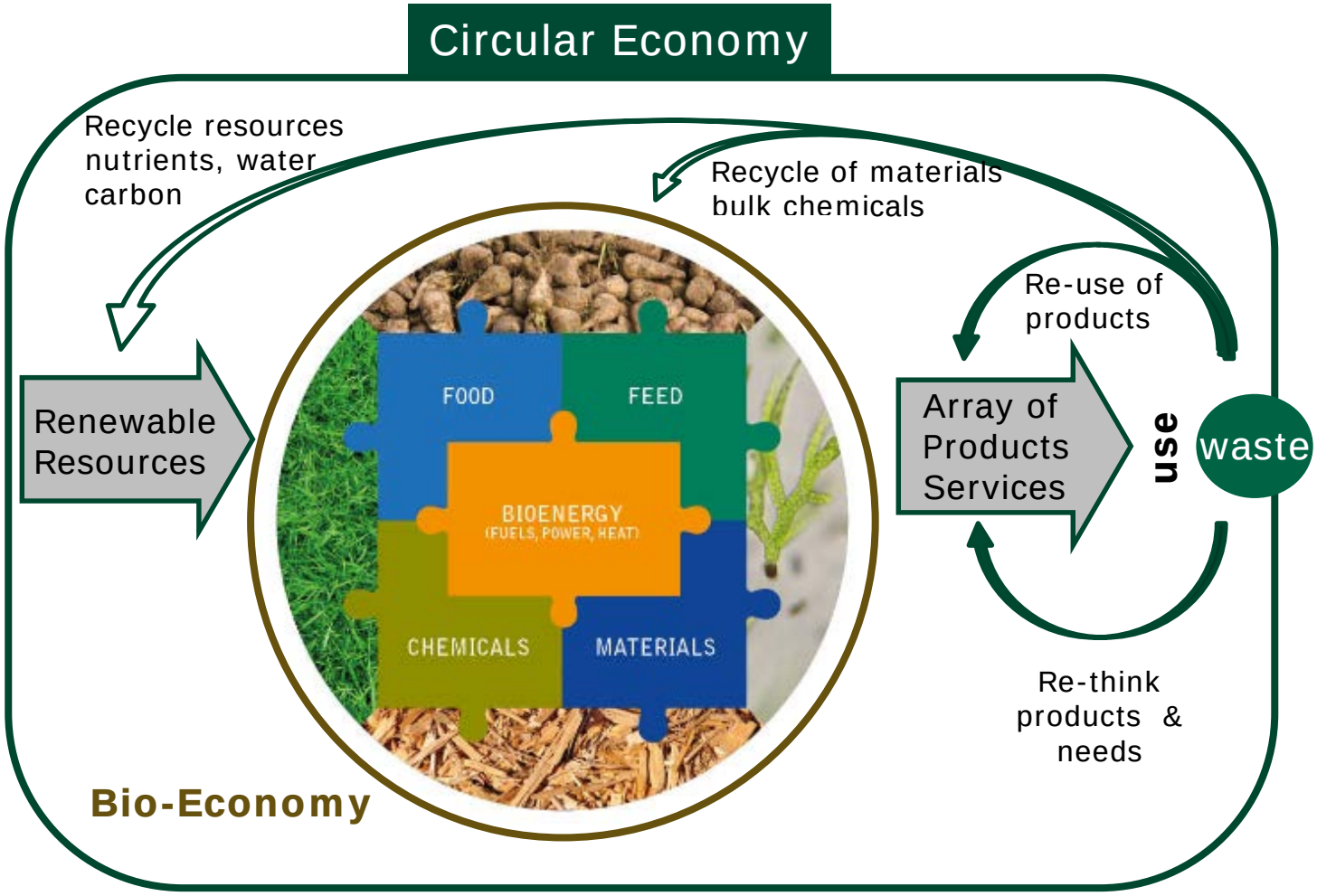
Resources depletion !

Production system is not sustainable

Global Warming !



Concept of future Economy



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Biorefineries in a future BioEconomy

Task 42 Activities 2016 – 2018

Countries represented:
AT, AUS, CAN, DEN, GER, IRE, IT, NL, USA

Scope involve 4 different Activity Areas (AAs)

- **AA1 - Biorefinery Systems**
  Analysis and assessment of biorefining in the whole value chain
- **AA2 - Product Quality**
  Reporting on related biobased products/ bioenergy standardisation, certification and policy activities
- **AA3- Evolving BioEconomy**
  Analysing and advising on perspectives biorefining in a Circular BioEconomy
- **AA4 - Communication, dissemination & training**
  Knowledge exchange, stakeholder involvement, reports & dissemination

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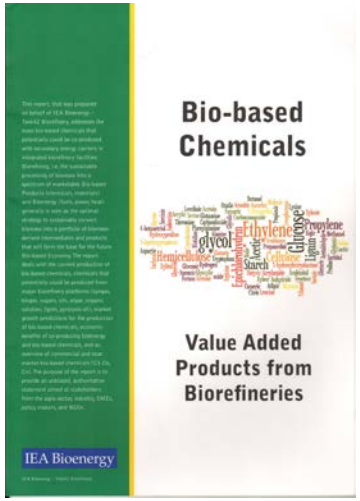
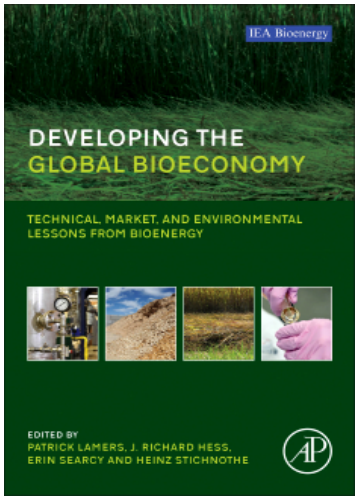
Results of Task 42 2016 – 2018

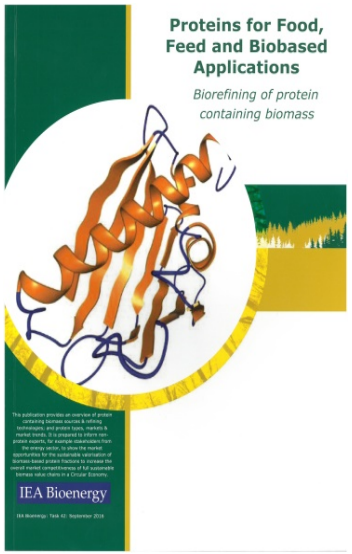
Deliverables

- Biorefinery Assement -> Biorefinery Fact Sheets
- Strategic Reports on Biobased Chemicals, Fiber Materials and Proteins
- Updates of national Country Reports
- Thematic Stakeholder Workshops together with IEA IETS, FAO and OECD, JRC, other Tasks
- Conference & training contributions, ...

Thematic reports...







Country Reports

AT, AUS, CAN, DEN, FRA, GER, IRE, IT, JAP, NL, NZ, TUR, UK, US

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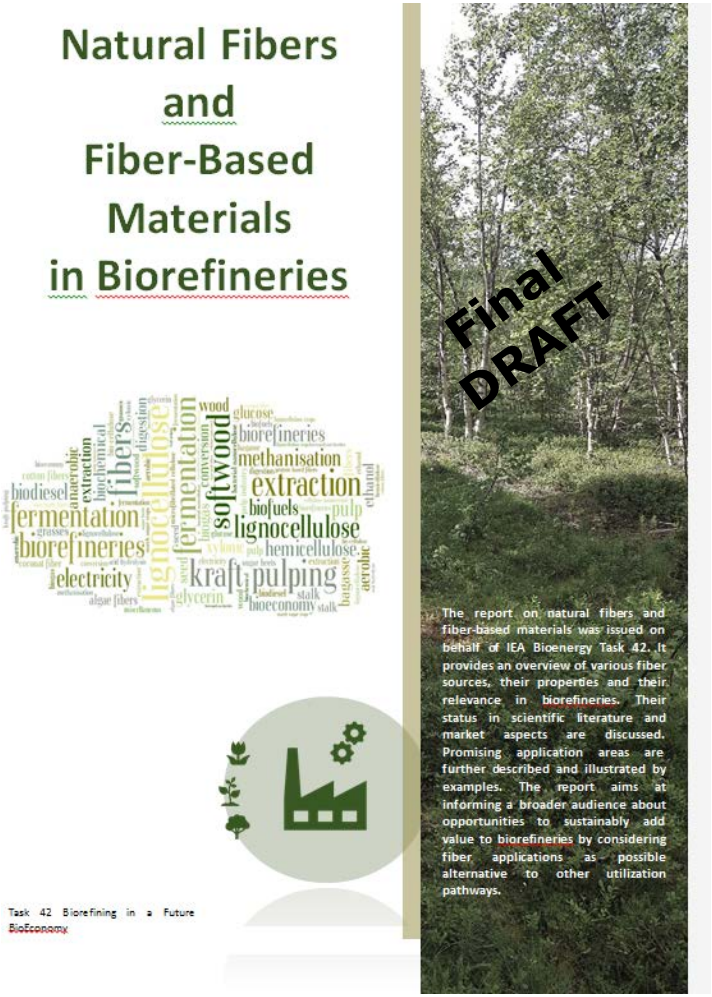
Coming up soon...



Report Coordinator

Tobias Stern & Team
Universität Graz

Available for download by end 2018

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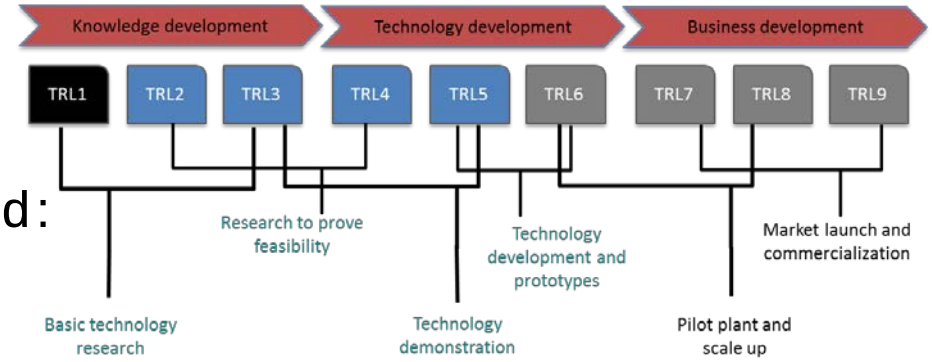
Sustainability assessment challenged

- Biorefinery concepts in development!
  - Emerging technologies
  - different TRLs



→ Data availability is limited:
  - Especially at low TRLs
  - Due to confidentiality

→ Stakeholder participation is restricted:
  - Due to confidentiality
  - or conflicting interests (e.g. collaboration)

Challenges in LCA & technoeconomic approach experienced: So far only totally aggregated and highly specific results are available

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Sustainability assessment

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Objectives of Assessment

Underpin sustainability claim of integrated biorefineries

Via Technical, Economic and Environmental (TEE) Assessment

→provide an **open access data platform**

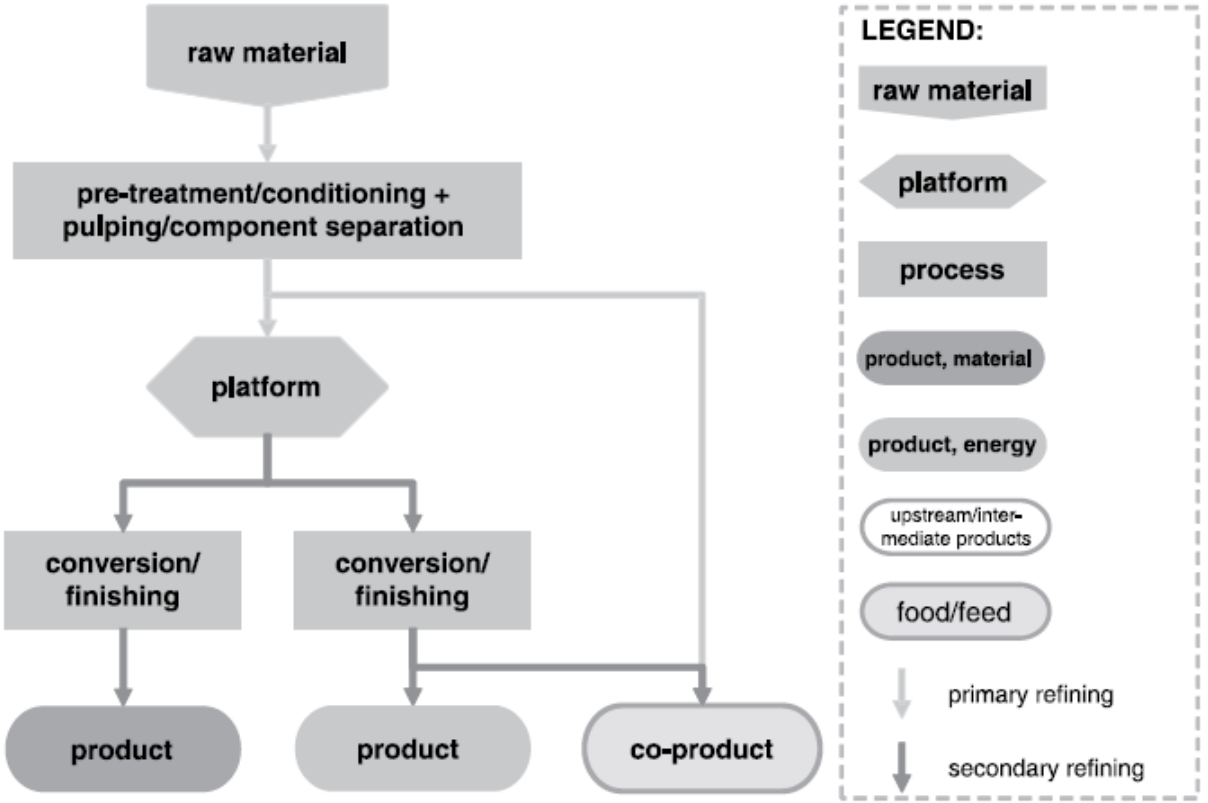
→quantitative environmental and economic assessment approach

→with generic initial biorefinery models for iterative refinement

→**encourage stakeholders** for the technology valuation of emerging biorefinery technologies

- Expert review/assumptions
- New experiences/results
- New concepts/process pathways
- Verify/improve data
- Share data and extend models and assessment

Biorefining Classification System

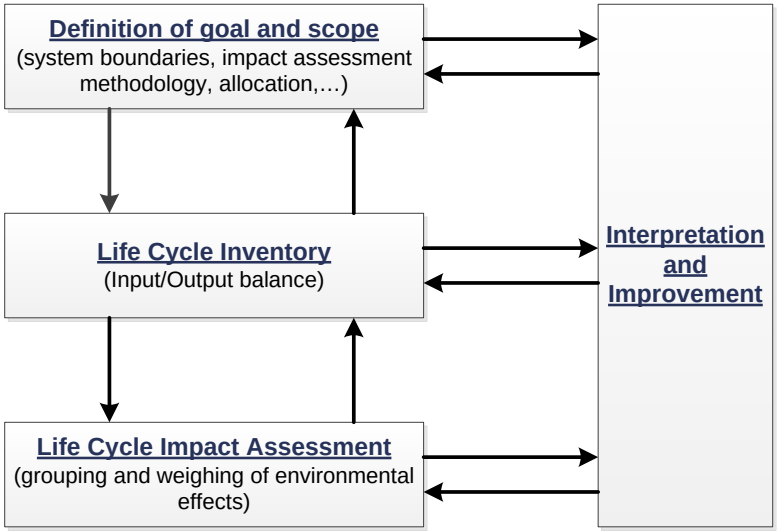


Reference: VDI Richtlinie 6310, part 1 (2016), Joanneum Research

Standardized approach to assessment

Calculation rules are intended to be in line with state of the art LCA methodologies:

- CEN TC 383 Sustainably produced biomass for energy use
- ISO 14040 Life Cycle Assessment
- ISO/TS 14067 Greenhouse gases - Carbon footprint of products
- ...



Use of published information

- LCA & techno-economic studies
- BAT documents
- National inventories/statistics
- various open access databases for default/standard values for GHG emission coefficients, heating values, fuel efficiency for agro inputs, fuels, electricity, ...

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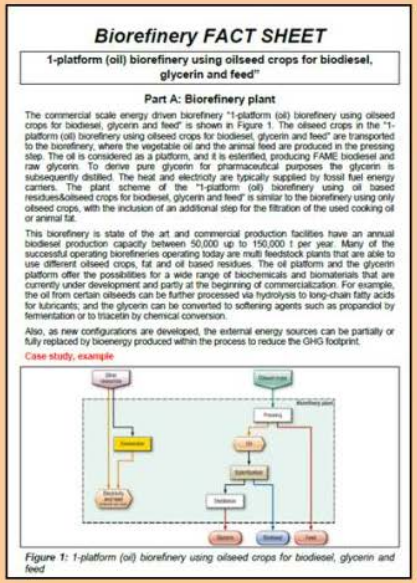
Biorefinery Fact Sheet

Part A: Biorefinery Plant



Biorefinery FACT SHEET

1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin and feed"

Part A: Biorefinery plant

The commercial scale energy driven biorefinery "1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin and feed" is shown in Figure 1. The oilseed crops in the "1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin and feed" are transported to the biorefinery, where the vegetable oil and the animal feed are produced in the pressing step. The oil is considered as a platform, and it is esterified, producing FAME biodiesel and raw glycerin. To derive pure glycerin for pharmaceutical purposes the glycerin is subsequently distilled. The heat and electricity are typically supplied by fossil fuel energy carriers. The plant scheme of the "1-platform (oil) biorefinery using oil based residues&oilseed crops for biodiesel, glycerin and feed" is similar to the biorefinery using only oilseed crops, with the inclusion of an additional step for the filtration of the used cooking oil or animal fat.

This biorefinery is state of the art and commercial production facilities have an annual biodiesel production capacity between 50,000 up to 150,000 t per year. Many of the successful operating biorefineries operating today are multi feedstock plants that are able to use different oilseed crops, fat and oil based residues. The oil platform and the glycerin platform offer the possibilities for a wide range of biochemicals and biomaterials that are currently under development and partly at the beginning of commercialization. For example, the oil from certain oilseeds can be further processed via hydrolysis to long-chain fatty acids for lubricants; and the glycerin can be converted to softening agents such as propandiol by fermentation or to triacetin by chemical conversion.

Also, as new configurations are developed, the external energy sources can be partially or fully replaced by bioenergy produced within the process to reduce the GHG footprint.

Case study, example

Figure 1: 1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin and feed

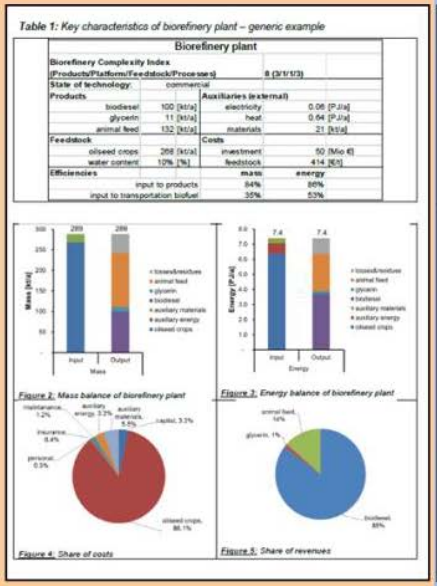


Table 1: Key characteristics of biorefinery plant – generic example

Biorefinery plant			
Biorefinery Complexity Index (Products/Platform/Feedstock/Processes)		8 (3/1/1/3)	
State of technology:	commercial		
Products		Auxiliaries (external)	
biodiesel	100 [kt/a]	electricity	0.06 [PJ/a]
glycerin	11 [kt/a]	heat	0.64 [PJ/a]
animal feed	132 [kt/a]	materials	21 [kt/a]
Feedstock		Costs	
oilseed crops	268 [kt/a]	investment	50 [Mio €]
water content	10% [%]	feedstock	414 [€/t]
Efficiencies		mass	energy
input to products		84%	86%
input to transportation biofuel		35%	53%

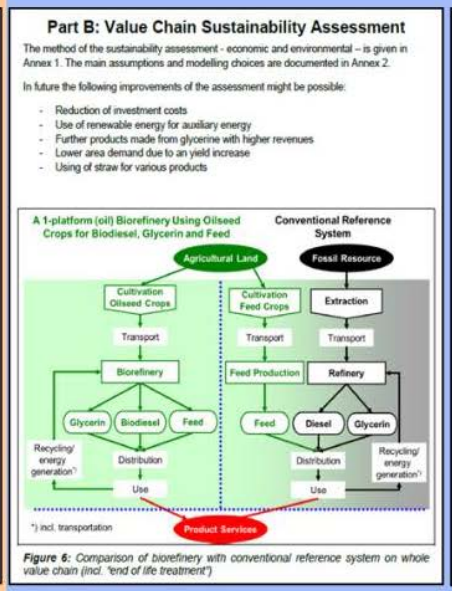
Figure 2: Mass balance of biorefinery plant

Figure 3: Energy balance of biorefinery plant

Figure 4: Share of costs

Figure 5: Share of revenues

Part B: Value Chain Assessment



Part B: Value Chain Sustainability Assessment

The method of the sustainability assessment - economic and environmental – is given in Annex 1. The main assumptions and modelling choices are documented in Annex 2.

In future the following improvements of the assessment might be possible:

- Reduction of investment costs
- Use of renewable energy for auxiliary energy
- Further products made from glycerine with higher revenues
- Lower area demand due to an yield increase
- Using of straw for various products

Figure 6: Comparison of biorefinery with conventional reference system on whole value chain (incl. "end of life treatment")

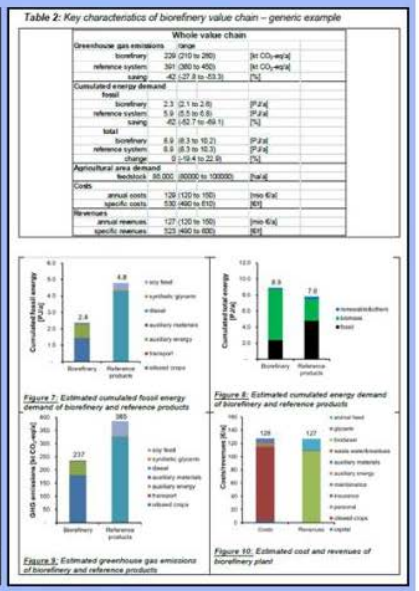


Table 2: Key characteristics of biorefinery value chain – generic example

Whole value chain		
Greenhouse gas emissions	range	
biorefinery	229 (210 to 280)	[kt CO_2-eq/a]
reference system	391 (380 to 450)	[kt CO_2-eq/a]
saving	-42 (-27.8 to -53.3)	[%]
Cumulated energy demand		
fossil		
biorefinery	2.3 (2.1 to 2.6)	[PJ/a]
reference system	5.9 (5.5 to 6.8)	[PJ/a]
saving	-62 (-62.7 to -69.1)	[%]
total		
biorefinery	8.9 (8.3 to 10.2)	[PJ/a]
reference system	8.9 (8.3 to 10.3)	[PJ/a]
change	0 (-19.4 to 22.9)	[%]
Agricultural area demand		
feedstock	85.000 (80000 to 100000)	[ha/a]
Costs		
annual costs	129 (120 to 150)	[mio €/a]
specific costs	530 (490 to 610)	[€/t]
Revenues		
annual revenues	127 (120 to 150)	[mio €/a]
specific revenues	523 (490 to 620)	[€/t]

Figure 7: Estimated cumulated fossil energy demand of biorefinery and reference products

Figure 8: Estimated cumulated energy demand of biorefinery and reference products

Figure 9: Estimated greenhouse gas emissions of biorefinery and reference products

Figure 10: Estimated cost and revenues of biorefinery plant

Annex:

Methodology of sustainability assessment and data with references

Reference: Joanneum Research (2014)

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Biorefinery Fact Sheets

Biorefinery Assessemet & Fact Sheet

4-platform biorefinery using grass silage and food residues for bio plastic, insulation material, fertilizer, electricity
3-platform biorefinery using wood chips for pulp, paper, turpentine, tall oil, bark, electricity and heat
1-platform biorefinery using starch crops for bioethanol and feed
3-platform biorefinery using wood chips for bioethanol, electricity, heat and phenols
1-platform biorefinery using oilseed crops for biodiesel, glycerine and feed
1-platform biorefinery using oil based residues for biodiesel, glycerine, bio oil & fertilizer
2-platform biorefinery using wood chips for FT-biofuels, electricity, heat and waxes
3-platform biorefinery using straw for FT-biofuels and methanol
2-platform biorefinery using wood chips for FT-diesel, FT-gasoline, heat and waxes
3-platform biorefinery using straw for FT-diesel and methanol
3-platform biorefinery using wood for renewable gasoline/diesel, biochar and pyrolysis oil
….

→For details see Task 42 webpage

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Biorefinery assessment ongoing and Fact Sheets in the pipeline

3-platform biorefinery (pulp, lignin, energy) using woodchips for pulp, lignin and energy; (LignoBoost process)

2-platform biorefinery (C5 & C6 sugar, lignin) using corn straw for the production of bioethanol and electricity & heat

2-platform biorefinery (C5 & C6 sugar, biogas) using sugar beet or cane for the biopolymer PHB and electricity & heat

2-platform biorefinery (C5 & C6 sugar, biogas) using maize for the production of biopolymer PLA and electricity & heat

…and more to come!

TEE analysis - System boundaries

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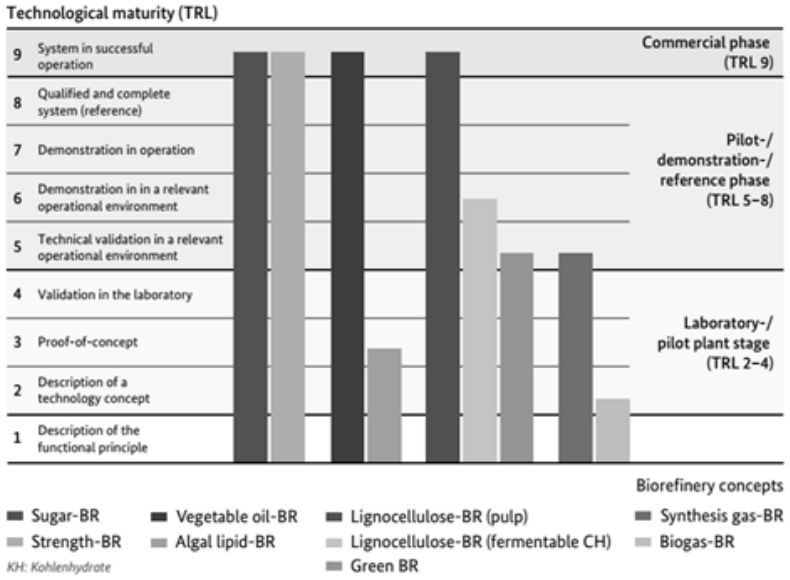
Balancing scope / System boundary:

Development status of biorefinery concept

- ☐ 9 - System in successful operation
- ☐ 8 - Qualified and complete system (reference)
- ☑ 7 - Demonstration in operation
- ☐ 6 - Demonstration in a relevant operational environment
- ☐ 5 - Technical validation in a relevant operational environment
- ☐ 4 - Validation in the laboratory
- ☐ 3 - Proof-of-concept
- ☐ 2 - Description of a technology concept
- ☐ 1 - Description of the functional principle



Source: Federal Government of Germany (2012) Biorefineries Roadmap - as part of the German Federal Government action plans for the material and energetic utilisation of renewable raw materials

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Environmental / Economic evaluation

primary data in tabular form along the process

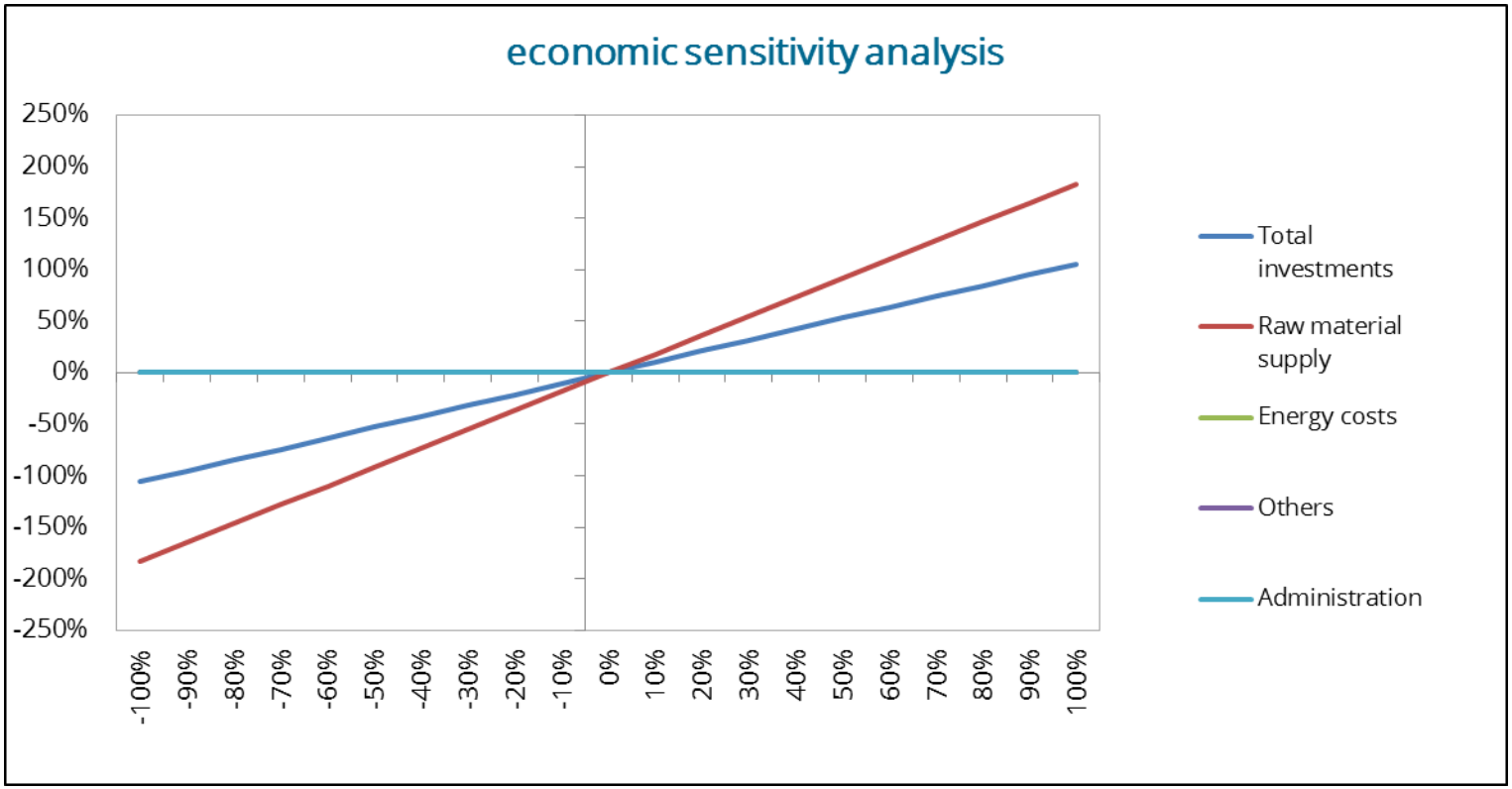
OVERVIEW RESULTS	operating result	unit	EtOH production cost	unit
	13.716.693	€/a	0,61	€/l

	Biorefinery CAPEX & OPEX[1)]	value	unit		value	unit
No.	*Parameter*					
A	**Investments**					
A.1	Investment sum	422.500.000	€	duration period	30	a
				revenues	140.672.196	€/a
B	**Investment costs**			discount rate	6%	
B.1	Write-offs	14.083.333	€/a	EtOH production	4.400.365.952	MJ/a
B.2	Imputed interest	25.350.000	€/a	EtOH production	164.131.516	kg/a
B.3	Maintenance	3.760.033	€/a	EtOH production	208.024.736	l/a
B.4	Taxes		€/a			
B.5	Insurance & Tax	3.341.912	€/a			
B.6	Administration		€/a			
	Fixed Operating Costs	46.535.278	€/a			
C	**Material and energy stream costs**					
C.1	Raw material supply	48.808.036	€/a	*Feedstock + Handling,*	*Feedstock cost*	*56 €/t*
C.2	Auxiliary and operating material	26.824.930	€/a			
				Energy supply is on-site (lignin &biogas); costs are integrated in total CAPEX and OPEX; accounted for excess electricity to grid		
C.3	Energy supply	-161.650	€/a			
C.4	Disposal costs	1.654.025	€/a	*disposal of ash*		
C.5	Transport costs		€/a	*included in raw material supply*		
C.6	Water supply costs	346.105	€/a			
E	**Labour costs**	2.948.780	€/a			
F	**other costs**		€/a			
G	**overheads**		€/a	*overheads are insurance & mainteanance*		
H	**overall evaluation**					
H.1	operating result	13.716.693	€/a			
H.2	overall EtOH production cost	126.955.504	€/a			
H.3	EtOH production cost	0,61	€/l			
H.4	1st generation EtOH production cost [2)]	0,50	€/l			

1) Humbird, D. et al (2011). Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol. Technical report. NREL.

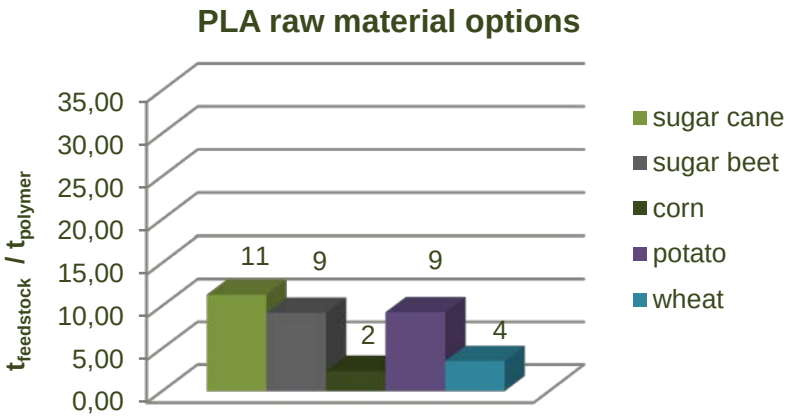
2) Jolesson, E. et al (2016). Techno-economic evaluation of integrated first- and second-generation ethanol production from grain and straw. Biotechnology for Biofuels, 9:1, pp.1-16

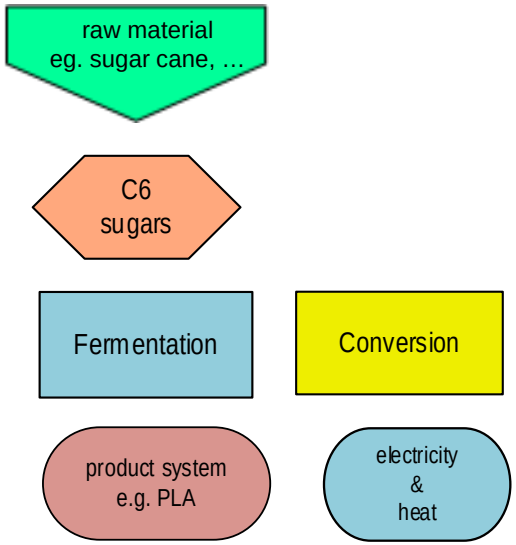
Biorefinery TEE Analysis Results communication

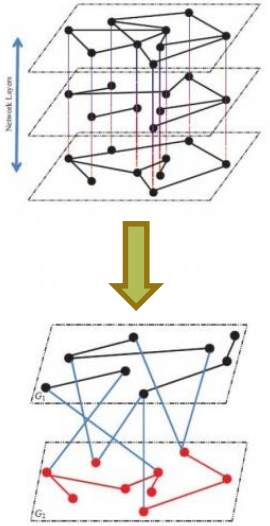


Evaluation of biorefineries
TEE Analysis
(Technical, Economic and Environmental Assessment)

- Supports update of biorefinery evaluation in the future (e.g. by further developments of the technology)
- Supports modular combination of biorefinery pathways to generate new value chains







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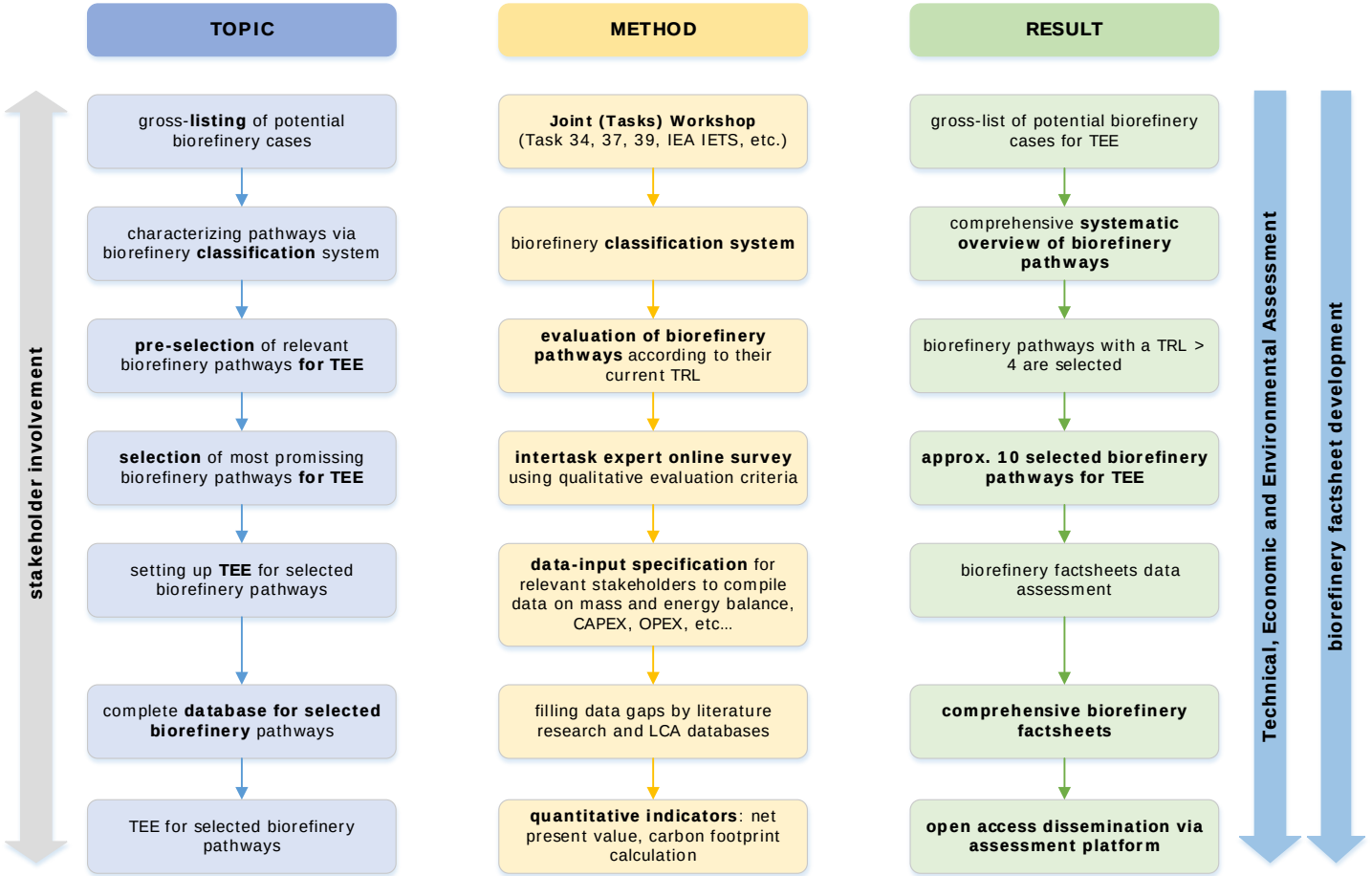
Outlook Collaborative Inter Task Project Technical, Economic and Environmental Assessment of Integrated Biorefineries



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Networking

IEA Bioenergy and its Tasks work on an international level to push ahead and progress within specified topics. The **work model for this is co-operation and interaction** between the participating countries to create additional momentum and utilise synergies.

Interaction between Task 42 and national stakeholders is vital and can create significant value on both sides!

Herzliche Einladung zum Stakeholderworkshop
22. November, 12:30-16:00, BOKU Wien

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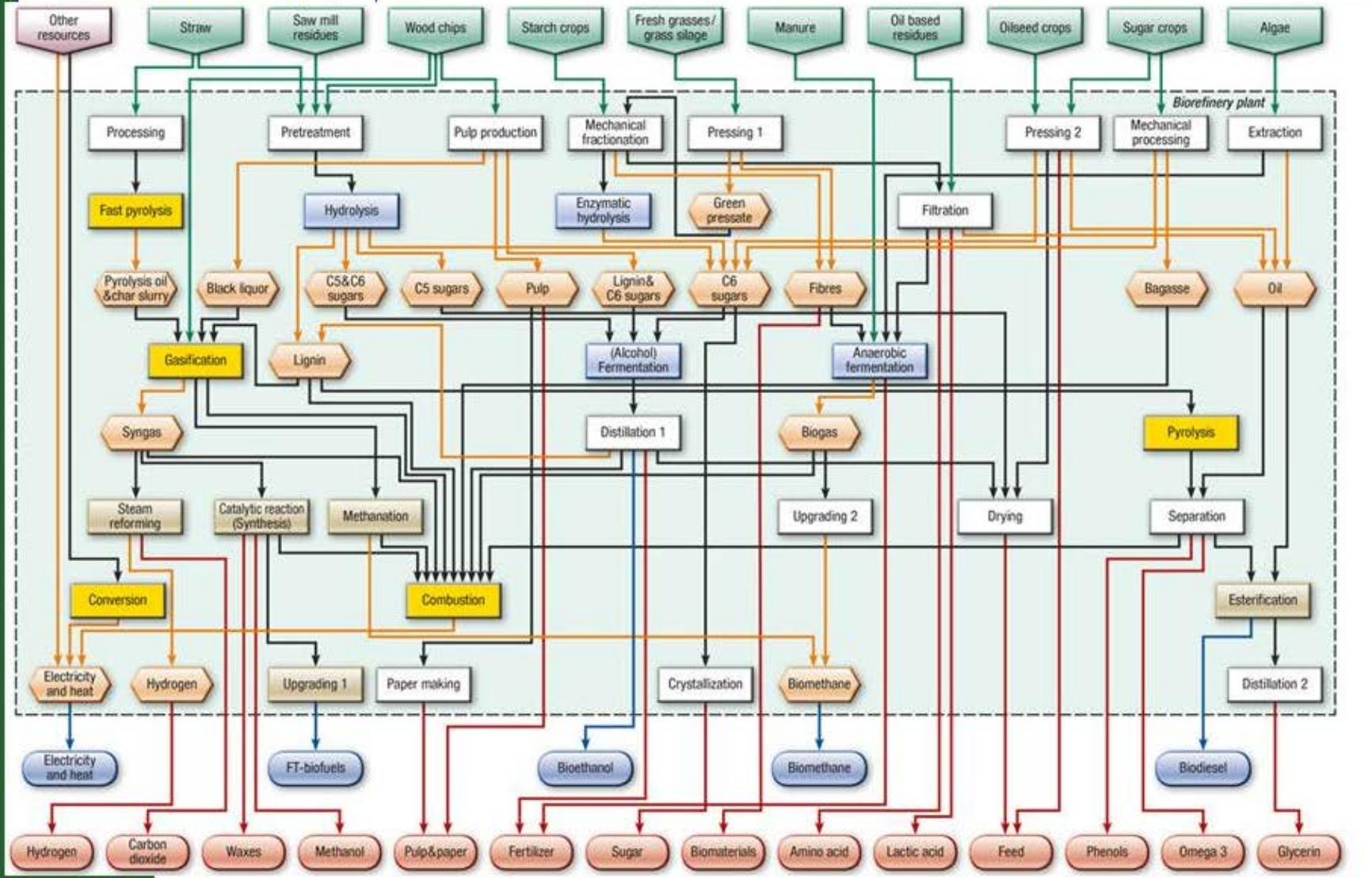
Task 42 Biorefining

Results so far .... Classification Scheme



Source: Joanneum Research, Austria