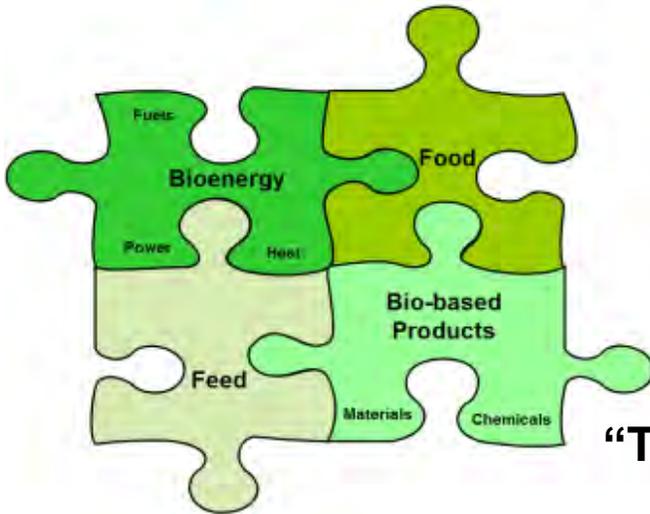


*The Austrian participation in Tasks 42 of IEA Bioenergy is financed by the Federal Ministry for Transport, Innovation and Technology / Department for Energy and Environmental Technologies*

# JOANNEUM RESEARCH Forschungsgesellschaft mbH



## Approach for the Integration of Biorefineries in the Existing Industrial Infrastructures



**“The role of industry in a transition towards the BioEconomy in relation to biorefinery”**

**Gerfried Jungmeier**

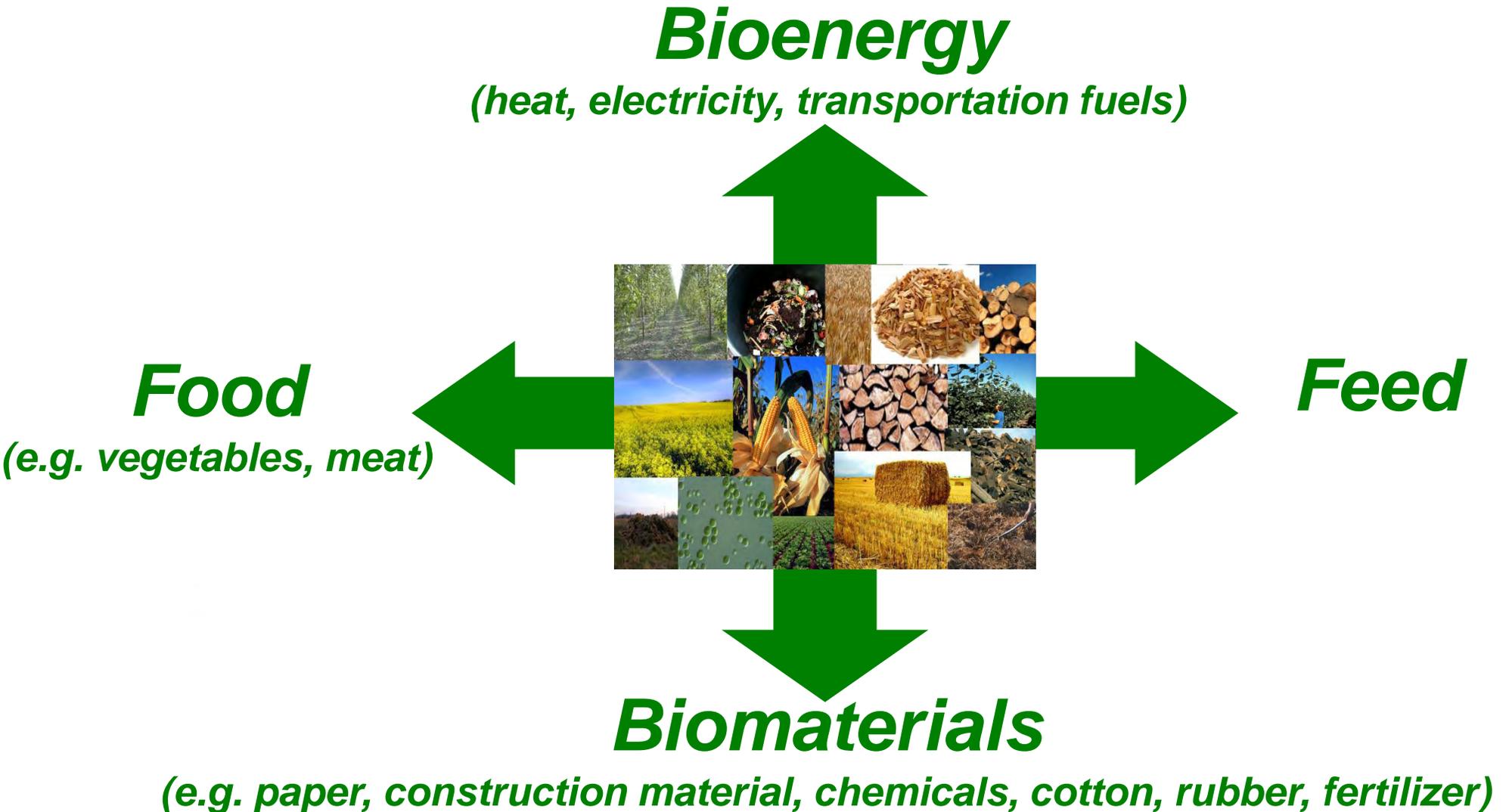
**Workshop @i-SUP2014**

**September 3, 2014 Antwerp/Belgium**

# This is Biomass for Biorefineries in the BioEconomy



# There is Competition for Different Biomass Uses



# A Statement



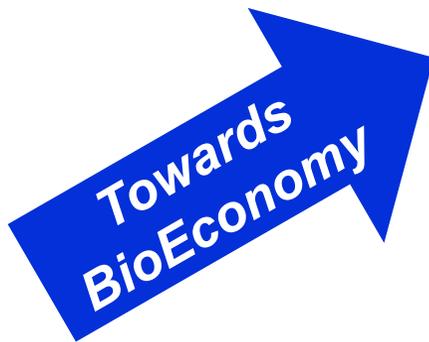
**“There is no scientific evidence that the material use of biomass provides greater sustainability benefits than the energetic use, or vice versa.**



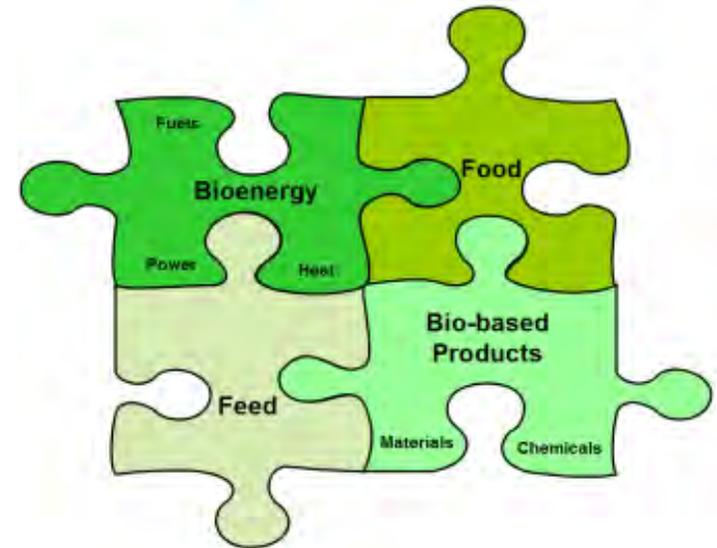
**BUT there is evidence that the combined energetic and material use (“biorefining”) of biomass has the potential for large sustainability benefits”**

# The New Way in BioEconomy: From Competition to Integration

## Competition



## Integration



**Bioenergy**  
(heat, electricity, transportation fuels)

**Food**  
(e.g. vegetables, meat)



**Feed**

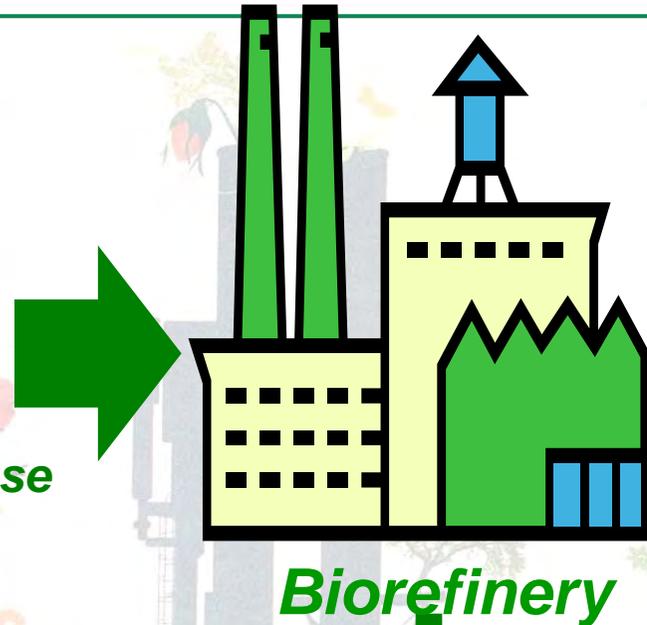
**Biomaterials**

(e.g. paper, construction material, chemicals, cotton, rubber, fertilizer)

# This is a Biorefinery

## Biomass Resources

- oil
- starch
- sugar
- lignocellulose
- ....



## Bioenergy

- *liquid/gaseous transport biofuels*
- *electricity*
- *heat*
- *solid fuels*

## Bioproducts

- *bulk chemicals*
- *fine chemicals*
- *animal feed*
- *food*
- *pulp&paper*
- *materials*
- *fertilizer*
- *gases*
- *.....*

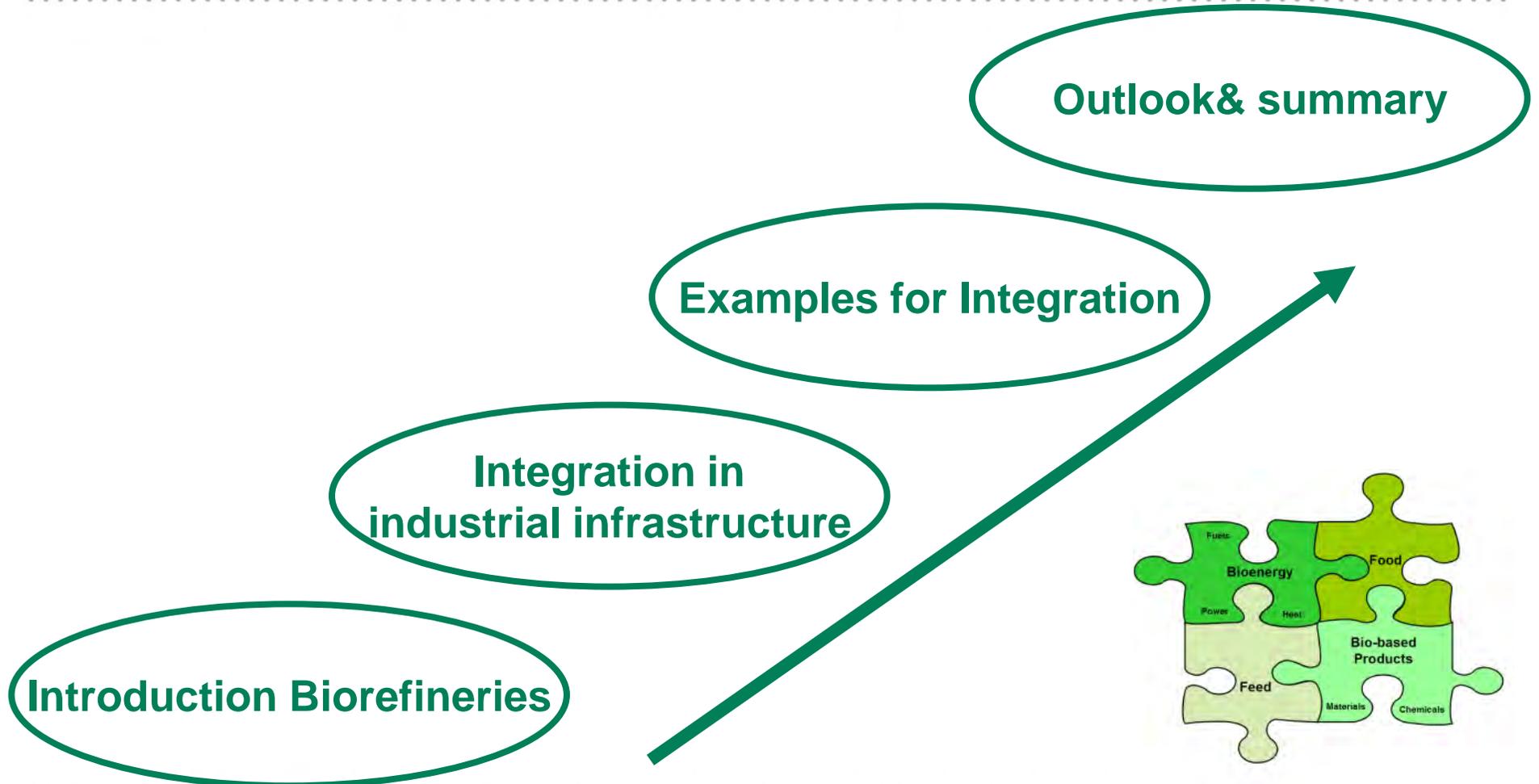
## Based on different conversion processes

- *Bio-chemical*
- *Thermo-chemical*
- *Physical-chemical*
- *Others*

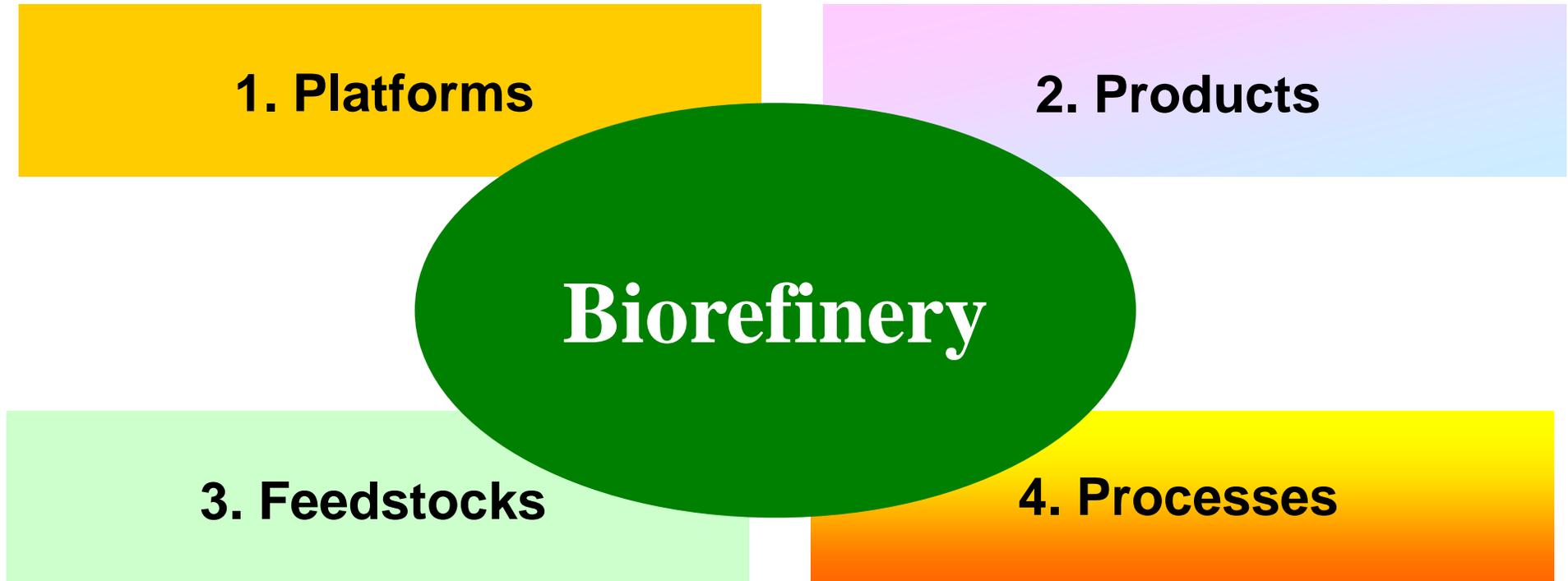
*“Biorefinery is the sustainable processing of biomass into a spectrum of marketable products”*

7

# Outline



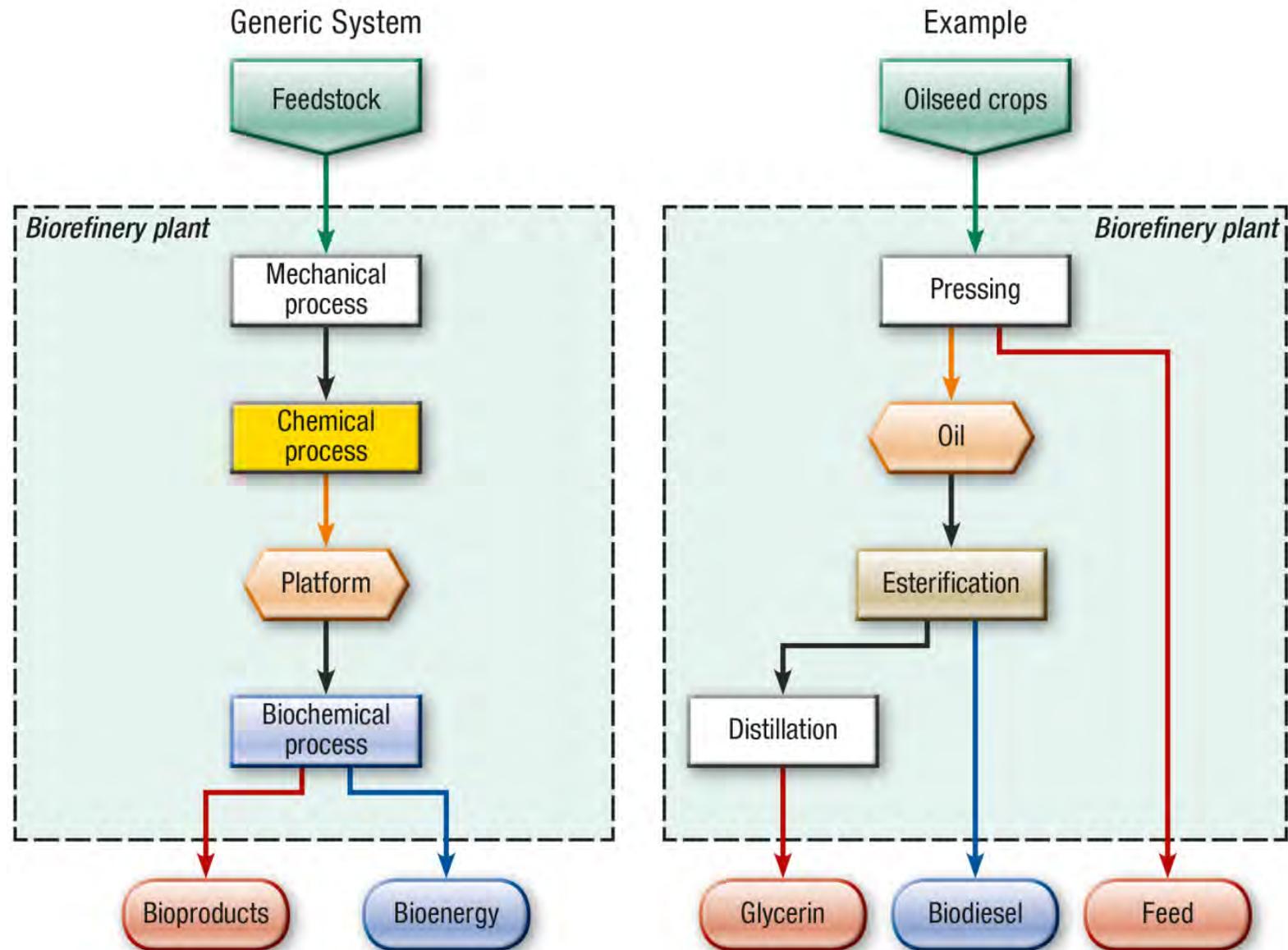
# The 4 Features to Characterise A Biorefinery Systems



## ***Naming:***

- *Number platforms (Name of platforms)/Feedstock/Products/Processes*
- *e.g. 2-platform (electricity&heat, syngas) biorefinery/wood chips/FT-biofuels, electricity, heat, waxes/steam gasification*

# Application of Classification System



# Classification System is Now in Use ....

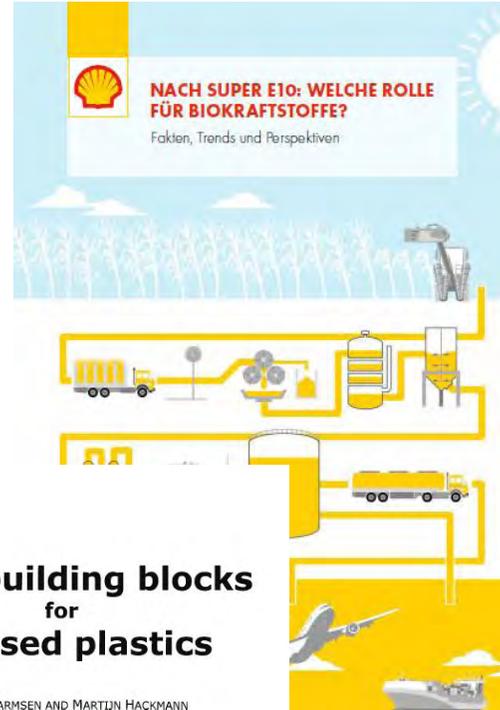
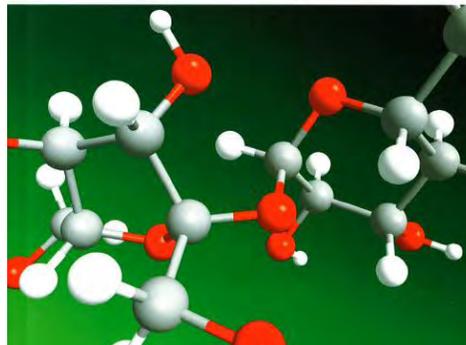


Joint European Biorefinery Vision for 2030  
Star-COLIBRI  
STRATEGIC TARGETS FOR 2020 – COLLABORATION INITIATIVE ON BIOREFINERIES



## Green building blocks for biobased plastics

PAULIEN HARMSEN AND MARTIJN HACKMANN



## NACH SUPER E10: WELCHE ROLLE FÜR BIODIESELSTOFFE?

Fakten, Trends und Perspektiven

ICS 13.020.20, 65.040.20, 71.020 VDI-RICHTLINIEN Februar 2014

VEREIN DEUTSCHER INGENIEURE	Klassifikation und Gütekriterien von Biorafinerien	VDI 6310 Blatt 1 Entwurf
-----------------------------------	--	--------------------------------

Classification and quality criteria of biorefineries

Einsprüche bis 2014-07-31

- vorzugsweise über das VDI-Richtlinien-Einspruchsportal <http://www.vdi.de/einspruchsportal>
- in Papierform an VDI-Gesellschaft Technologies of Life Sciences Fachbereich Biotechnologie Postfach 10 11 39 40002 Düsseldorf

Inhalt	Seite	Inhalt	Seite
Vorbemerkung	2	<b>6 Anwendung ausgewählter Methoden auf das Praxisbeispiel „grüne Biorafinerie“</b>	38
Einführung	2	6.1 Einführung	38
<b>1 Anwendungsbereich</b>	3	6.2 Beschreibung der Anlage – Biowerkstoffmarkt, Bundesland	39
<b>2 Normative Verweise</b>	4	6.3 Ökonomische Bewertung	41
<b>3 Begriffe</b>	4	6.4 Ökologische Bewertung	46
<b>4 Technologie der Biorafinerie</b>	6	6.5 Stufenbewertung	51
4.1 Klassifizierung von Biorafinerianlagen	6	6.6 Wahrnehmung gesellschaftlicher Verantwortung	51
4.2 Technologische Konzepte	8	<b>6.7 Fazit aus der Anwendung der Gütekriterien</b>	52
<b>5 Definition von Bewertungsmethoden und zugehöriger Kenngrößen</b>	14	<b>7 Schlussfolgerung</b>	52
5.1 Allgemeine Standortfaktoren	14	Schlusssatz	54
5.2 Integrationsniveau und Standards für Biorafinerien	15		
5.3 Biomassebereitstellung	16		
5.4 Marktstrategische Ausblicke	22		
5.5 Methodischer Rahmen zur Ermittlung von Kenngrößen	23		
5.6 Definition von Bewertungsgrößen/Bewertung	24		
5.7 Wahrnehmung gesellschaftlicher Verantwortung	36		

VDI-Gesellschaft Technologies of Life Sciences  
Fachbereich Biotechnologie

VDI-Handbuch Biotechnologie  
VDI-Handbuch Energietechnik  
VDI-Handbuch Ressourcenmanagement in der Umwelttechnik  
VDI-Handbuch Technik Biomasse/Boden  
VDI-Handbuch Verfahrenstechnik und Chemieingenieurwesen, Band 1: Bewertung/Stoffwerte  
VDI-Handbuch Verfahrenstechnik und Chemieingenieurwesen, Band 2: Planung/Projektierung  
VDI-Handbuch Verfahrenstechnik und Chemieingenieurwesen, Band 5: Spezielle Verfahrenstechnik



## Roadmap Biorafinerien

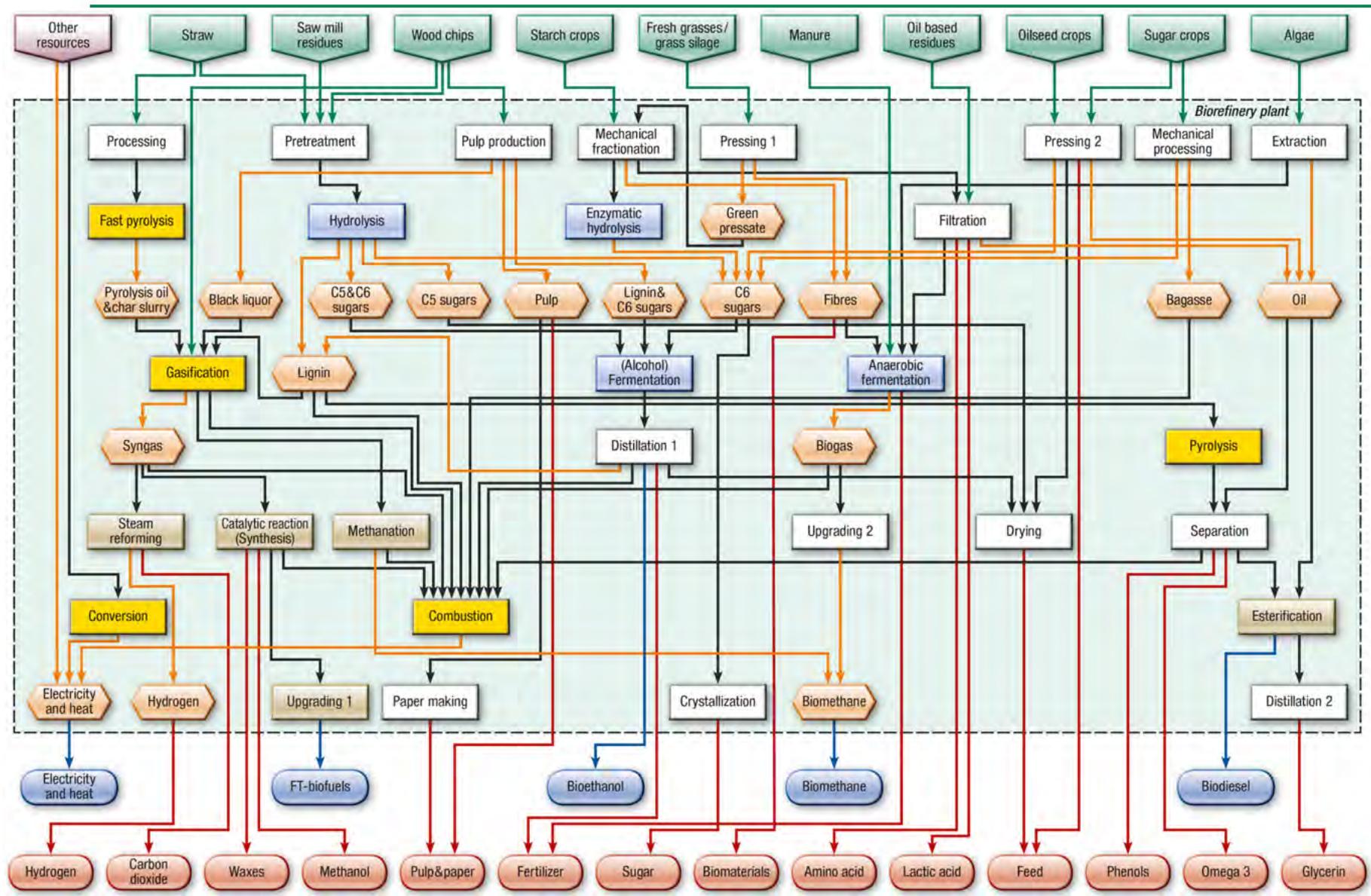
im Rahmen der Aktionspläne der Bundesregierung zur stofflichen und energetischen Nutzung nachwachsender Rohstoffe



European Biorefinery Joint Strategic Research Roadmap  
Star-COLIBRI  
STRATEGIC TARGETS FOR 2020 – COLLABORATION INITIATIVE ON BIOREFINERIES



# 14 Biofuel-driven Biorefineries for Biobased Economy in 2025



# Report on “Biofuel-driven Biorefineries”

IEA Bioenergy

Task 42 Biorefining

## Biofuel-driven Biorefineries



**A Selection of the Most Promising  
Biorefinery Concepts to  
Produce Large Volumes of Road  
Transportation Biofuels by 2025**

.....Based on this **first selection of most promising biorefinery concepts to produce large volumes of road transportation biofuels by 2025** the Task 42 is assessing the sustainability of these biorefinery concepts by analyzing economic, environmental and social aspects in comparison to conventional processes and products.

**In a next step a “biorefinery fact sheet”** for each of these selected “energy driven” biorefineries is developed, key characteristics for a specific production capacity of road transportation biofuel .....

[www.iea-bioenergy.task42-biorefineries.com](http://www.iea-bioenergy.task42-biorefineries.com)

This report, that was prepared on behalf of IEA Bioenergy – Task42 Biorefinery, addresses a selection of the most promising biorefinery concepts to produce large volumes of road transportation biofuels by 2025. Biorefining, i.e. the sustainable processing of biomass into a spectrum of marketable bio-based products (food/feed ingredients, chemicals, materials) and bioenergy (fuels, power, heat), is the optimal approach to use biomass resources as efficient as possible, thereby optimising the specific financial added-value obtained from the biomass at acceptable social and ecological impact. In energy or biofuel-driven biorefineries the main focus is to produce transportation fuels from biomass, where chain composing agro-, forestry and process residues are used to co-produce added-value bio-based products to make the overall product portfolio more market competitive.

The road transportation biofuels produced in both commercial scale, demonstration scale and conceptual biofuel-driven biorefineries dealt with in this report are: 1) biodiesel from oilseed crops and residues, 2) bioethanol from sugar and starch crops, 3) bioethanol from straw – biochemical pathway, 4) bioethanol from wood – combined bio-/thermochemical pathway, 5) bio-methane from grass and manure, 6) bio-methane from wood, 7) FT-biofuels from straw, 8) FT-biofuels from wood, 9) bioethanol from wood and liquor, 10) bioethanol from starch crops and straw, 11) biofuels from microalgae. Concepts 3, 4, and 5 are environmentally assessed in more detail in section 5.

The purpose of the report is to provide an unbiased, authoritative statement aimed at stakeholders from the agro-sector, forestry sector, industry, SMEs, policy makers, and NGOs.

IEA Bioenergy

# Purpose of the Biorefinery Fact Sheet

*What are the facts & figures of different biorefineries?*

*Look here, you find facts & figures in our Biorefinery Fact Sheet*

„Biorefinery Fact Sheets“ is *linking element* of Task 42 activities:

- ✓ **Market deployment aspects for biorefineries** (success factors, changing technologies, central/decentral processing, Biorefinery-Complexity-Index)
- ✓ **Stakeholder support for future BioEconomy** (integration in existing industrial infrastructures, Factsheets major biorefineries, National case-studies, added-value products)
- ✓ **Optimal sustainable biomass valorization** (supply chains, biomass demand, optimal biomass valorisation)
- ✓ **Policy&decision advice** (roadmap, policies, country reporting)
- ✓ **Dissemination&training activities** (task&stakeholder meetings, website incl. data-base biorefineries, newsletters, reports, brochures & leaflets, presentations, training course)

# Overview Biorefinery Fact Sheet

## Part A: Biorefinery Plant

### Biorefinery FACT SHEET

"2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification"

#### Part A: Biorefinery plant

The demonstration scale energy driven biorefinery 2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification" is shown in Figure 11.

Within the 2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification" the wood chips are gasified with steam to produce a product gas, which is used to produce raw FT-biofuels via a catalytic reaction (FT-synthesis). The final quality of the transportation FT biofuel is reached in the upgrading step, e.g. hydroprocessing. The process residues are combusted to produce electricity and heat. As a further product waxes are produced.

Depending on the further successful development beside the steam gasification of wood, which is suitable for smaller to medium sized gasifiers also the gasification with oxygen for large applications (e.g. entrained flow gasification) might become interesting. The large amount of syngas will then be an optimal starting point to produce additional synthetic products depending on the market demand for biomass based chemicals, e.g. methanol.

Case study, example

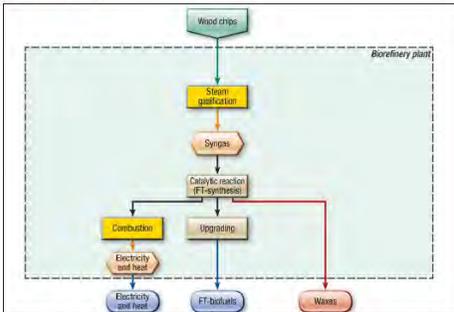


Figure 11: 2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification

Table 3: Key characteristics of biorefinery plant – Austrian feasibility study

Biorefinery plant			
Biorefinery Complexity Index (Products/Platform/Feedstock/Processes)	14.5 (4.6/3/2/5)		
State of technology:	conceptual		
Products	FT-diesel 105 [kt/a]	FT-gasoline 70 [kt/a]	waxes 10 [kt/a]
Feedstock	wood chips 1,459 [kt/a]	water content 45% [%]	
Efficiencies	input to products 12.4%	input to transportation biofuel 11.8%	mass energy 54% 49%
Auxiliaries (external)	electricity 0 [PJ/a]	heat 0 [PJ/a]	materials 29 [kt/a]
Costs	investment 500 [Mio €]	feedstock 100 [€]	

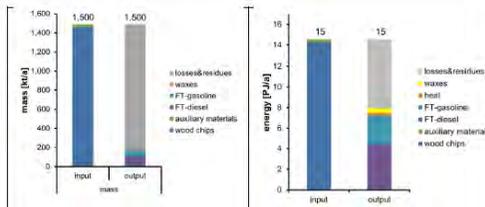


Figure 12: Mass balance of biorefinery plant

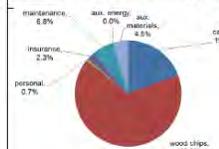


Figure 14: Share of costs

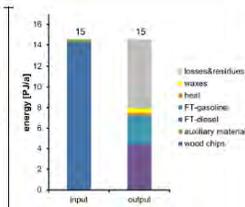


Figure 13: Energy balance of biorefinery plant

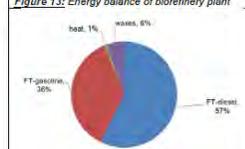


Figure 15: Share of revenues

## 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

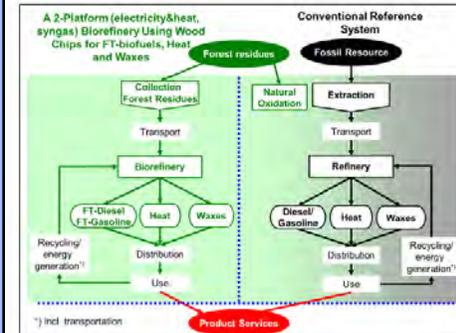


Figure 16: Comparison of biorefinery with conventional reference system on whole value chain (incl. "end of life treatment")

Table 4: Key characteristics of biorefinery value chain – generic example

Whole value chain		
Greenhouse gas emissions	range	
biorefinery	70 (66 to 011)	[kt CO <sub>2</sub> -eq/a]
reference system	690 (640 to 790)	[kt CO <sub>2</sub> -eq/a]
saving	-620 (-67 to -592)	[%]
Cumulated energy demand		
fossil		
biorefinery	0.6 (0.56 to 0.69)	[PJ/a]
reference system	9.2 (8.5 to 11)	[PJ/a]
saving	-93 (-92 to -95)	[%]
total	14.9 (14 to 17)	[PJ/a]
biorefinery	9.6 (9.1 to 11)	[PJ/a]
reference system	9.6 (9.1 to 11)	[PJ/a]
change	52 (27 to 87)	[%]
Agricultural area demand		
feedstock	0 to 0	[ha/a]
Costs		
annual costs	220 (200 to 250)	[Mio €/a]
specific costs	1,200 (1100 to 1400)	[€/t]
Revenues		
annual revenues	224 (210 to 260)	[Mio €/a]
specific revenues	1,200 (1100 to 1400)	[€/t]

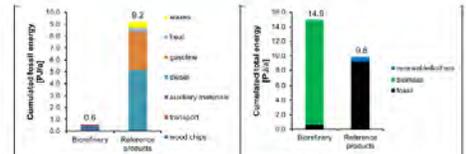


Figure 17: Estimated cumulated fossil energy demand of biorefinery and reference products

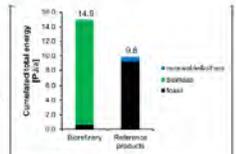


Figure 18: Estimated cumulated energy demand of biorefinery and reference products

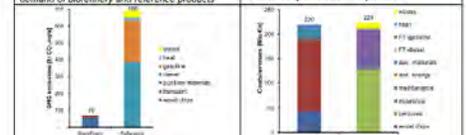


Figure 19: Estimated greenhouse gas emissions of biorefinery and reference products

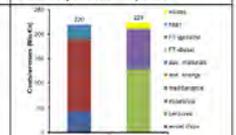


Figure 20: Estimated cost and revenues of biorefinery plant

## Annex:

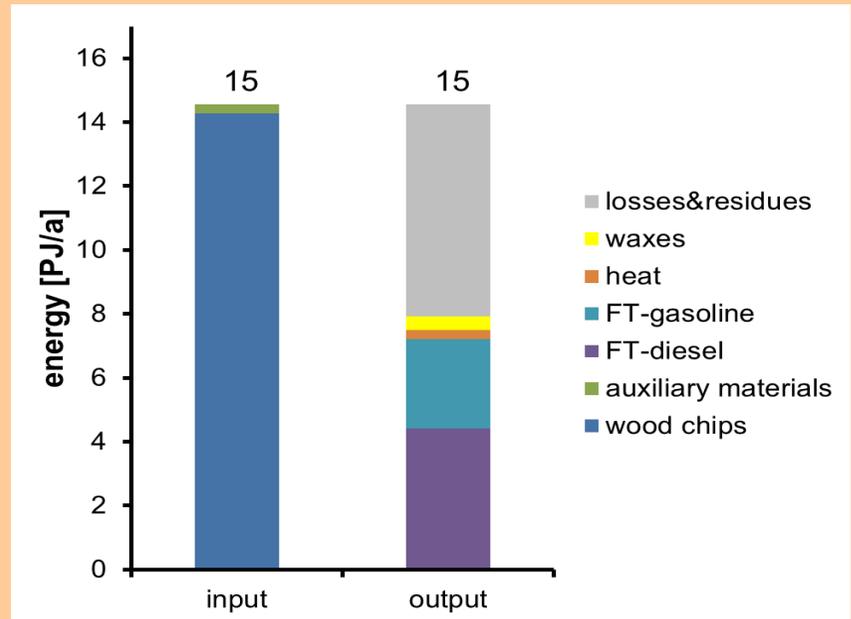
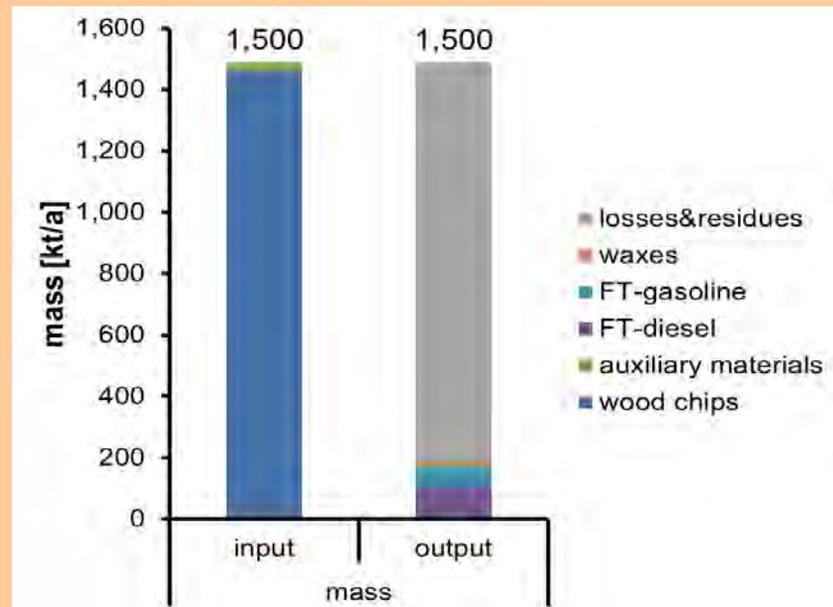
## Methodology of sustainability assessment and data with references

# Part A: Biorefinery Plant Mass and Energy Balance

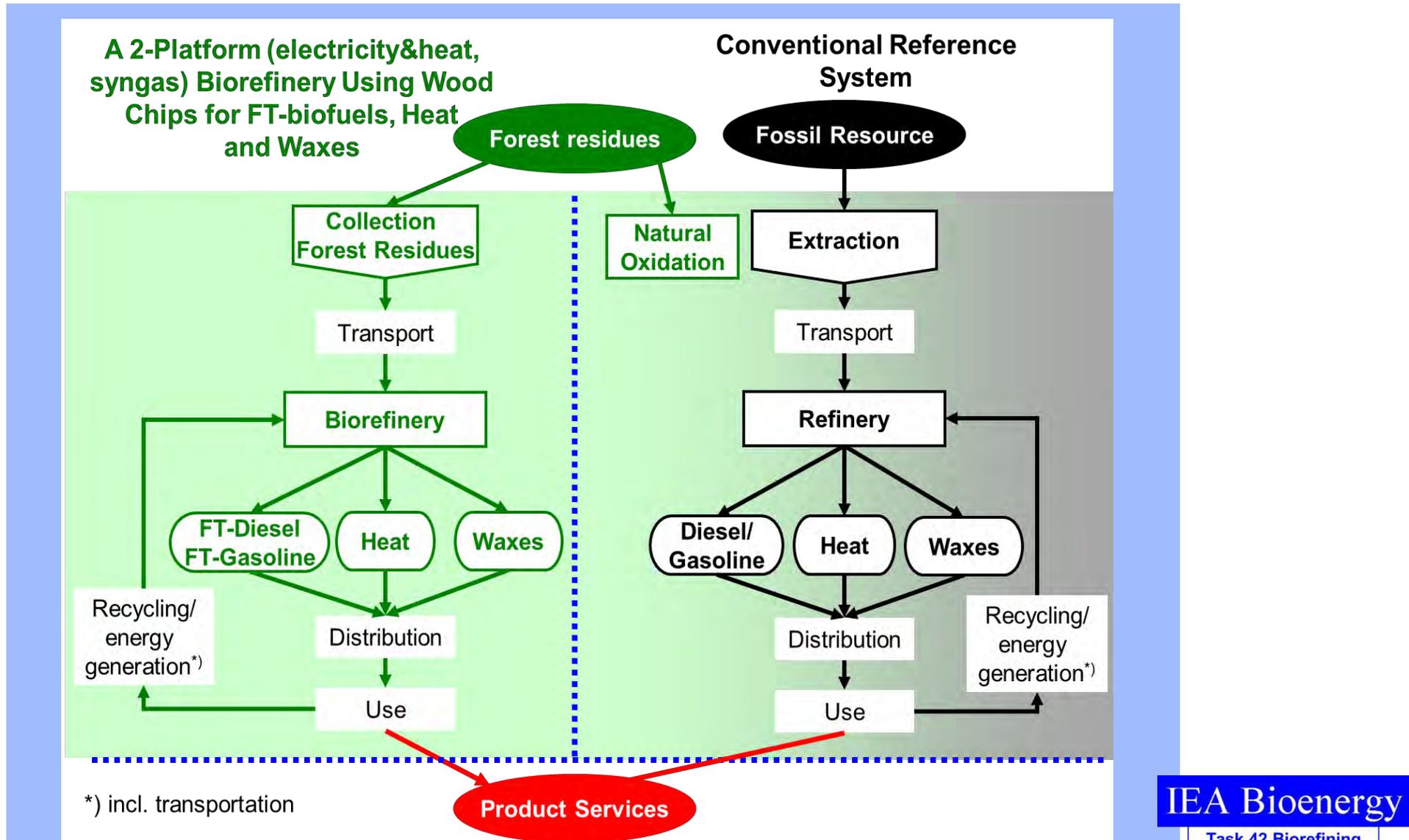
Biorefinery plant			
Biorefinery Complexity Index (Products/Platform/Feedstock/Processes)		14.5 (4.5/3/2/5)	
State of technology:		conceptual	
Products		Auxiliaries (external)	
FT-diesel	105 [kt/a]	electricity	0 [PJ/a]
FT-gasoline	70 [kt/a]	heat	0 [PJ/a]
heat	0.3 [PJ/a]		
waxes	10 [kt/a]	materials	29 [kt/a]
Feedstock		Costs	
wood chips	1,459 [kt/a]	investment	500 [Mio €]
water content	45% [%]	feedstock	100 [€/t]
Efficiencies		mass	energy
input to products		12.4%	54%
input to transportation biofuel		11.8%	49%

**“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”**

*Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)*



# Part B: Value Chain Assessment System Boundaries & Reference System



# Part B: Value Chain Assessment Overview

**“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”**

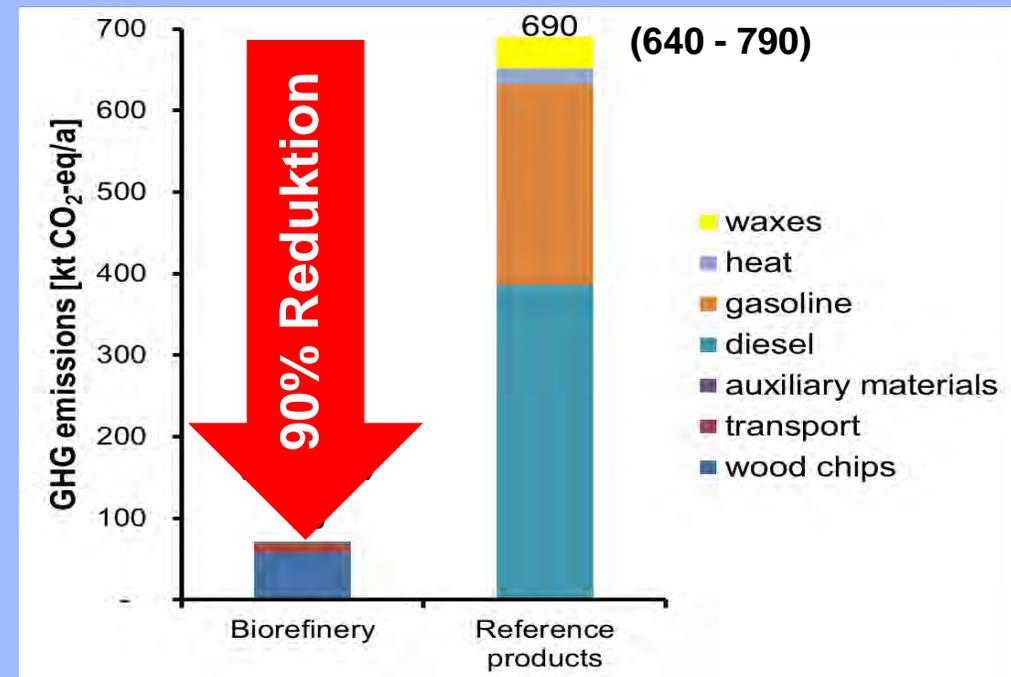
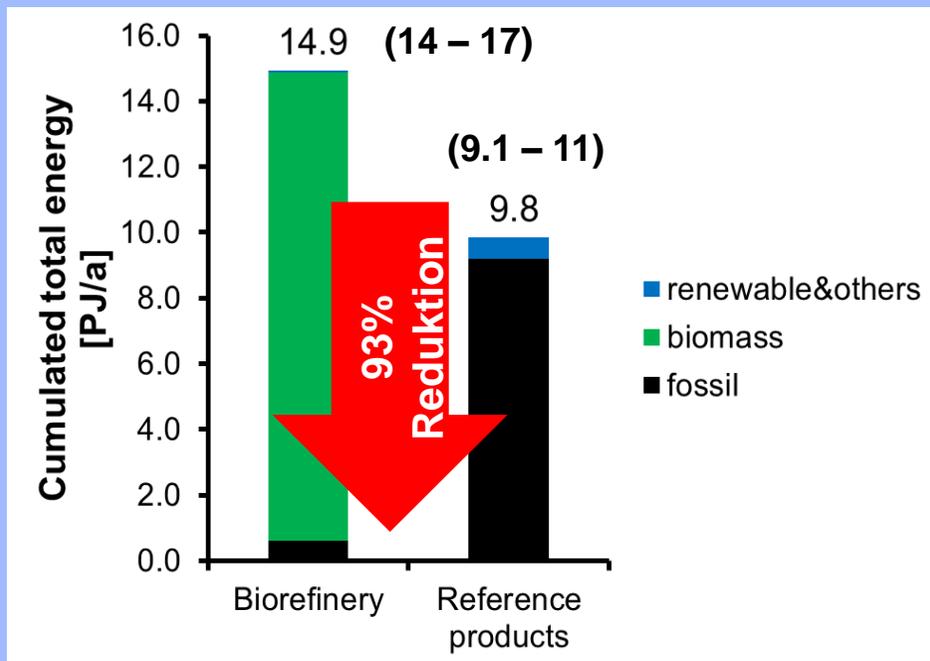
Whole value chain			
<b>Greenhouse gas emissions</b>		range	
biorefinery	70	(66 to 81)	[kt CO <sub>2</sub> -eq/a]
reference system	690	(640 to 790)	[kt CO <sub>2</sub> -eq/a]
saving	-90	(-87 to -92)	[kt CO <sub>2</sub> -eq/a]
<b>Cumulated energy demand</b>			
<b>fossil</b>			
biorefinery	0.6	(0.56 to 0.69)	[PJ/a]
reference system	9.2	(8.5 to 11)	[PJ/a]
saving	-93	(-92 to -95)	[%]
<b>total</b>			
biorefinery	14.9	(14 to 17)	[PJ/a]
reference system	9.8	(9.1 to 11)	[PJ/a]
change	52	(27 to 87)	[%]
<b>Agricultural area demand</b>			
feedstock	-	(0 to 0)	[ha/a]
<b>Costs</b>			
annual costs	220	(200 to 250)	[Mio €/a]
specific costs	1,200	(1100 to 1400)	[€/t]
<b>Revenues</b>			
annual revenues	224	(210 to 260)	[Mio €/a]
specific revenues	1,200	(1100 to 1400)	[€/t]

*Communication in typical ranges & orders of magnitude!*

Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)

# Part B: Value Chain Assessment Primary Energy & GHG Emissions

**“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”**

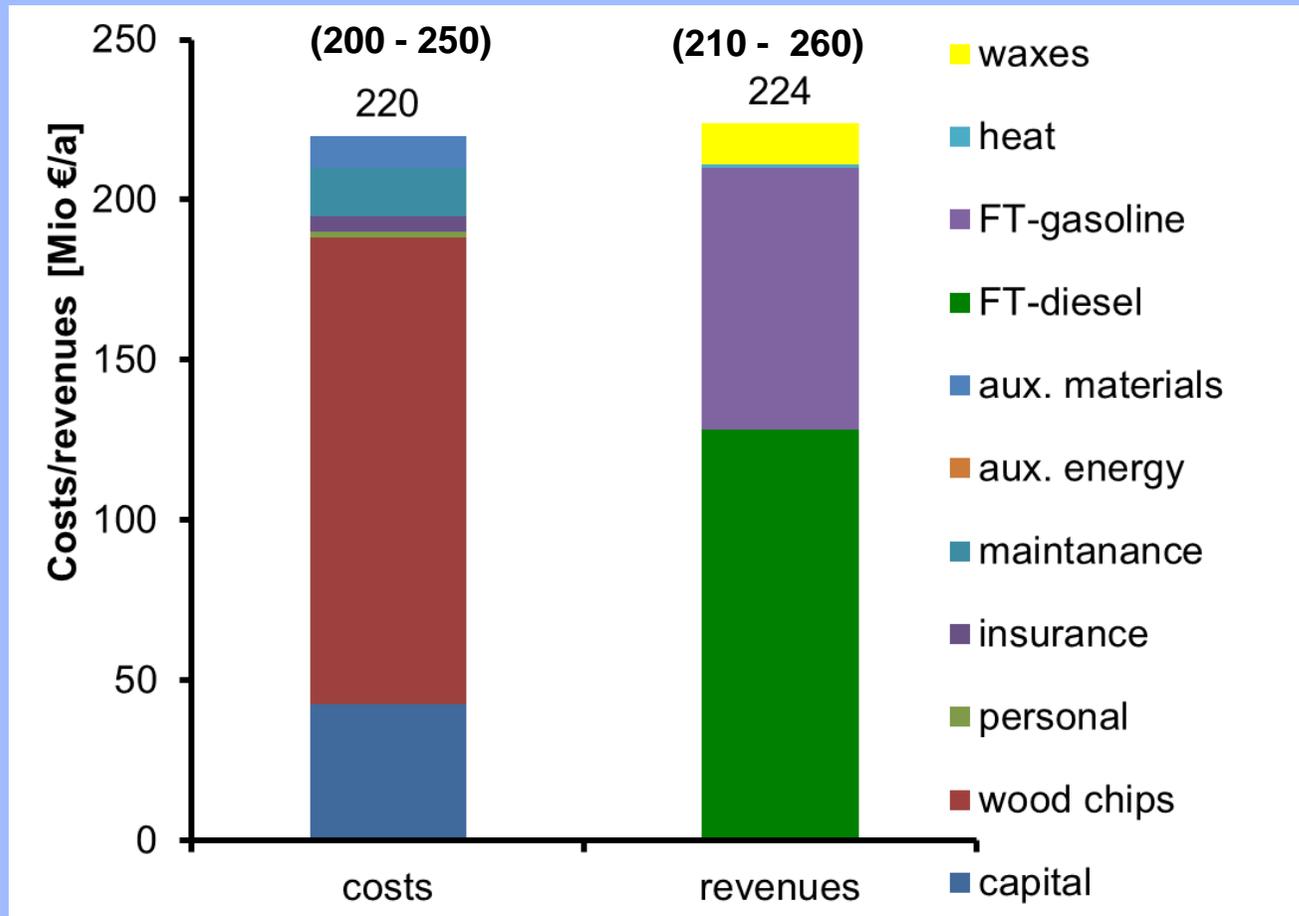


Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)

# Part B: Value Chain Assessment

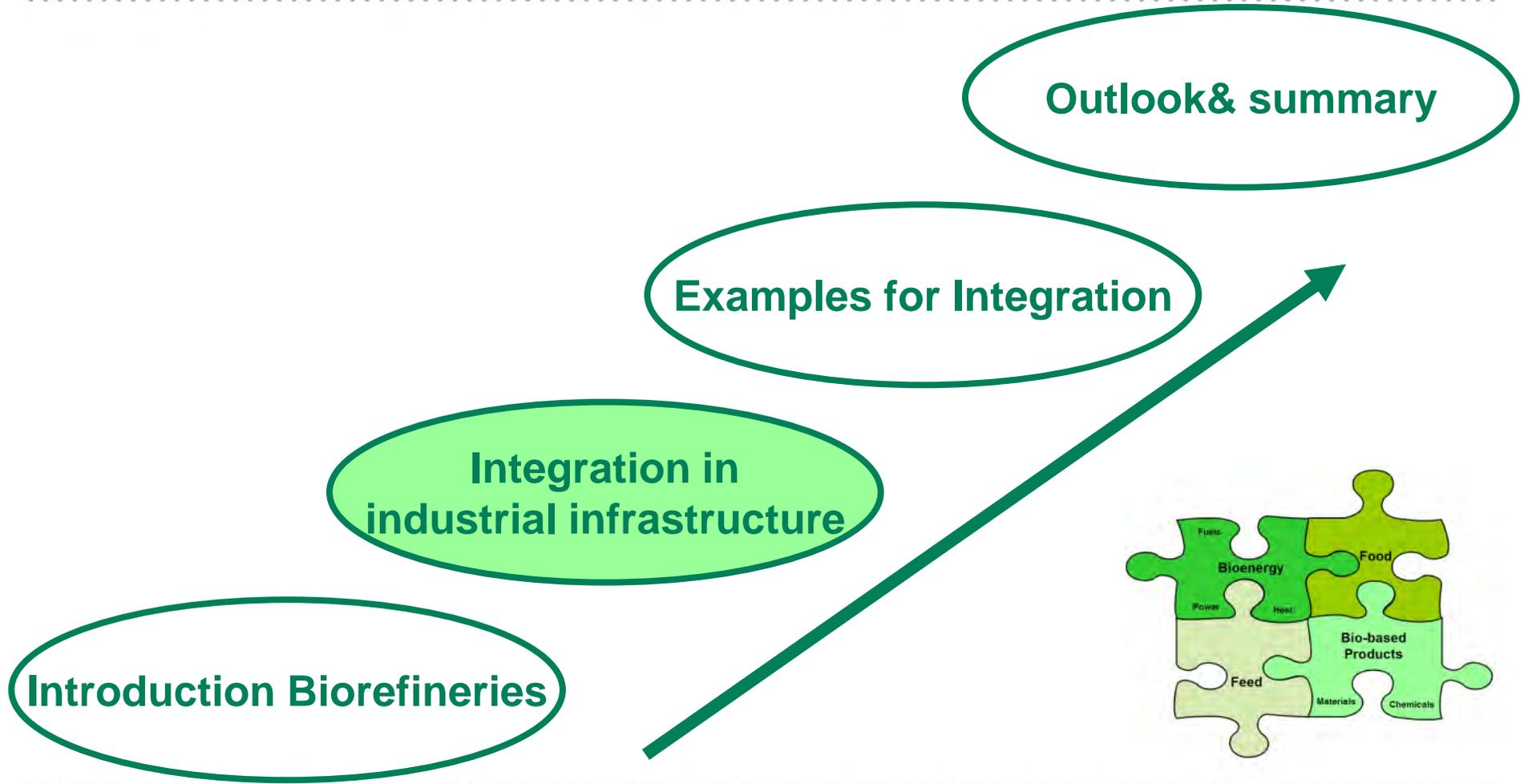
## Cost and Revenues

*“2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification”*



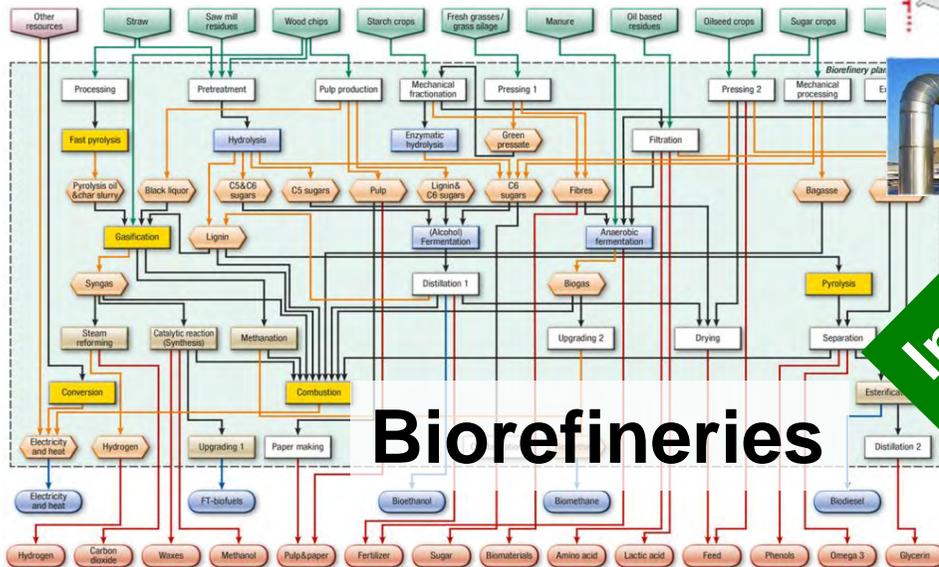
*Own calculations based on Austrian feasibility study (Hofbauer et al. 2008)*

# Outline



# Upgrading Strategies Infrastructures to BioEconomy

21



**Biorefineries**

**Integration**

# Classification of Existing Industrial Infrastructure

22

1. Power and CHP plants
2. Biofuel plants
3. Oil refineries
4. Pulp and paper industry
5. Wood industry
6. Biogas/Biomethane plants
7. Chemical industry
8. Waste treatment plants
9. Food industry
10. Others

***10 Main industry sectors with 31 subsectors***

***classified by***  
***- feedstock***  
***- platforms***  
***- products***  
***- processes***

# Database of Existing Industrial Infrastructure

## 1 Power and CHP plants

- 1.1 heating plant
- 1.2 CHP plant
  - 1.2.1 biomass
  - 1.2.2 fossil (oil, gas, coal)
  - 1.2.3 waste

## 2 Biofuel facilities

- 2.1 biodiesel facilities
- 2.2 bioethanol facilities

## 3 Oil refineries

## 4 Pulp and paper industry

- 4.1 pulp
- 4.2 paper
- 4.3 pulp and paper

## 5 Wood industry

- 5.1 pellet facilities
- 5.2 wood based boards
- 5.3 saw mill

## 6 Biogas/Biomethane plants

- 6.1 biogas CHP
- 6.2 biomethane
- 6.3 green refinery

## 7 Chemical industry

- 7.1 anorganic and organic chemicals
- 7.2 industrial gases
- 7.3 fertiliser
- 7.4 candles and waxes
- 7.5 synthetic material production
- 7.6 food and animal feed additives

## 8 Waste treatment facilities

- 8.1 sewage treatment plants
- 8.2 landfill gas facilities
- 8.3 composting plants

## 9. Food industry

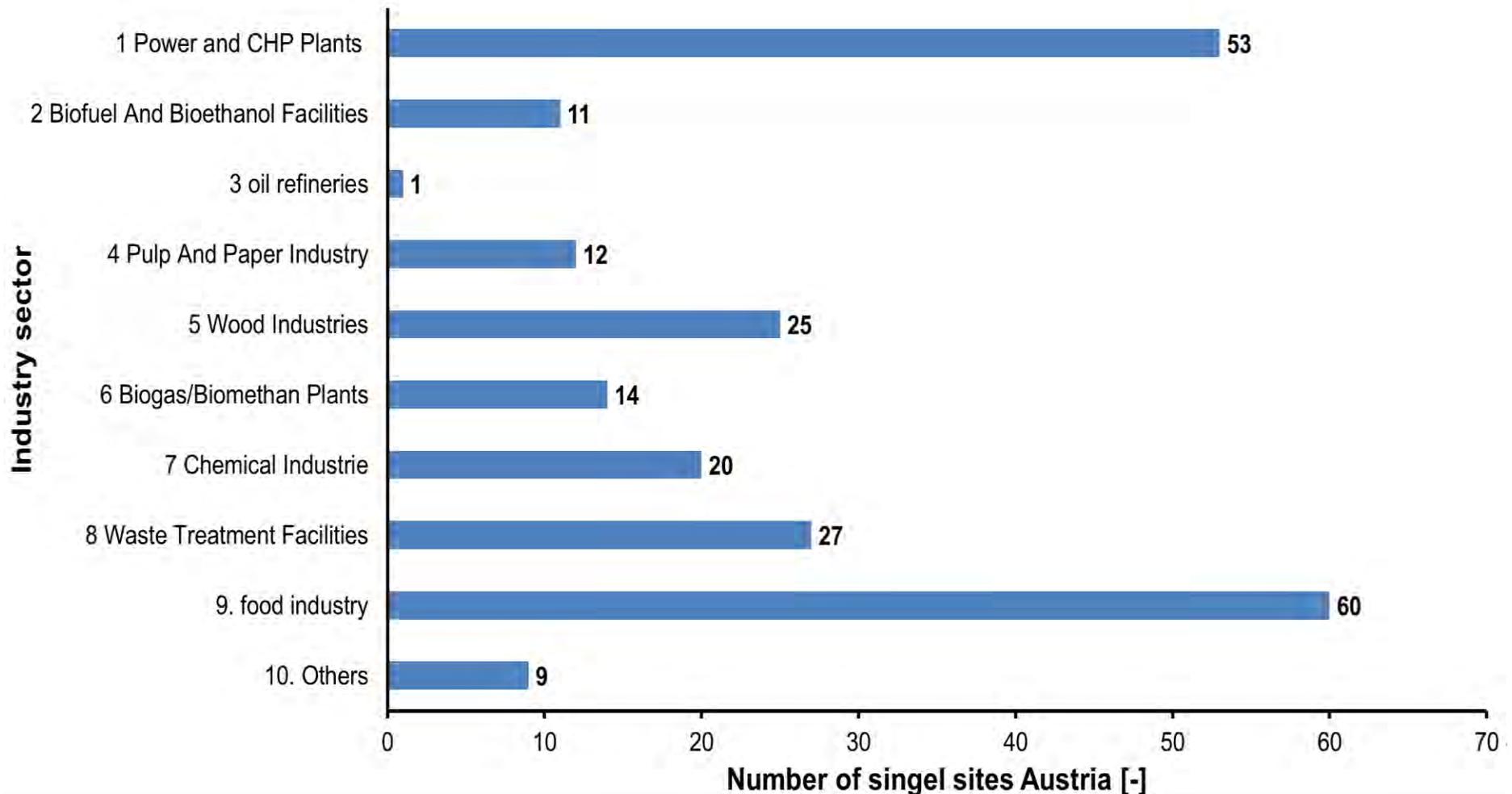
- 9.1 breweries
- 9.2 sugar mills
- 9.3 starch mills
- 9.4 oil presses
- 9.6 fruit + vegetable processing
- 9.7 creameries
- 9.8 bakeries

## 10. Others

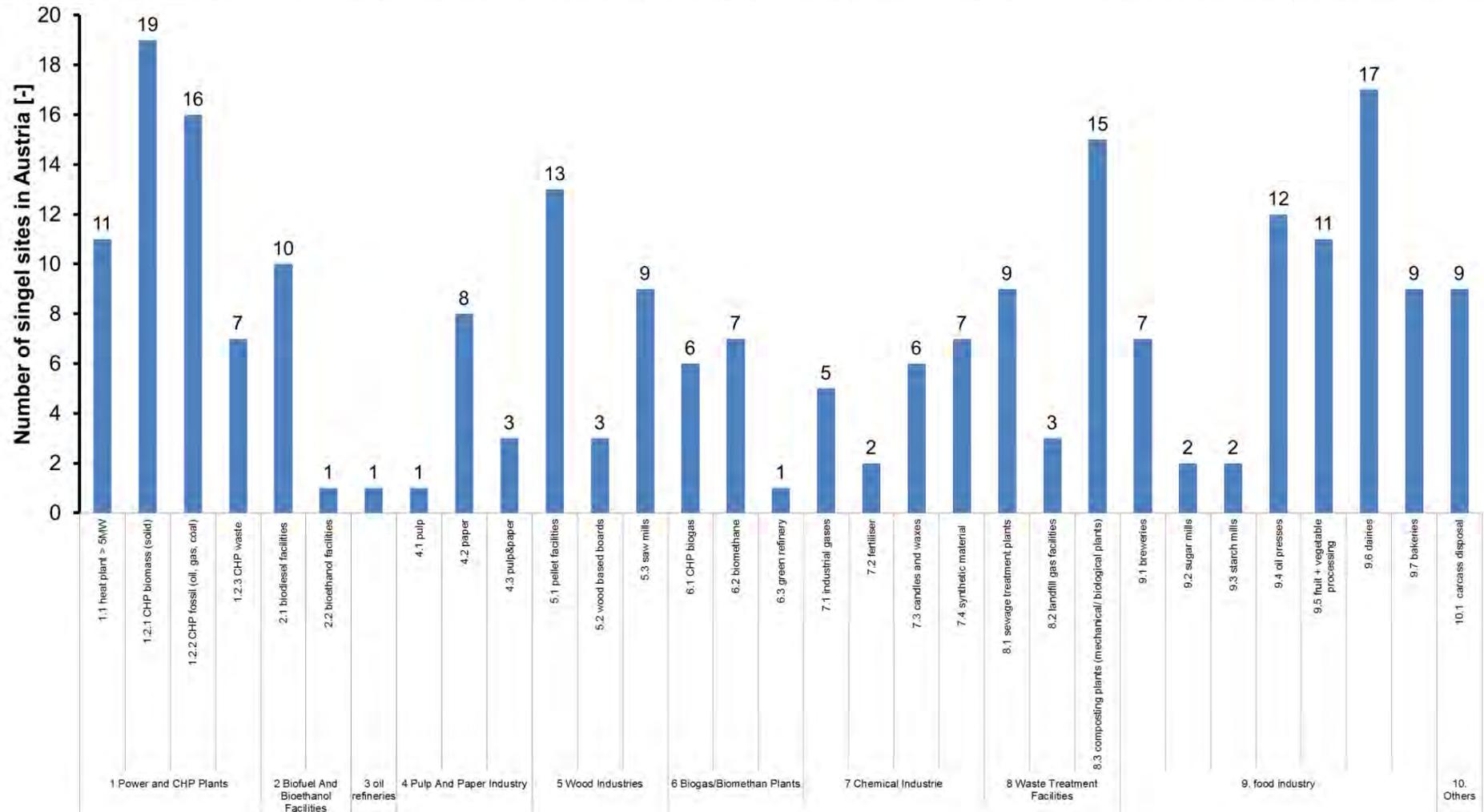
**feedstock, processes, platforms, products**

# Example Austria: 232 Sites in the 10 Main Industry Sectors

24



# Example Austria: Number of Sites in the 31 Industry Subsectors



# Identifying Upgrading Opportunities Towards Biorefineries in the Biobased Industry

26

*Integration opportunities:  
same features in industrial  
infrastructure and the biorefineries*

Existing Industrial infrastructures  
are described based on 4 features

Biorefineries are described  
based on 4 features

**Result**

**High number of common features gives a high possibility for upgrading**

# Importance of Features for Integration

***feedstocks&products***  $\geq$  ***platforms***  $\geq$  ***products***

**Feedstocks: very strong**

**Products: very strong**

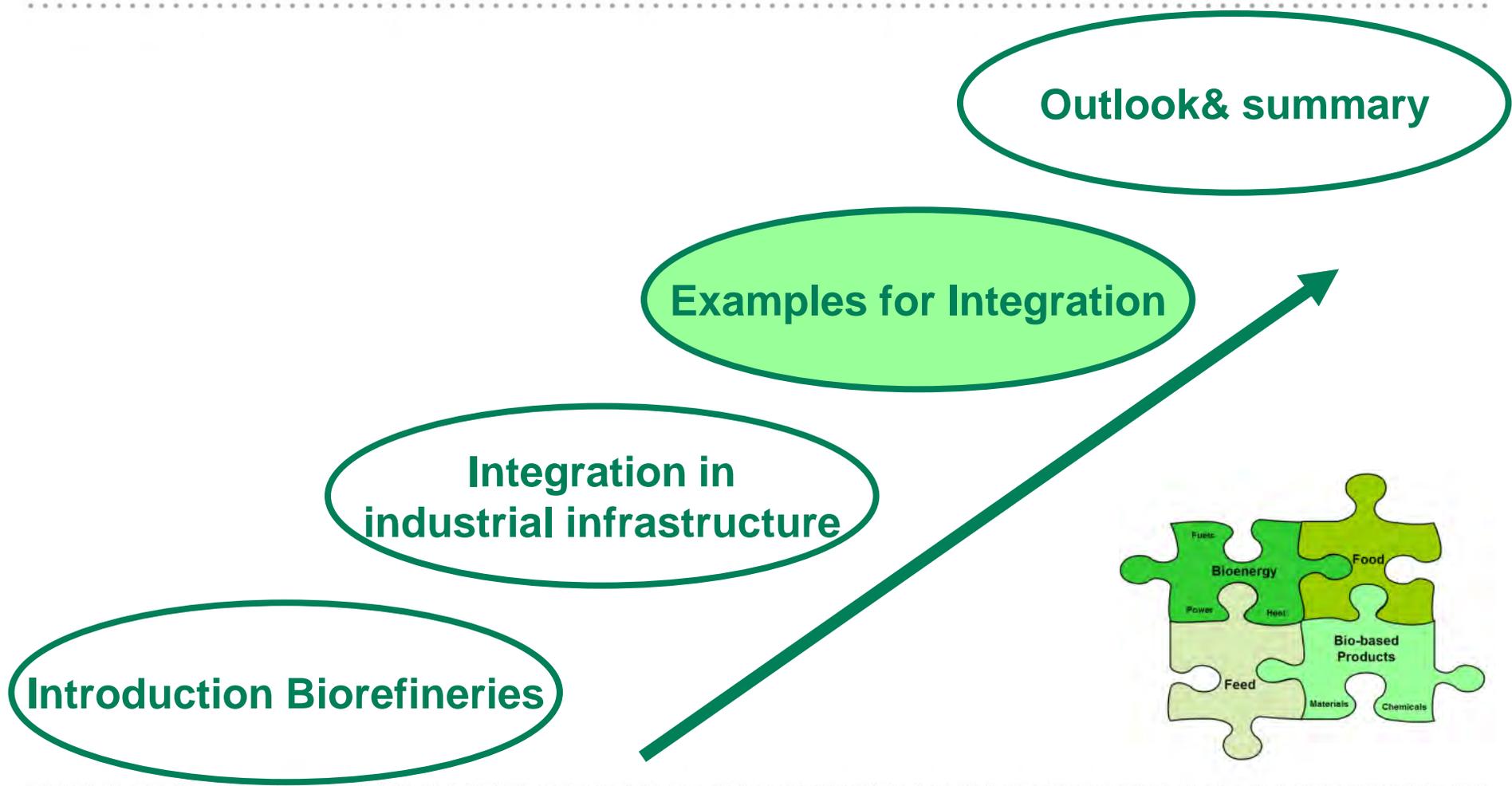
**Platforms: strong**

**Processes: possible**

**Example Austria**

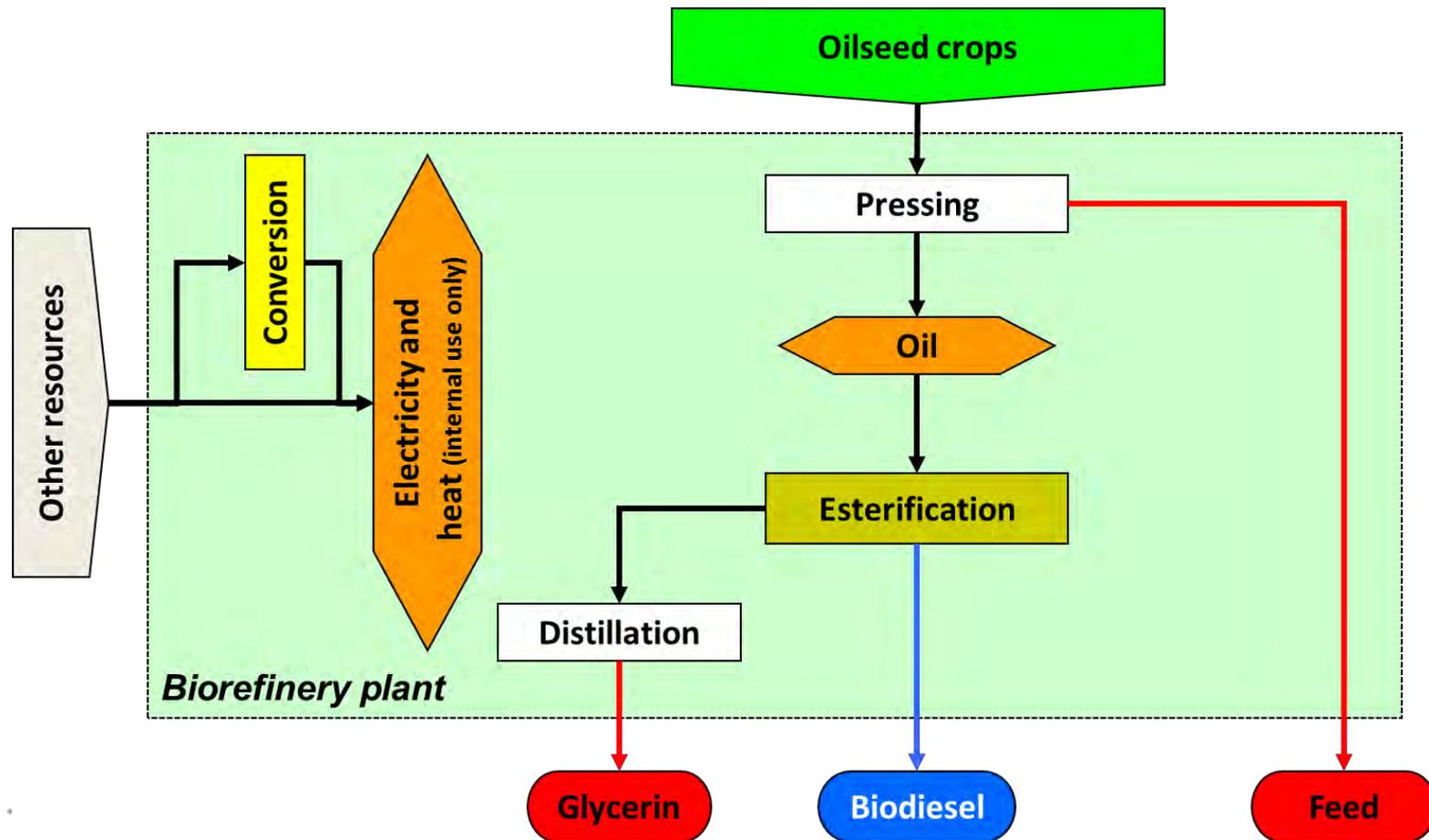
**10 industry sectors and  
14 biofuel-driven biorefineries**

# Outline



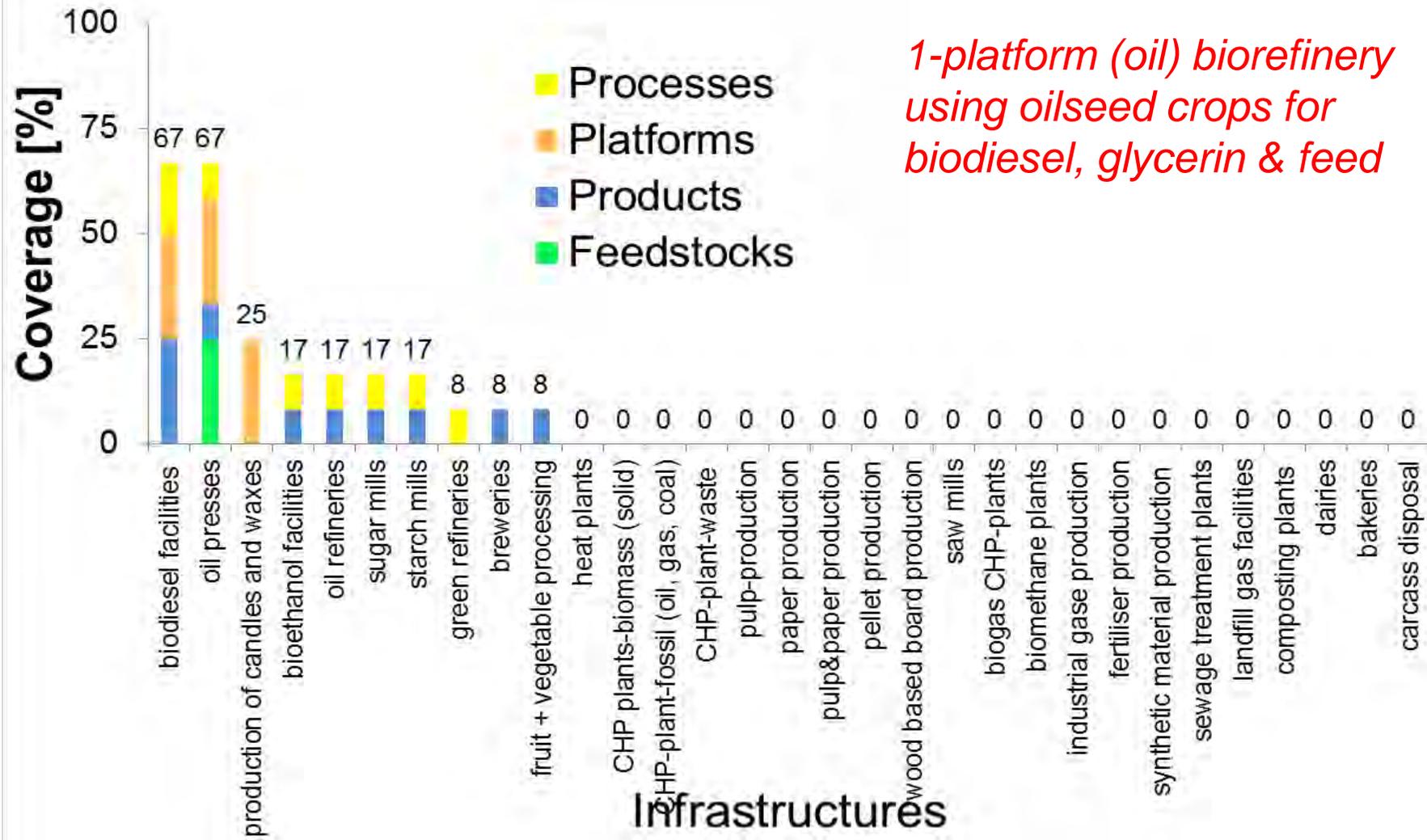
# Example I: How to Integrate this Biorefinery?

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



# Example I: 1 Biorefinery and 31 Industry Subsectors

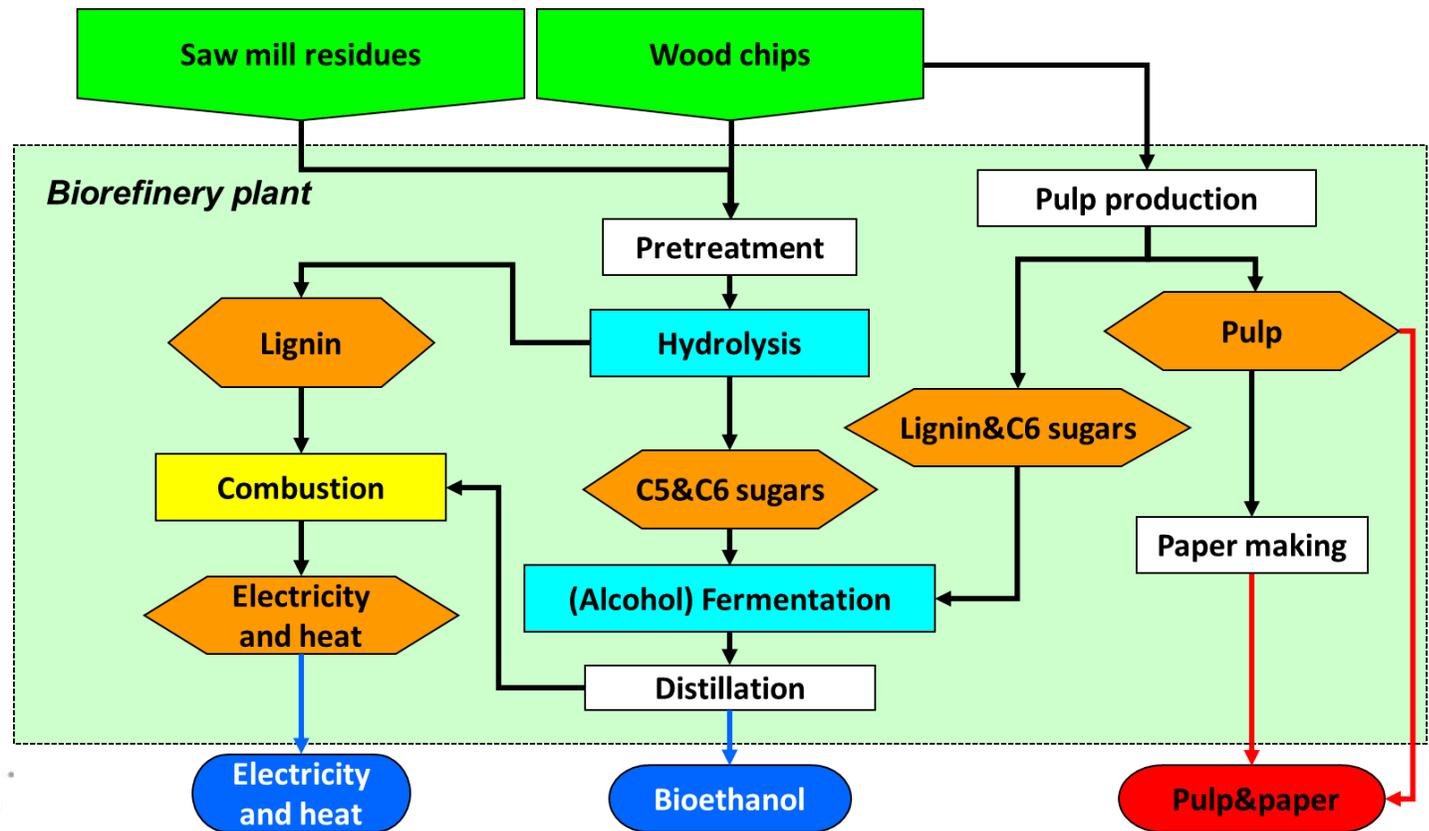
30



*1-platform (oil) biorefinery  
using oilseed crops for  
biodiesel, glycerin & feed*

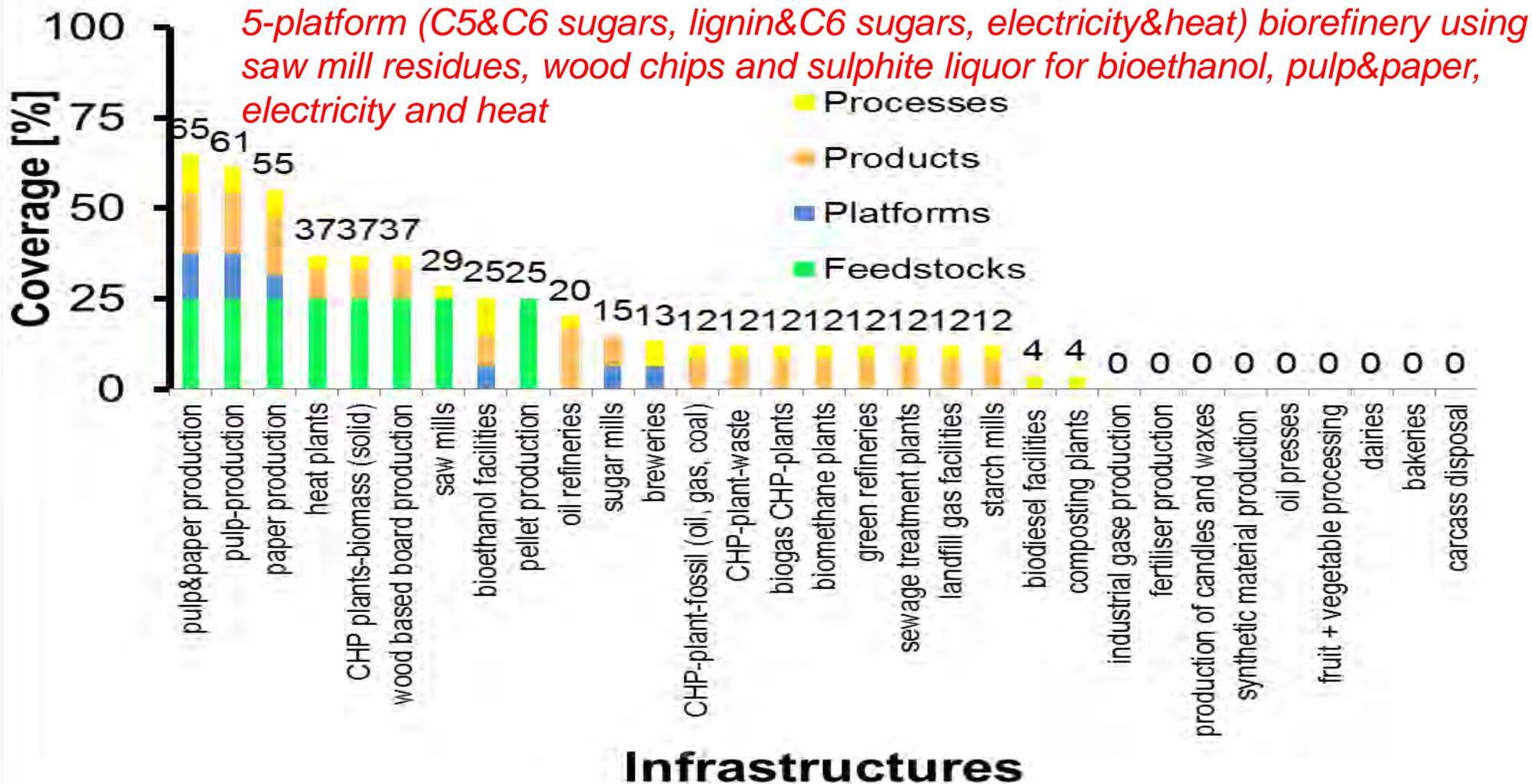
# Example II: How to Integrate this Biorefinery?

*5-platform (C6&C5 sugar, lignin&C6 sugar, electricity&heat) biorefinery using saw mill residues, wood chips and sulfite liquor for bioethanol, pulp&paper, electricity&heat*



# Example II: 1 Biorefinery and 31 Industry Subsectors

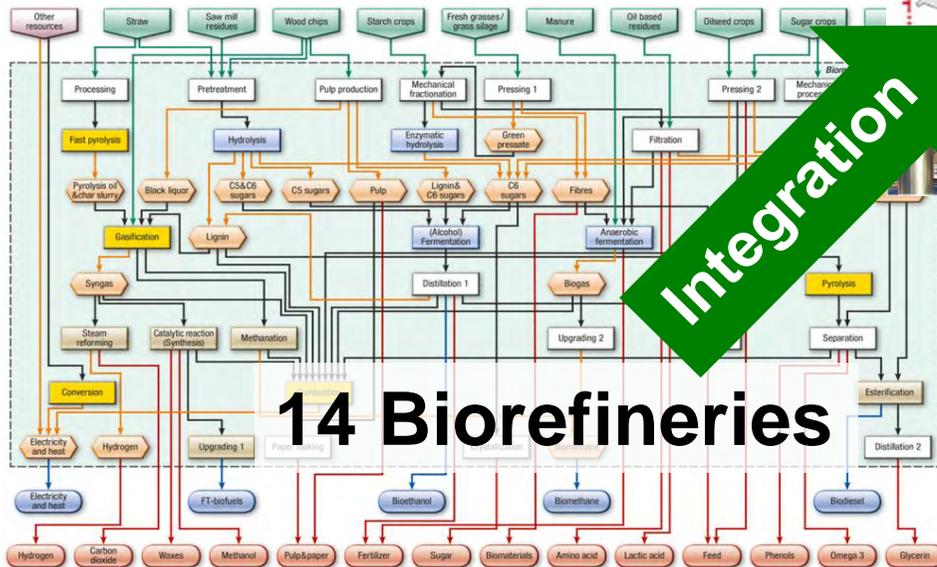
32



# How to Upgrade an existing Industrial Infrastructures to one of the 14 Biorefineries?



Infrastructure in 31 industry subsectors

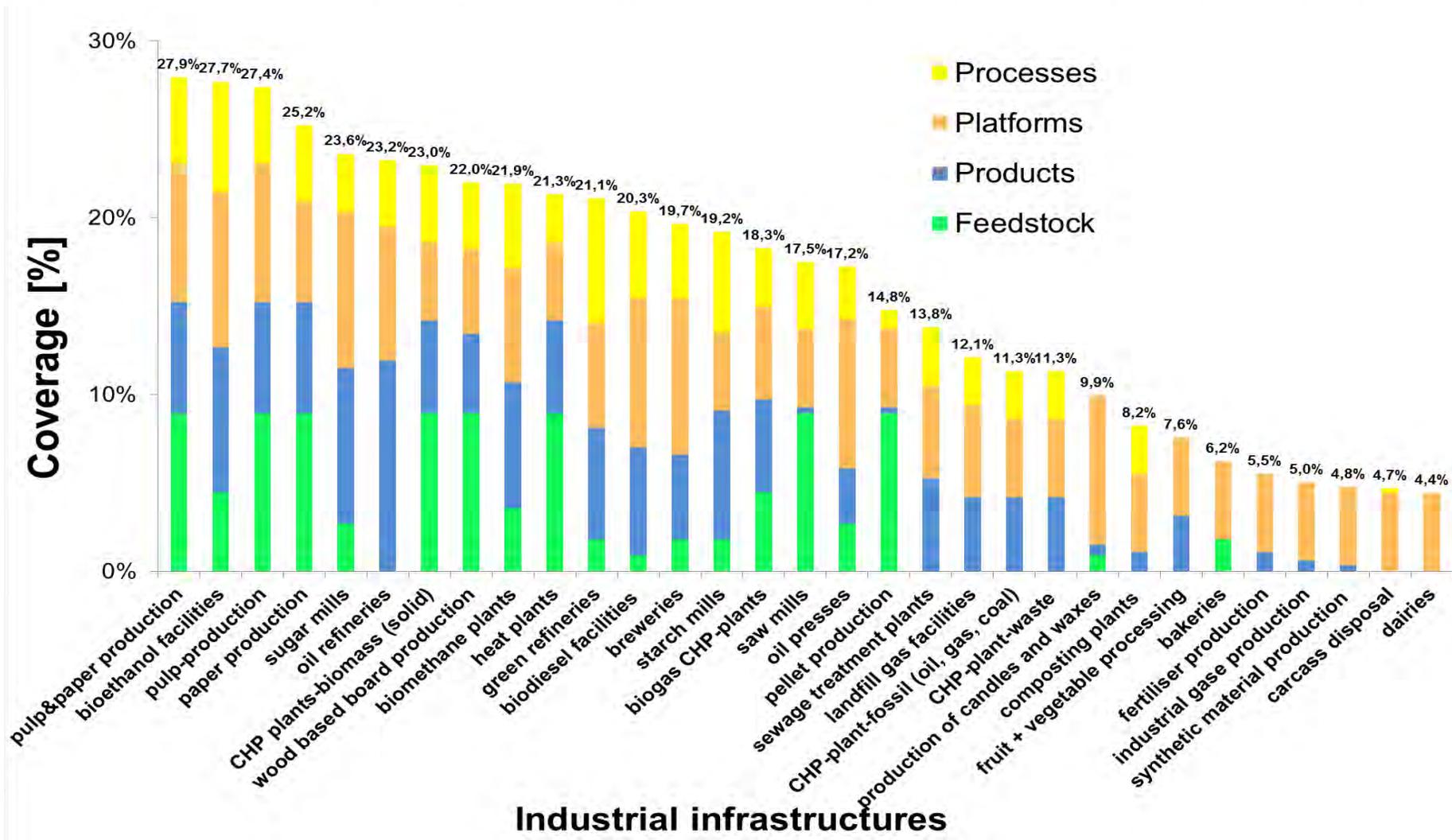


14 Biorefineries



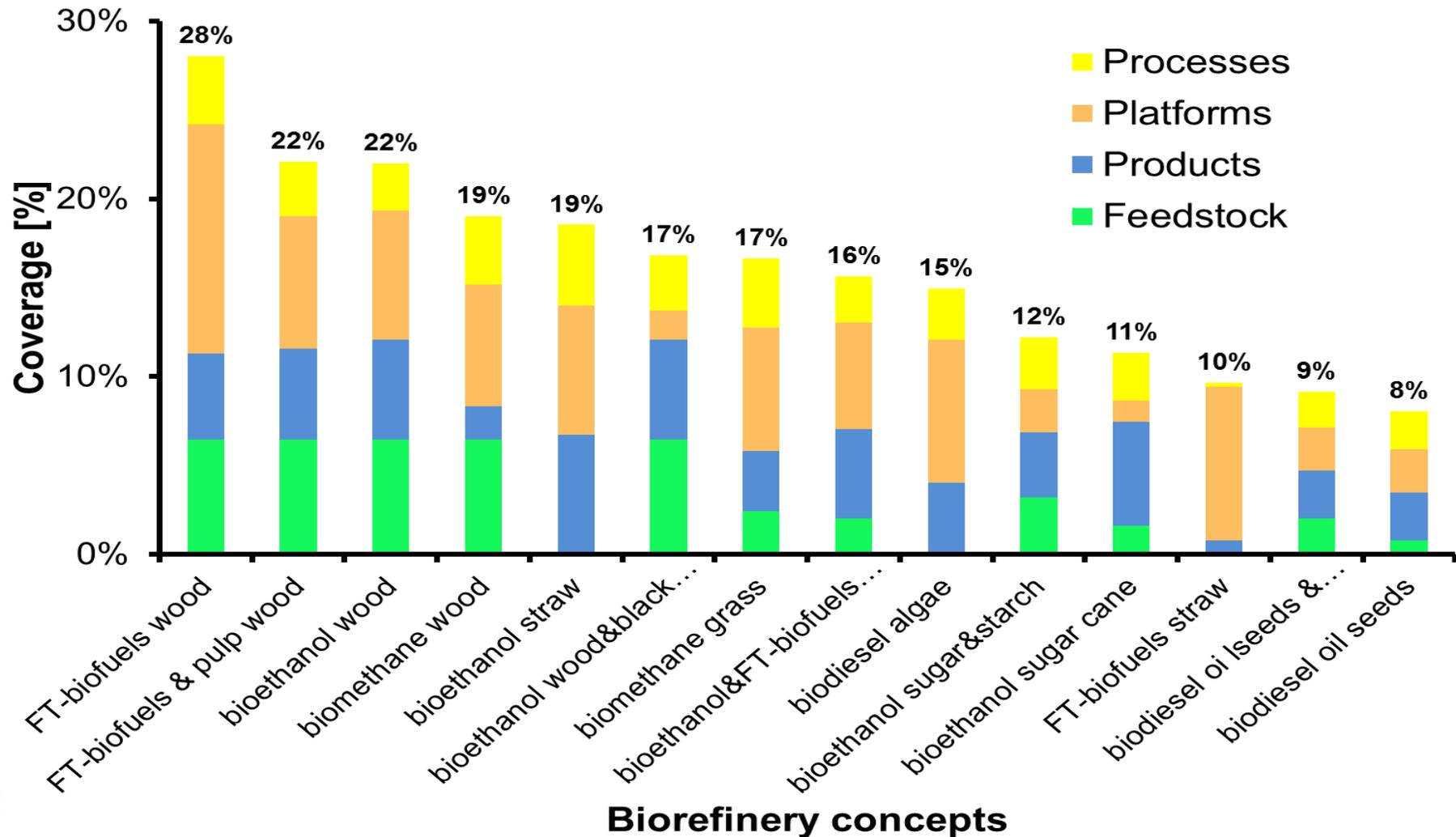
# Coverage: 14 Biorefineries and 31 Industry Subsectors

34

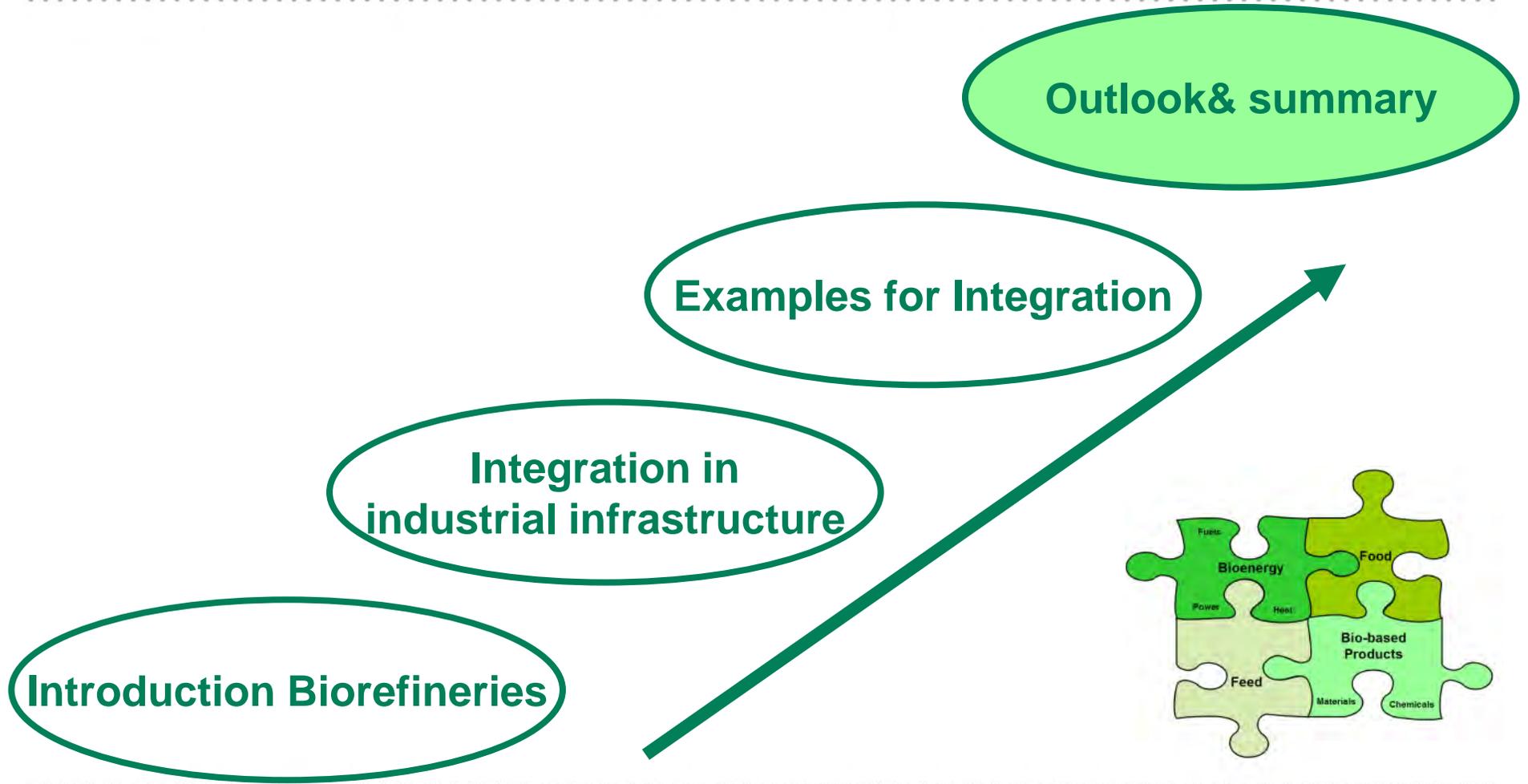


# Coverage: 31 Industry Subsectors and 14 Biorefineries

35



# Outline



# Outlook

37

1. Discussion to further develop this approach
2. Apply to other countries and biorefineries
3. Extend “Biorefinery Fact Sheet” to the most promising integration options

# Summary

Assist **stakeholders** in developing a **BioEconomy** to minimize technical, economic&financial risks

**Integration opportunities:** High number of common features in industrial infrastructure & biorefineries

Database of **existing industrial infrastructure** with 10 main industry sectors and 31 subsectors

**Biorefinery integration** in industrial infrastructure: feedstocks&products  $\geq$  platforms  $\geq$  processes

**Biorefinery Fact Sheet** gives facts&figures on biorefinery plant and value chain sustainability assessment

Selection of interesting “**Biofuel-driven Biorefineries**” for Biobased Economy 2025 by IEA Bioenergy Task 42 “Biorefinery”

**Classification of biorefineries** via 4 features: platforms, products, feedstocks, processes

Task 42 Biorefining

IEA Bioenergy aims to facilitate the commercialisation and market deployment of environmentally sound, socially acceptable, and cost competitive bioenergy systems and technologies



Task 42 Biorefining: Sustainable processing of biomass into a spectrum of marketable food & feed ingredients, bio-based chemicals, materials,....

> Read more



Activities

Knowledge dissemination

Market deployment

Stakeholder positioning

Sustainable biomass valorisation

Policy advice

Training

News

New map of US biorefineries available  
March 28, 2014

Project results presented at conference  
February 17, 2014

Tomorrow's Energy...  
...ing in Graz  
... online  
...ber 6, 2013

Biofuel-driven Biorefineries Report 2013  
February 1, 2013

Poster IEA Bioenergy Task42

Calendar

April 8, 2014 - 7th ...  
...- Conference  
2014: A Conference for a Low Carbon Future - Edmonton, Canada  
May 12, 2014 - Conference  
9th Biopolymer Symposium- Philadelphia, USA

More calendar

Recent publications

Green Building Blocks for

**Austrian Team Leader**  
**Gerfried Jungmeier**  
JOANNEUM RESEARCH  
gerfried.jungmeier@joanneum.at

Challenges to be tackled

- Develop industry legitimacy and a level-playing field for sustainable biomass use
- Multi-sectoral stakeholder involvement in the development and implementation of sustainable value chains
- Technology development and biorefinery scale-up using best

[www.IEA-Bioenergy.Task42-Biorefineries.com](http://www.IEA-Bioenergy.Task42-Biorefineries.com)  
[www.nachhaltigwirtschaften.at/iea](http://www.nachhaltigwirtschaften.at/iea)