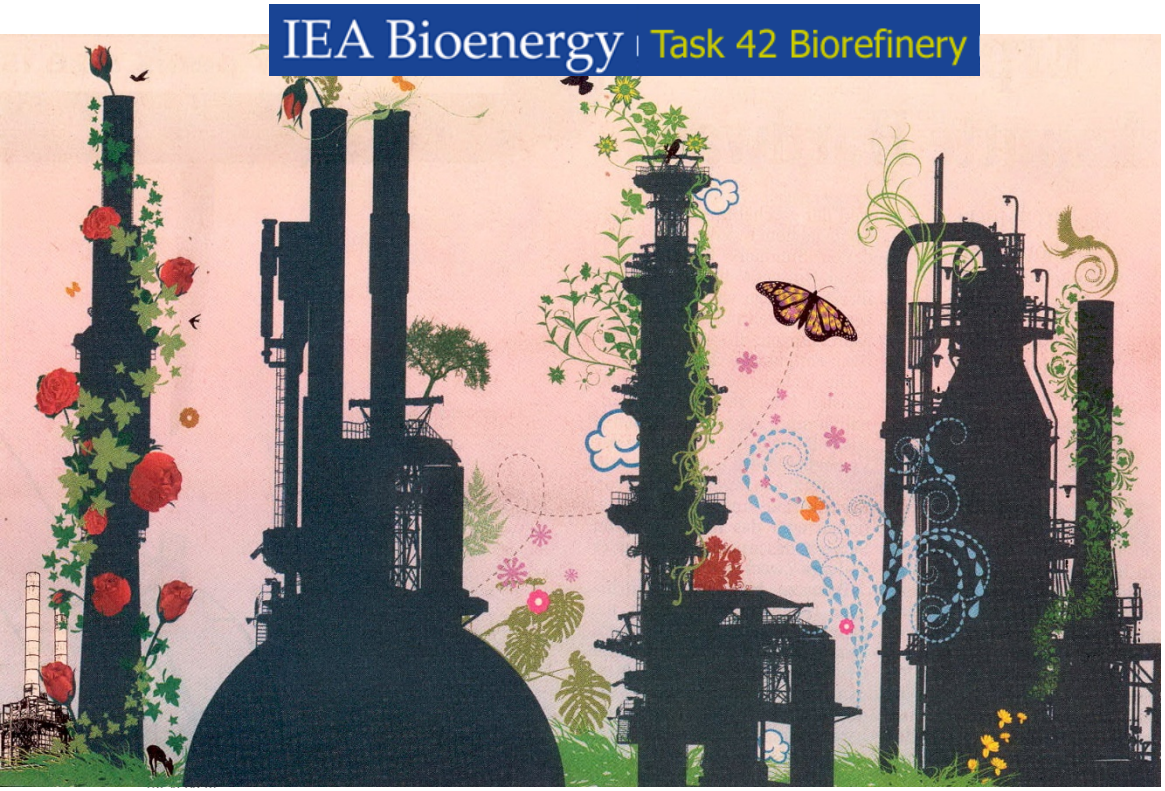
JOANNEUM RESEARCH Forschungsgesellschaft mbH



Sustainability Assessment, Classification and Perspectives of Bioenergy-driven Biorefineries

Activities of IEA Bioenergy Task 42 „Biorefineries“

Gerfried Jungmeier

III Latin American Conference “Biorefineries – Ideas for a Sustainable World”;
Pucon, Chile, November 19 -21, 2012, 2012

IEA FORSCHUNGS KOOPERATION

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

This is Biomass for Transportation Biofuels and Biorefineries

Outline

Outlook and Conclusions

Biorefinery Assessment

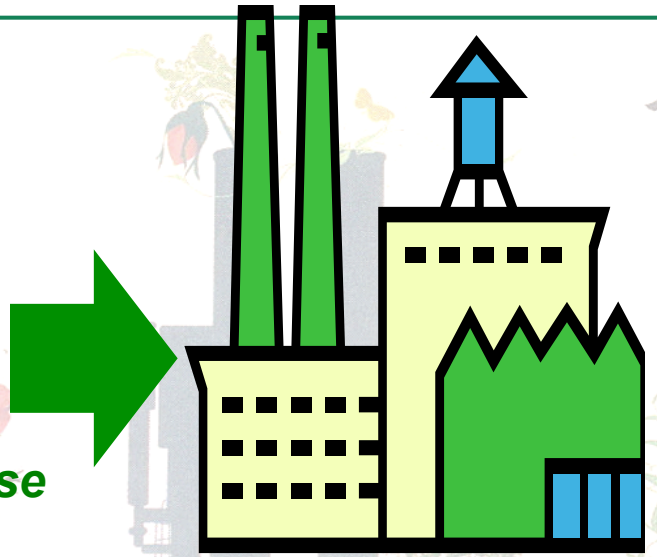
Biofuel Driven Biorefineries

Introduction

Scheme of a Biorefinery

IEA Bioenergy | Task 42 Biorefinery

Biomass Resources
- *oil*
- *starch*
- *sugar*
- *lignocellulose*
- *....*



Biorefinery

Bioenergy

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

Bioproducts

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

Based on different conversion processes
- *Bio-chemical*
- *Thermo-chemical*
- *Physical-chemical*
- *Others*

Definition of IEA Task 42 "What is a Biorefinery?"

IEA Bioenergy | Task 42 Biorefinery

JOANNEUM RESEARCH RESOURCES

"Biorefinery is the sustainable processing of biomass into a spectrum of marketable products"

- ***Biorefinery***: **concepts, facilities, processes, clusters of industries**
- ***Sustainable***: **maximising economics & social aspects, minimising environmental impacts, fossil fuel replacement, closed cycles**
- ***Processing***: **upstream processing, transformation, fractionation, thermo-chemical and biochemical conversion, extraction, separation, downstream processing**
- ***Biomass***: **wood & agricultural crops, organic residues, forest residues, aquatic biomass**
- ***Spectrum***: **multiple energic and non-energic products**
- ***Marketable***: **Present and forecasted (volume and prices)**
- ***Products***: **both intermediates and final products (i.e. food, feed, materials, chemicals, fuels, power, heat)**

The two Different Motivations for A Biorefinery

"Bioproduct-driven" Biorefinery

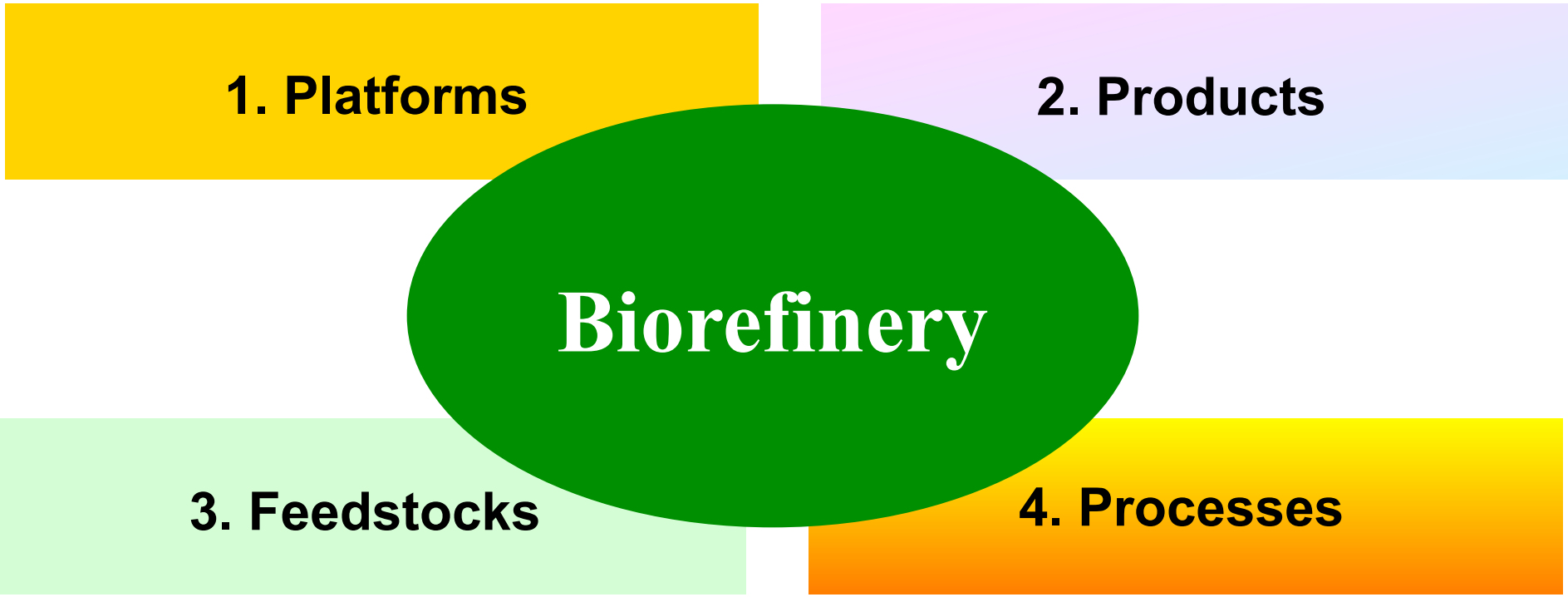
e.g. pulp&paper, lactic acid

"Bioenergy-driven" Biorefinery

e.g. bioethanol, FT-biofuels

The 4 Features to Characterise A Biorefinery Systems

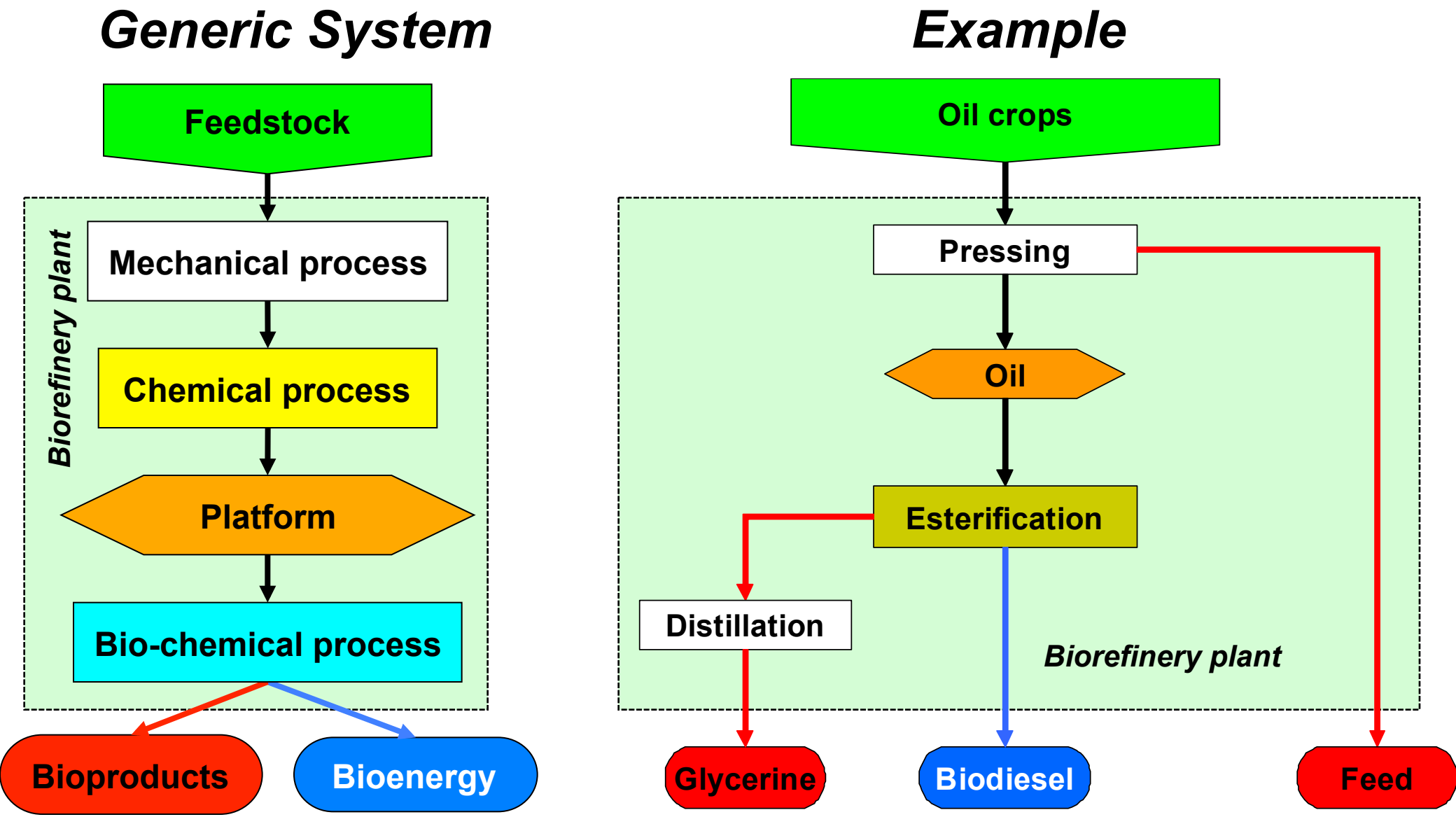
IEA Bioenergy | Task 42 Biorefinery

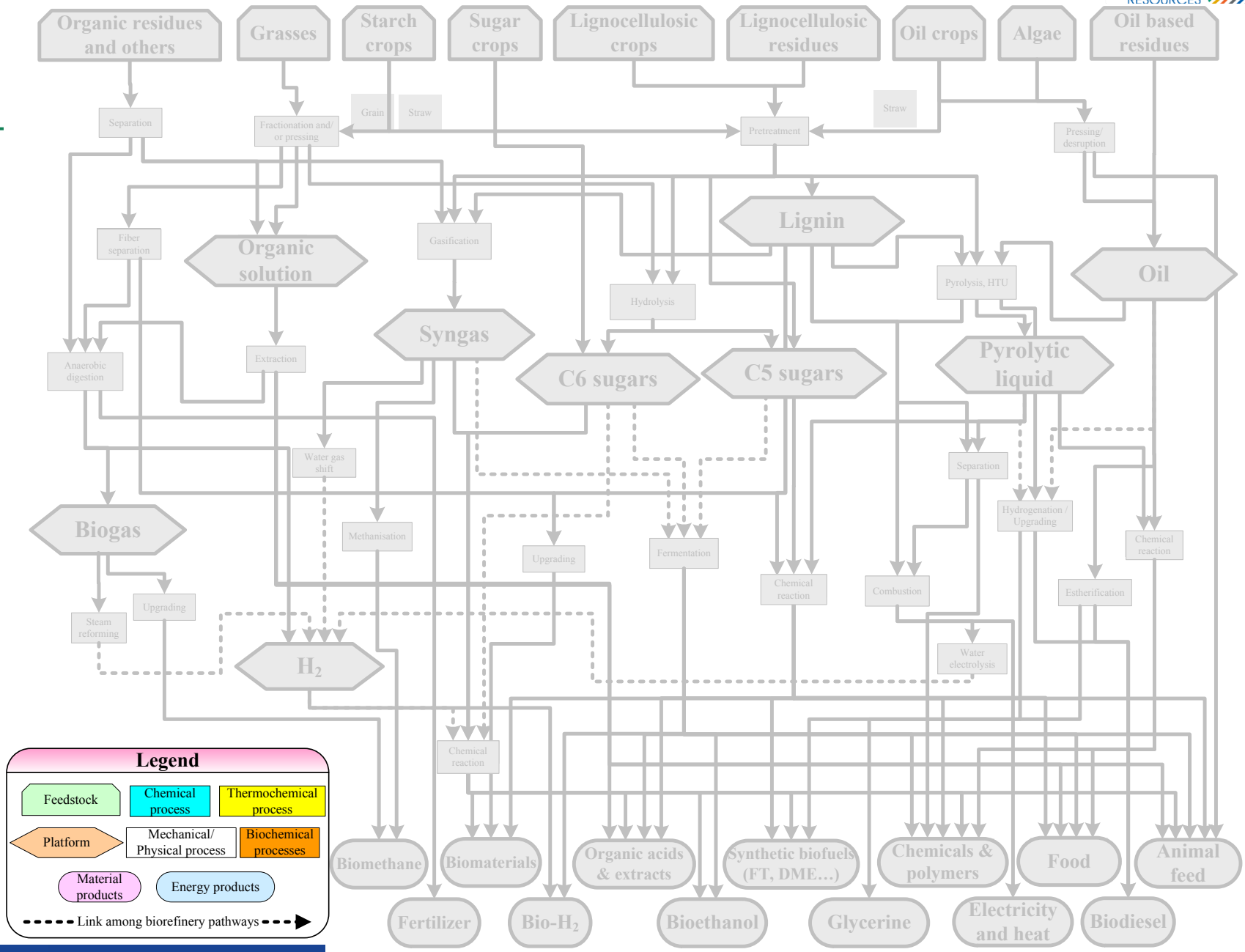


Naming:

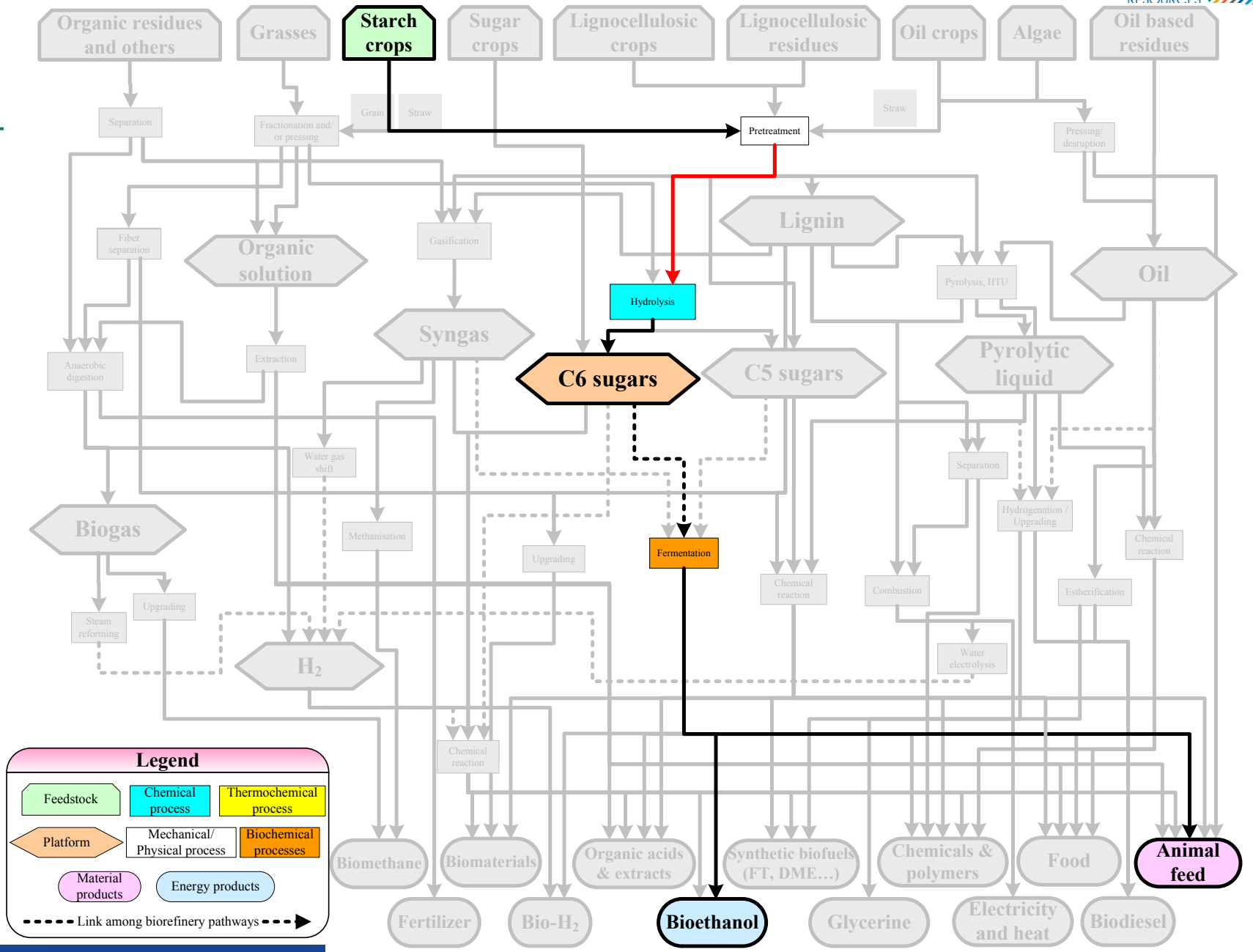
- *Number platforms (Name of platforms)/Feedstock/Products/Processes*
- ***e.g. „A 1-Platform Biorefinery with Rape for Biodiesel, Animal Feed & Glycerine“***

Application of Classification System

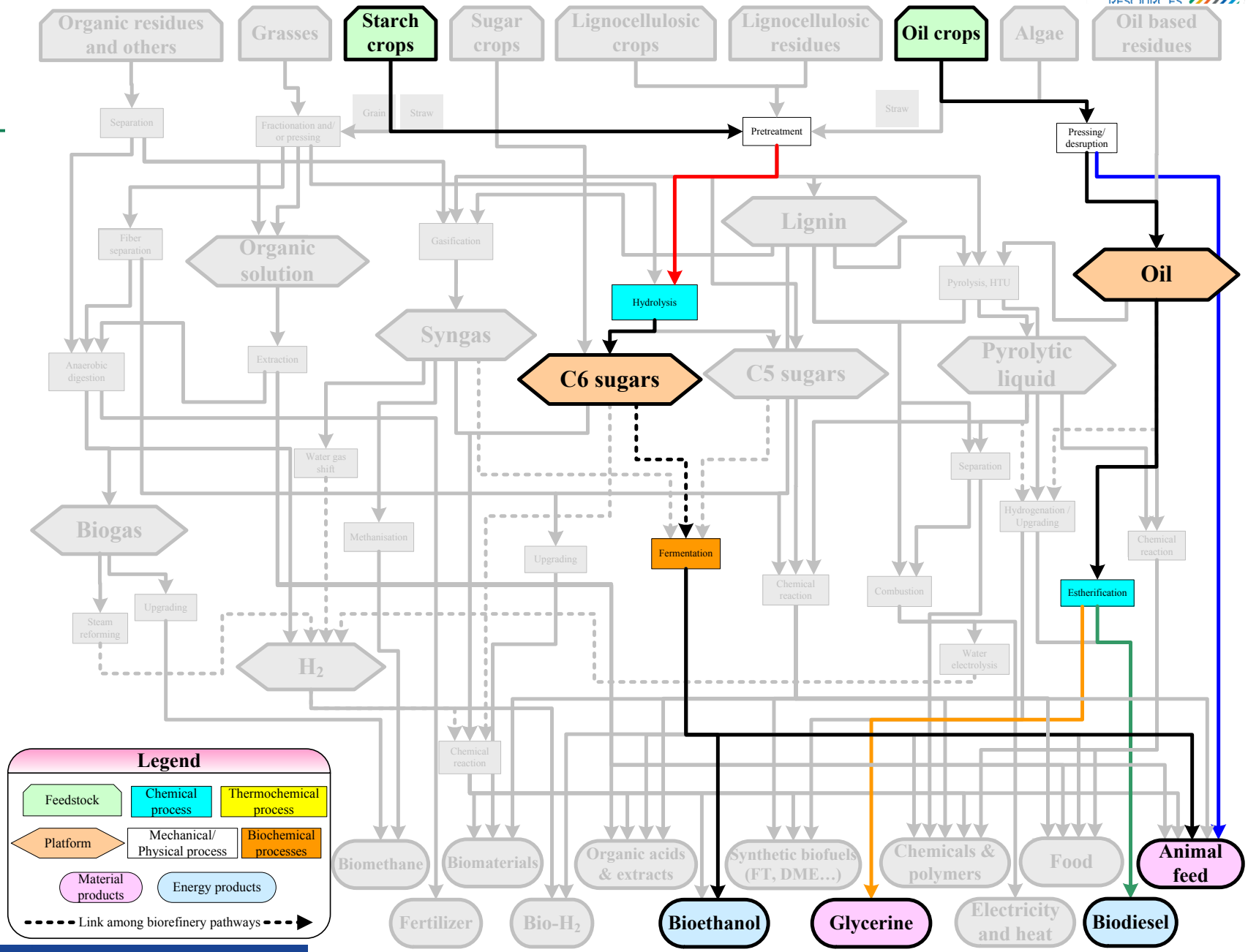



Organic residues and others
Grasses
Starch crops
Sugar crops
Lignocellulosic crops
Lignocellulosic residues
Oil crops
Algae
Oil based residues
Separation
Fractionation and/ or pressing
Grain
Straw
Pretreatment
Straw
Pressing/ desruption
Fiber separation
Organic solution
Gasification
Lignin
Pyrolysis, HTU
Oil
Hydrolysis
Syngas
C6 sugars
C5 sugars
Pyrolytic liquid
Anaerobic digestion
Extraction
Water gas shift
Separation
Biogas
Methanisation
Upgrading
Fermentation
Hydrogenation / Upgrading
Chemical reaction
Chemical reaction
Combustion
Estherification
Steam reforming
Upgrading
H_2
Water electrolysis
Chemical reaction
Biomethane
Biomaterials
Organic acids & extracts
Synthetic biofuels (FT, DME…)
Chemicals & polymers
Food
Animal feed
Fertilizer
Bio-H_2
Bioethanol
Glycerine
Electricity and heat
Biodiesel
Legend
Feedstock
Chemical process
Thermochemical process
Platform
Mechanical/ Physical process
Biochemical processes
Material products
Energy products
Link among biorefinery pathways

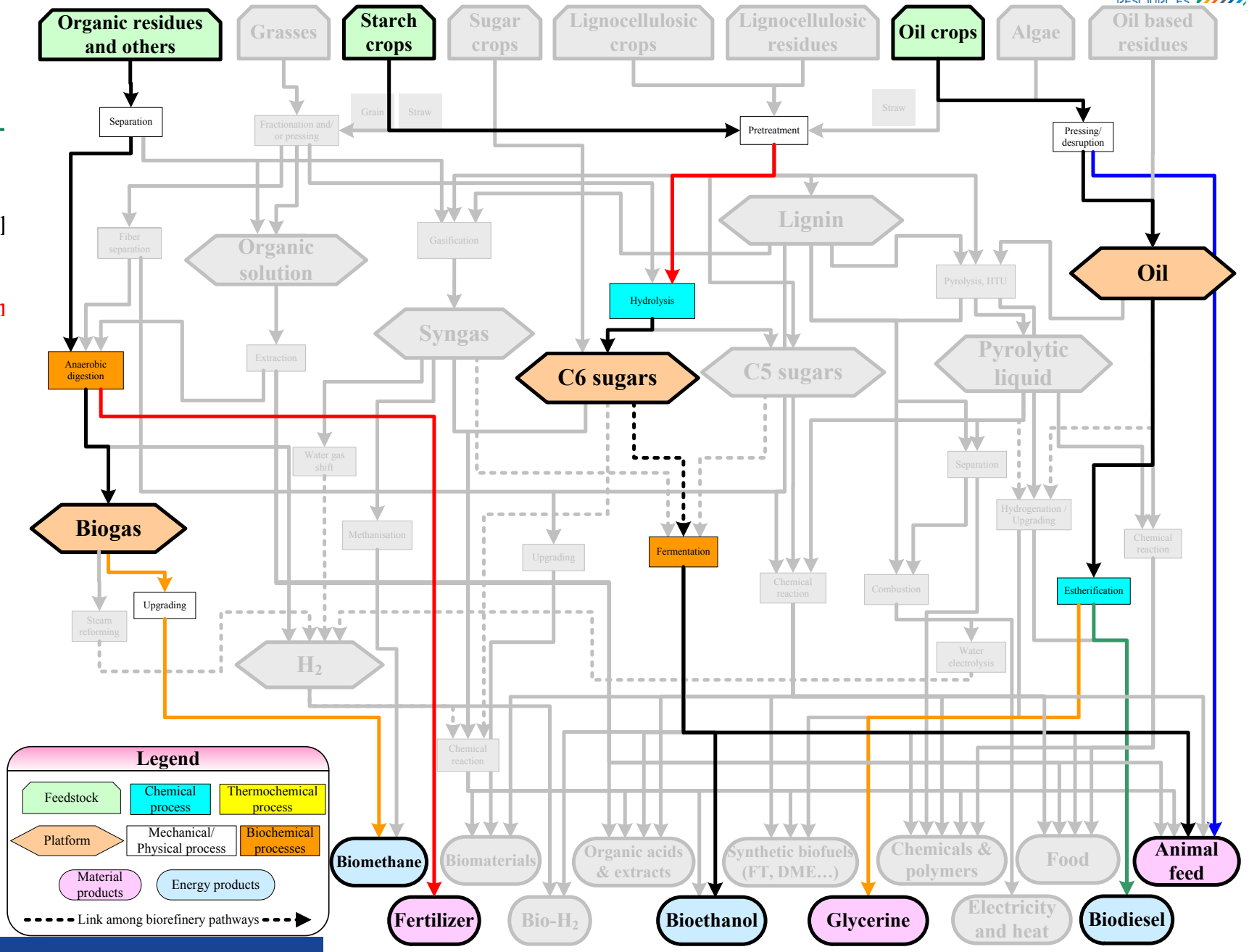
1. Bioethanol from starch



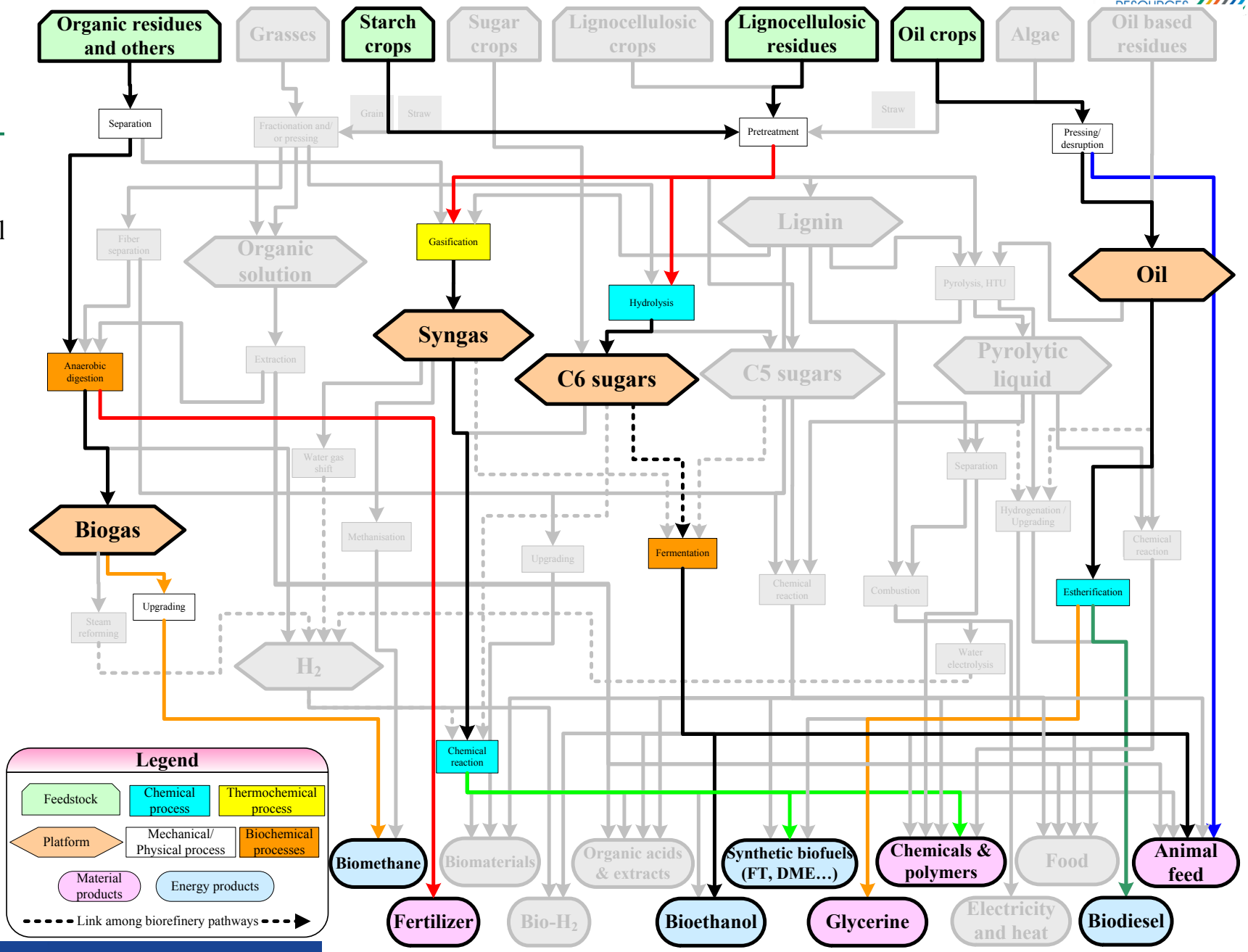
1. Bioethanol from starch
2. **Biodiesel from oil crop**



1. Bioethanol from starch
2. Biodiesel from oil crop
3. **Biomethane from organic residues**

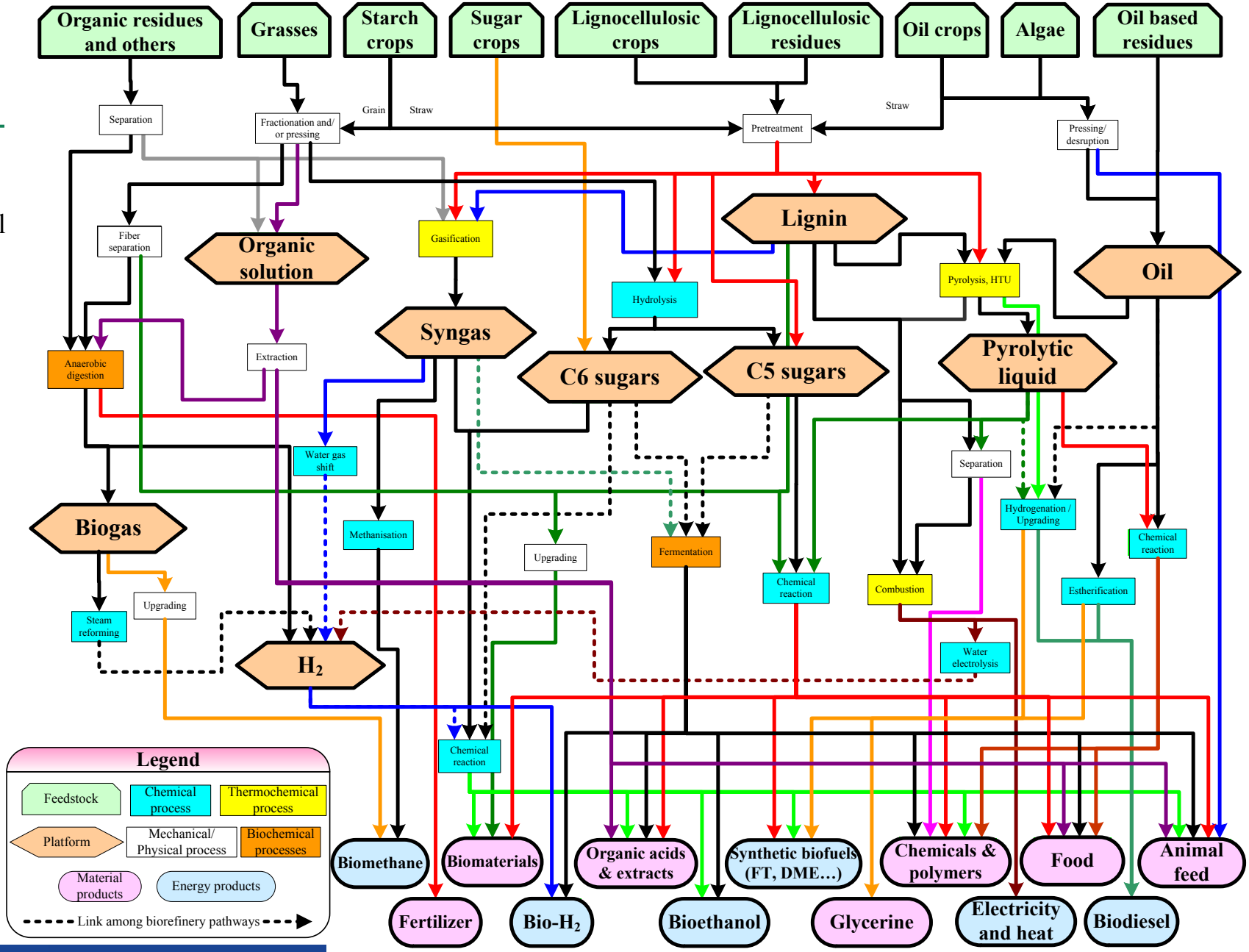


1. Bioethanol from starch
2. Biodiesel from oil crop
3. Biomethane from organic residues
4. **FT-Fuels from lignocellulosic residues**

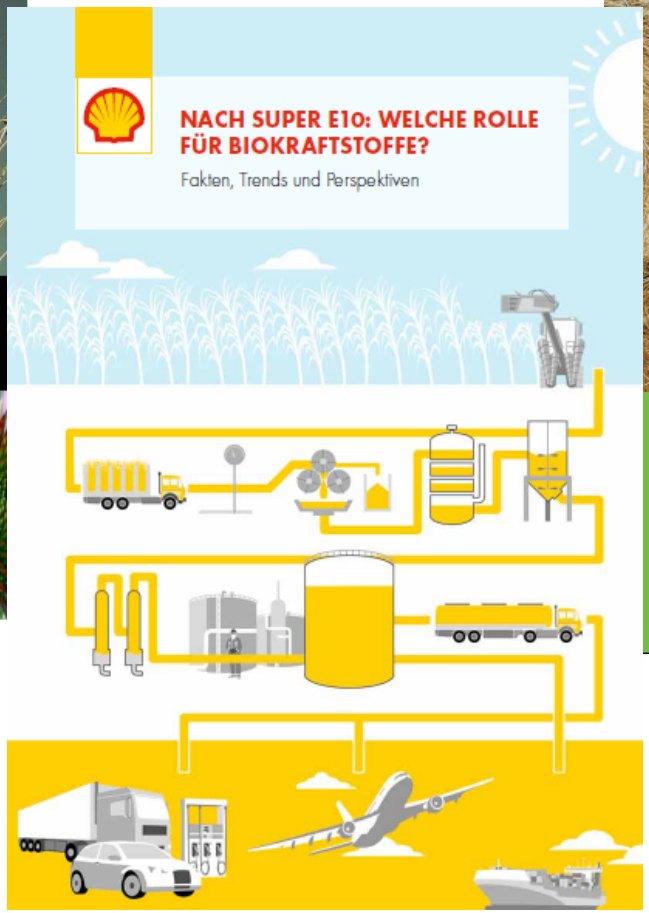


1. Bioethanol from starch
2. Biodiesel from oil crop
3. Biomethane from organic residues
4. FT-Fuels from lignocellulosic residues

…



Classification System is now in Use ….



Outline

Outlook and Conclusions

Biorefinery Assessment

Biofuel Driven Biorefineries

Introduction

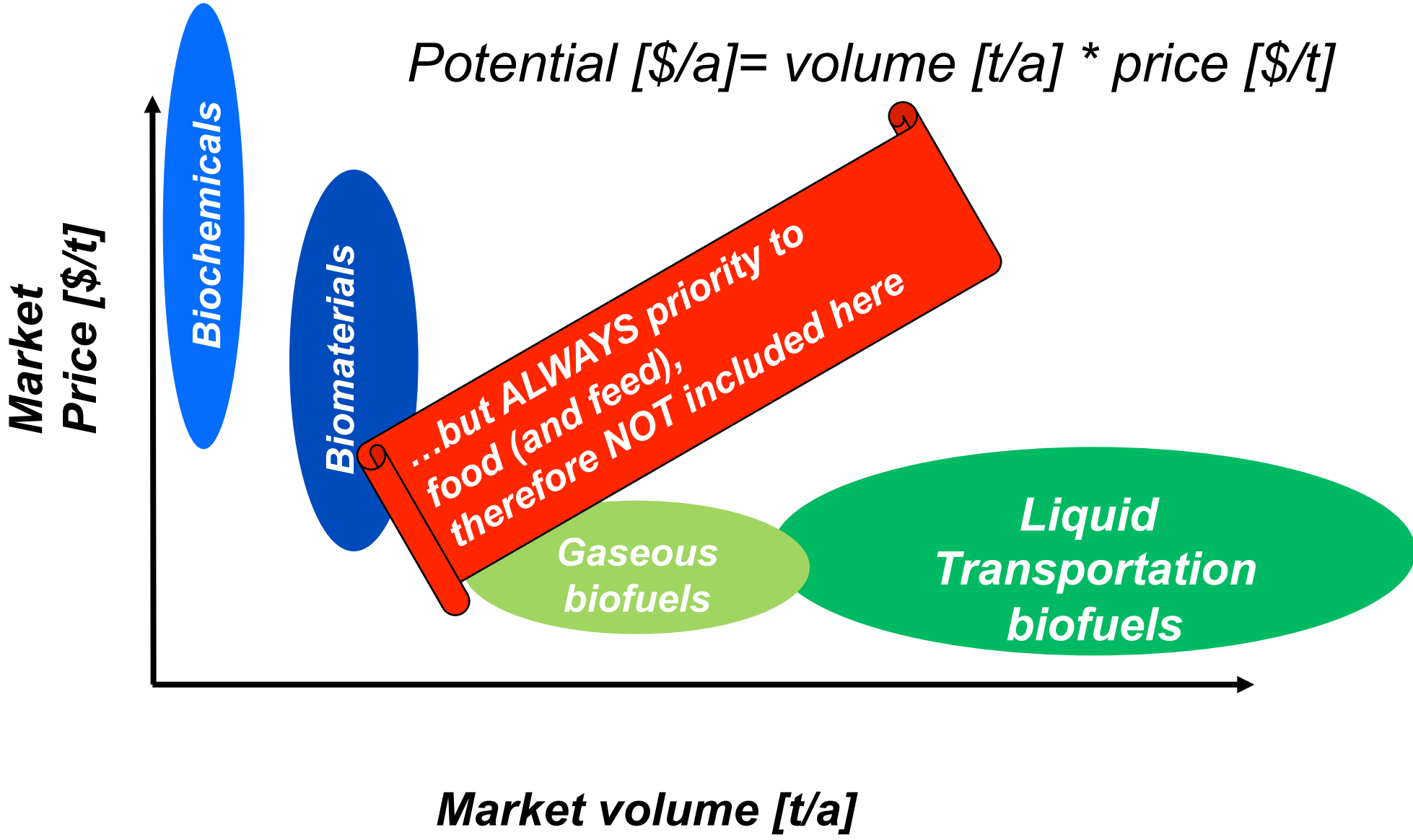
What are "Biofuel Driven" Biorefineries?

„A transportation biofuel driven biorefinery aims to produce huge volumes of liquid and/or gaseous transportation biofuels co-producing (high value) bio-chemicals and biomaterials"

- **Expectation:** **the biochemicals and biomaterials give additional economic and environmental benefits to reduce production costs and environmental impacts of transportation biofuels**
- **Optimisation strategies:** **trade off between maximizing amount of transportation biofuels production and additional benefits from bio-chemicals and bio-materials is necessary**

Is the key interest of IEA Bioenergy

Product Trade off: Market Volume and Price



„Bioenergy-driven“ Biorefinery Concepts

Road transportation biofuels:

- ✓ Biodiesel
- ✓ Bioethanol *)
- ✓ FT-Biofuel *)
- ✓ Biomethane*) from biogas and SNG (synthetic natural gas)

Based on ongoing activities in the 11 countries:
A, AUS, CA, DK, FR, G, I, IR, NL, T, US

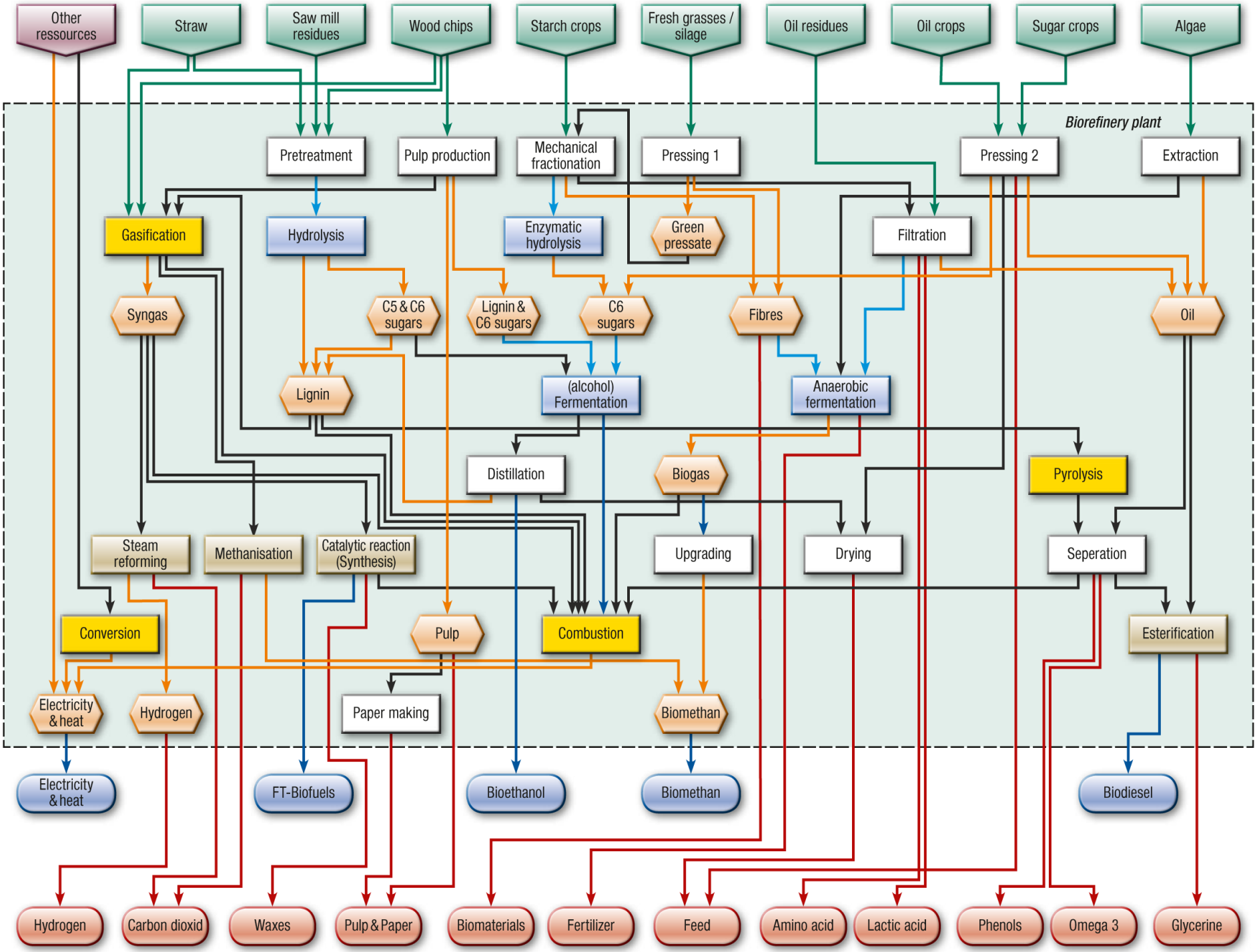
Biomass feedstocks:

- ✓ Oil crops and residues
- ✓ Starch and sugar crops
- ✓ Wood
- ✓ Staw
- ✓ Gras
- ✓ Saw mill residues
- ✓ Sulfite spent liquor
- ✓ Algae

Biomaterials/-products:

- ✓ *Animal feed*
- ✓ *Glycerine*
- ✓ *Phenole*
- ✓ *Pulp/paper*
- ✓ *Amino acids*
- ✓ *Lactic acids*
- ✓ *Fertilser*
- ✓ *Waxes*
- ✓ *Hydrogen*
- ✓ *Carbon dioxide*

*) *coproduction of electricity, heat and lignin pellets*


Other ressources
Straw
Saw mill residues
Wood chips
Starch crops
Fresh grasses / silage
Oil residues
Oil crops
Sugar crops
Algae
Biorefinery plant
Pretreatment
Pulp production
Mechanical fractionation
Pressing 1
Pressing 2
Extraction
Gasification
Hydrolysis
Enzymatic hydrolysis
Green pressate
Filtration
Syngas
C5 & C6 sugars
Lignin & C6 sugars
C6 sugars
Fibres
Oil
Lignin
(alcohol) Fermentation
Anaerobic fermentation
Distillation
Biogas
Pyrolysis
Steam reforming
Methanisation
Catalytic reaction (Synthesis)
Upgrading
Drying
Seperation
Conversion
Pulp
Combustion
Esterification
Electricity & heat
Hydrogen
Paper making
Biomethan
Electricity & heat
FT-Biofuels
Bioethanol
Biomethan
Biodiesel
Hydrogen
Carbon dioxid
Waxes
Pulp & Paper
Biomaterials
Fertilizer
Feed
Amino acid
Lactic acid
Phenols
Omega 3
Glycerine

Implementation Perspectives of Energy Driven Biorefinery Concepts

1. Commercial energy driven biorefineries

- ✓ state of the art
- ✓ worldwide in commercial operation under current economic condition

2. Demonstrated energy driven biorefineries

- ✓ main processes are demonstrated on a technical scale at one/more locations worldwide
- ✓ further technical optimization needed
- ✓ No commercial operation under current conditions
- ✓ Expectation: commercial operation ≥ 2020

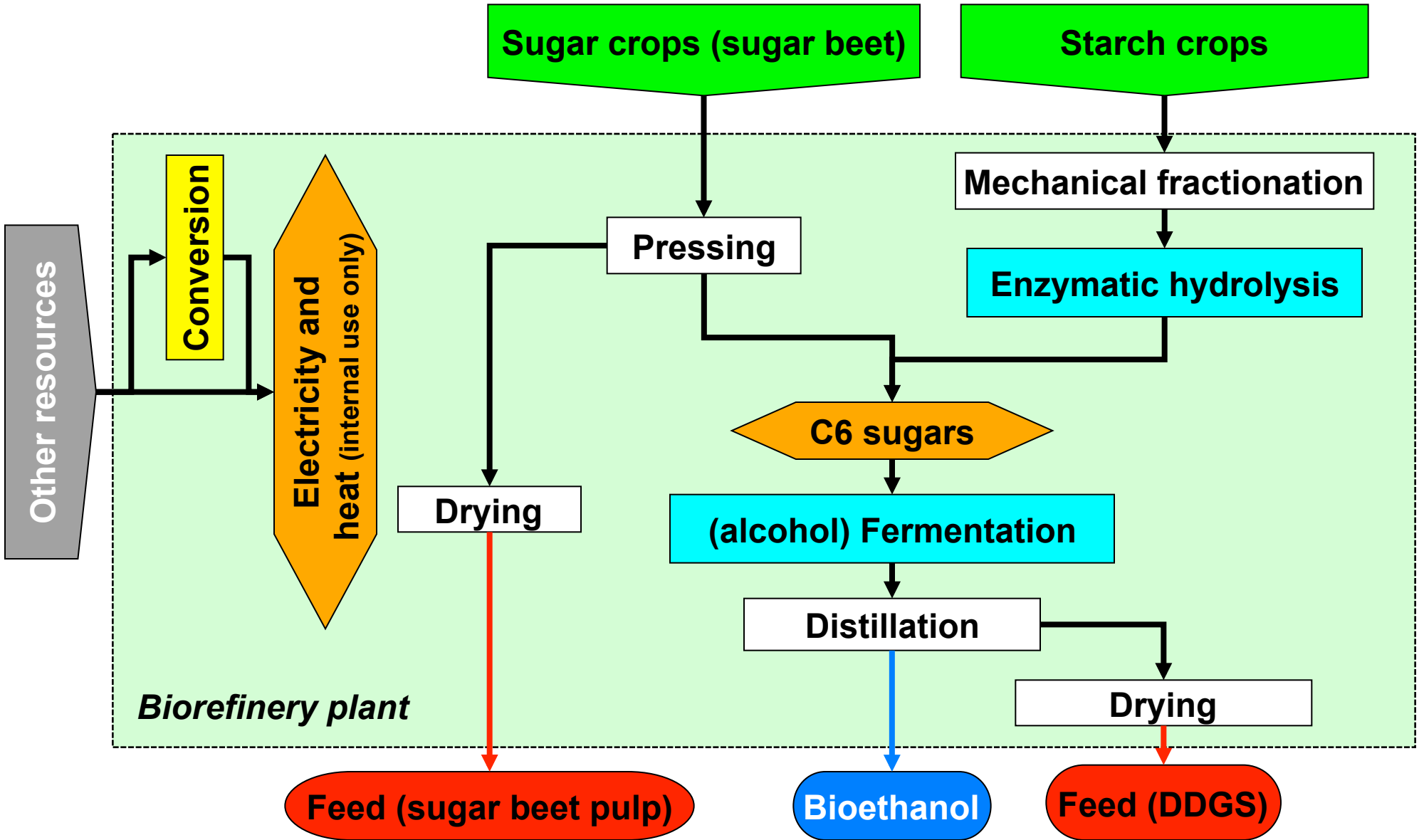
3. Conceptual energy driven biorefineries until 2025

- ✓ not demonstrated on technical scale so far
- ✓ further necessary R&D developments and successful demonstrated
- ✓ expectation: can be commercially operated ≥ 2025.

Commercial Energy Driven Biorefineries

- “1-platform (oil) biorefinery using **oil crops for biodiesel**, glycerin and feed“
- “1-platform (oil) biorefinery using oil based **residues&oil crops for biodiesel**, glycerin and feed“
- “1-platfrom (C6 sugar) biorefinery using **sugar&starch crops for bioethanol** and feed“

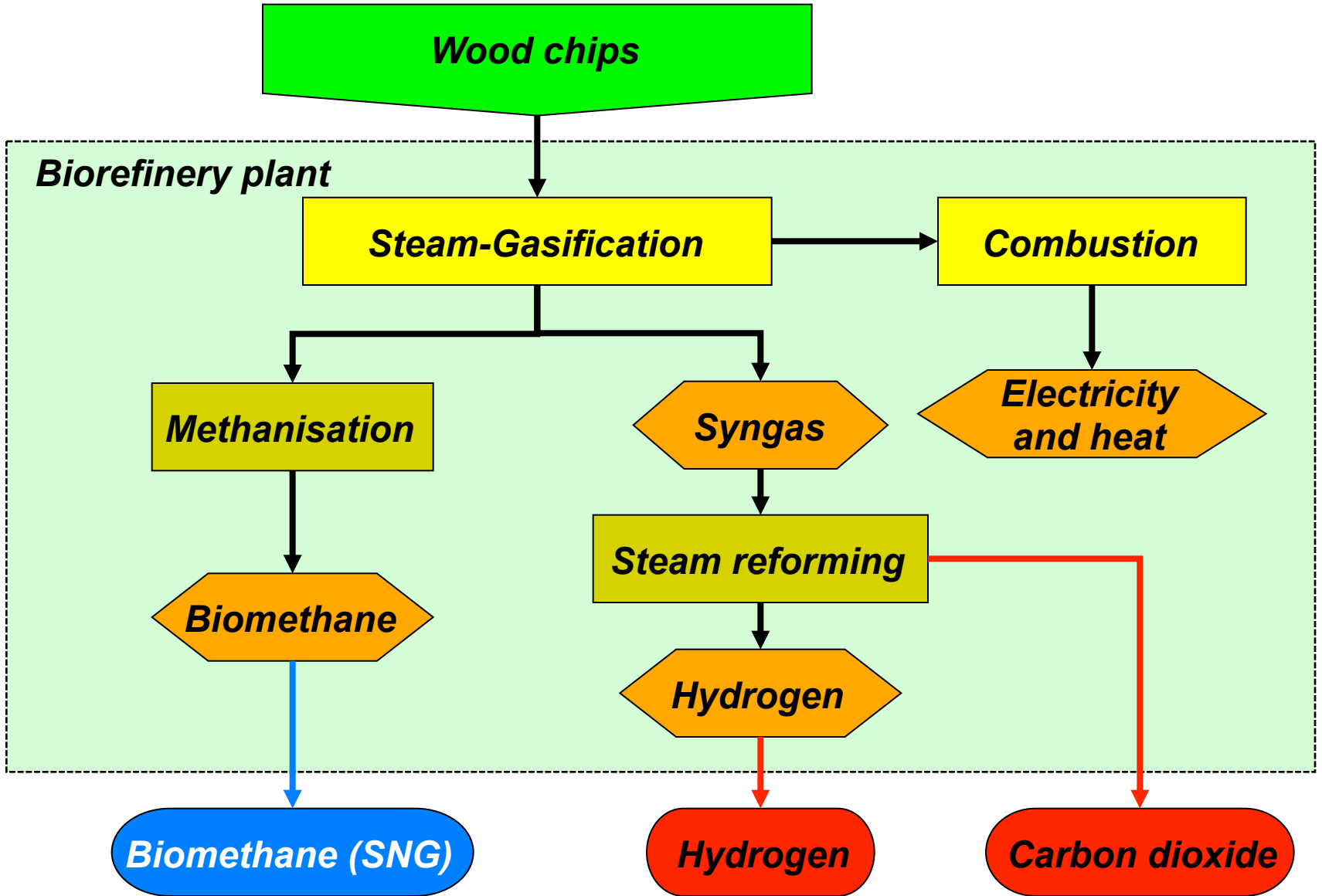
1-platfrom (C6 sugar) biorefinery using **sugar&starch crops for bioethanol**



Demonstrated Energy Driven Biorefineries

- “4-platfrom (C6-, C5- sugars, lignin, electricity&heat) biorefinery using **straw for bioethanol**, electricity, heat and feed“
- “3-platform (C6&C5 sugar, electricity&heat, lignin) biorefinery using **wood chips for bioethanol**, electricity, heat and phenols“
- “5-platform (biogas, biomethane, green pressate, fibers, electricity&heat) biorefinery using **grass for biomethane**, lactic acid, biomaterials and fertilizer“
- “4-platform (electricity&heat, hydrogen, biomethane, syngas) biorefinery using **wood chips for biomethane** (SNG), hydrogen and carbon dioxide“
- “5-platfrom (C6 sugars, C6&C5 sugar, lignin, syngas, electricity&heat) biorefinery using **starch crops and straw for bioethanol**, FT-biofuels, feed, electricity and heat“

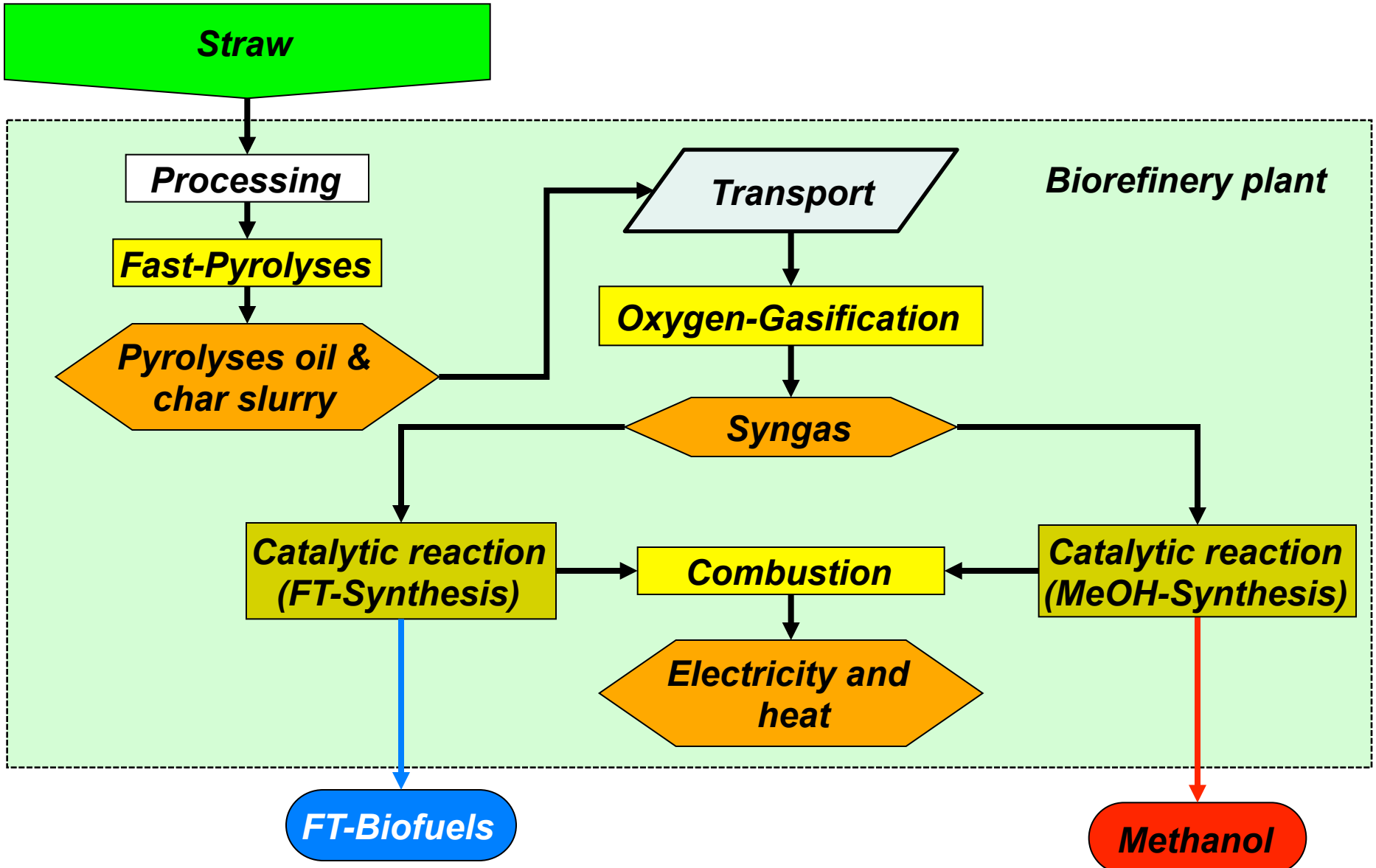
4-platform (electricity&heat, hydrogen, bio-methane, syngas) biorefinery using **wood chips for biomethane (SNG)**, hydrogen and carbon dioxide



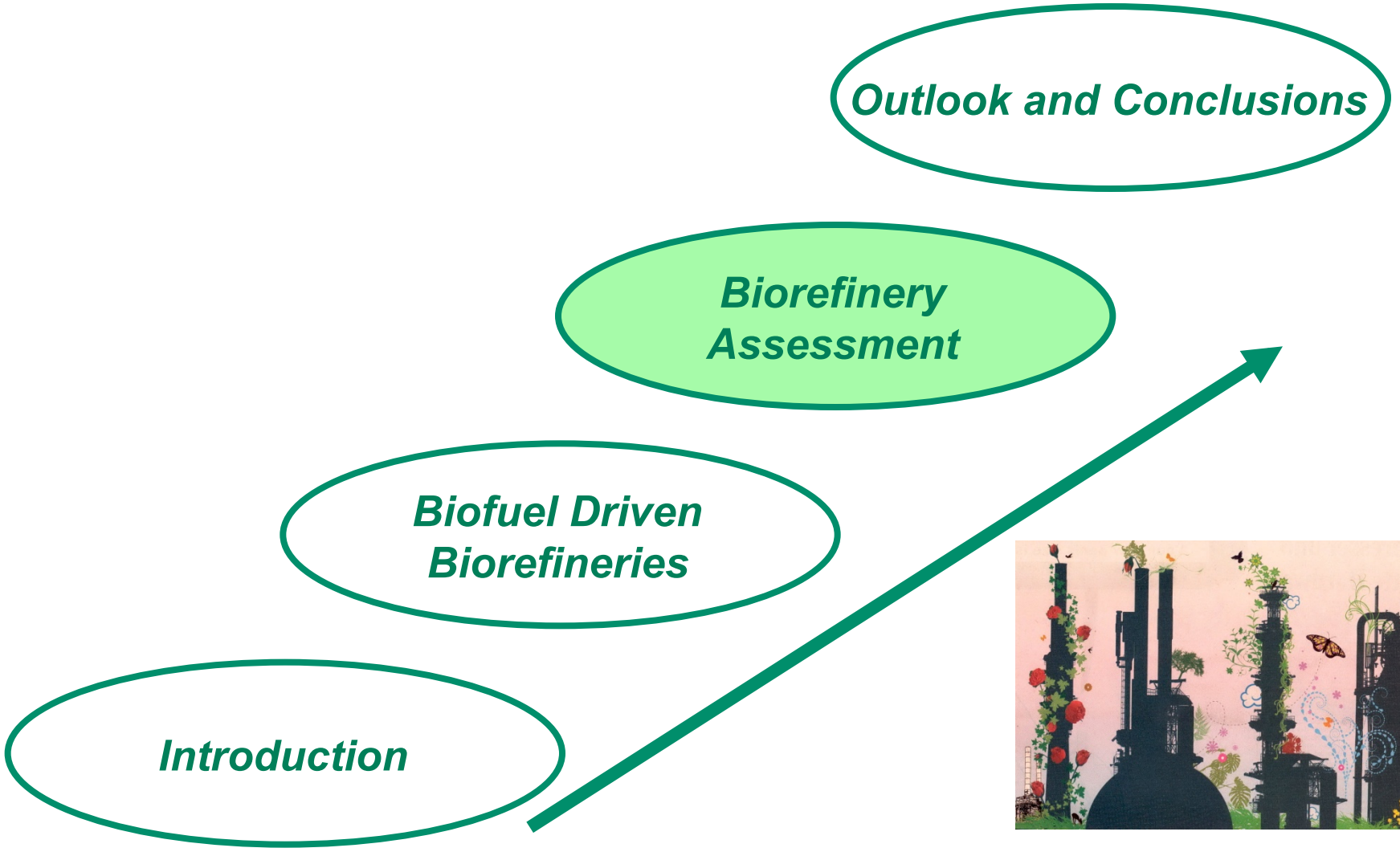
Conceptual Energy Driven Biorefineries until 2025

- “2-platform (electricity&heat, syngas) biorefinery using **wood chips for FT-Biofuels**, electricity, heat and waxes with steam gasification“
- “3-platform (pyrolyses oil, syngas, electricity&heat) biorefinery using **straw for FT-biofuels** and methanol with oxygen gasification“
- “3-platform (pulp, syngas, electricity&heat) biorefinery using **wood chips for FT-biofuels**, electricity, heat and pulp“
- “4-platform (C6&C5 sugar, lignin&C6 sugar, electricity&heat) biorefinery using **saw mill residues, wood chips and sulfite liquor for bioethanol**, pulp&paper, electricity and heat“
- “4-platform (biogas, biomethane, oil, electricity&heat) biorefinery using **algae for biodiesel, biomethane**, electricity, heat and glycerin, Omega 3 and fertilizer“.

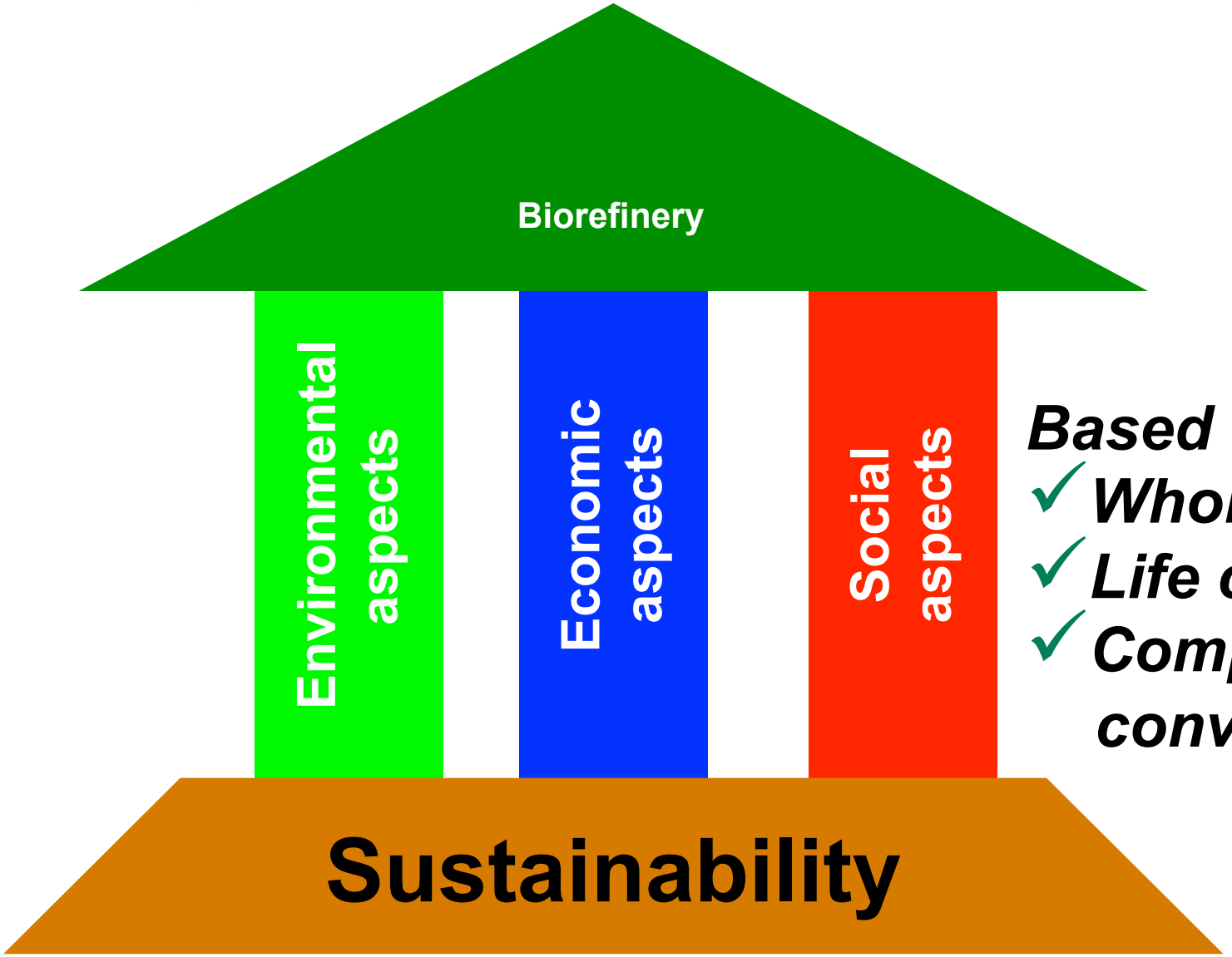
“3-platform (pyrolyses oil, syngas, elec.&heat) biorefinery using **straw for FT-biofuels** and methanol with oxygen gasification“



Outline


Outlook and Conclusions
Biorefinery Assessment
Biofuel Driven Biorefineries
Introduction

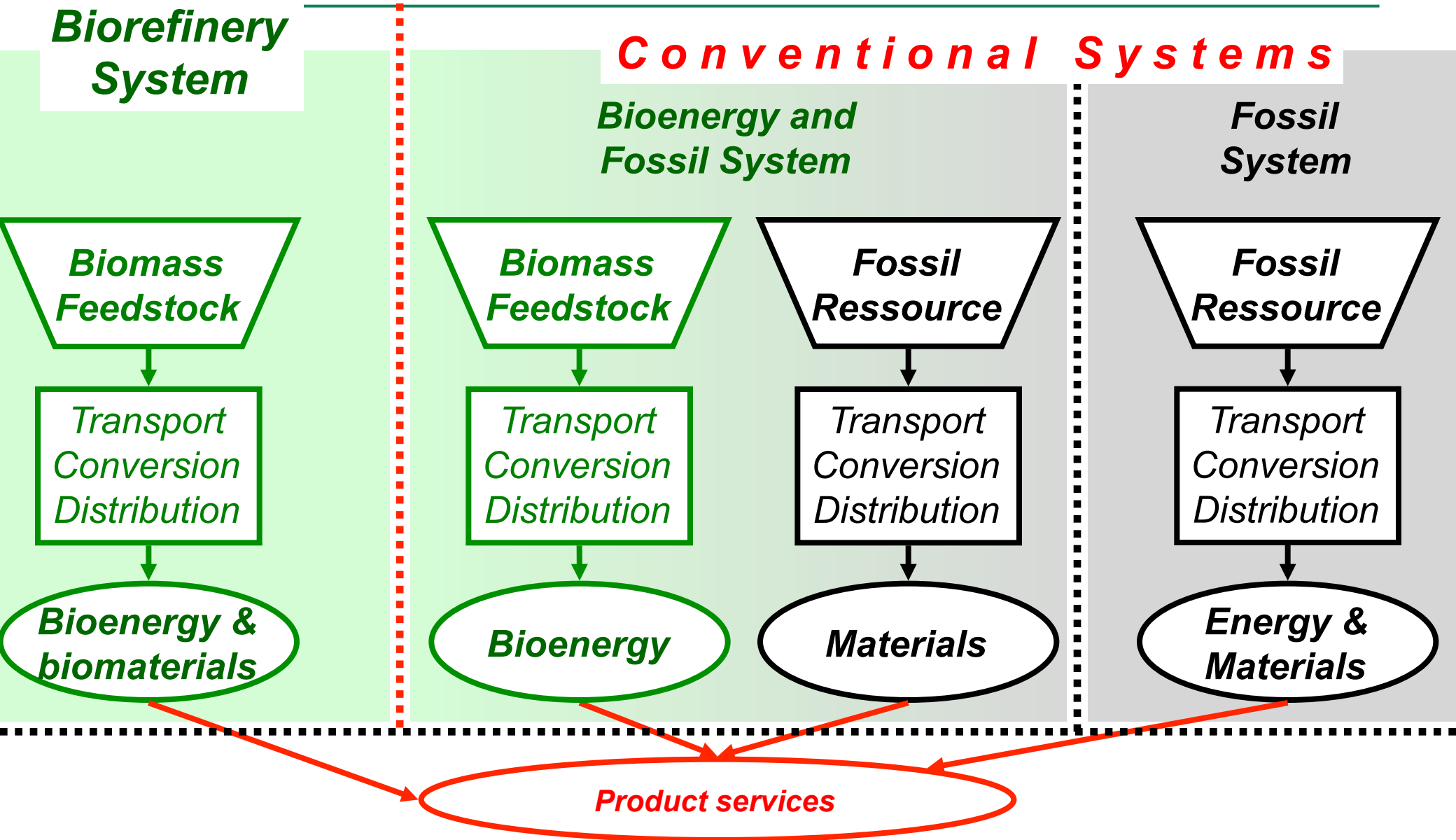
Sustainability Assessment of Biorefineries



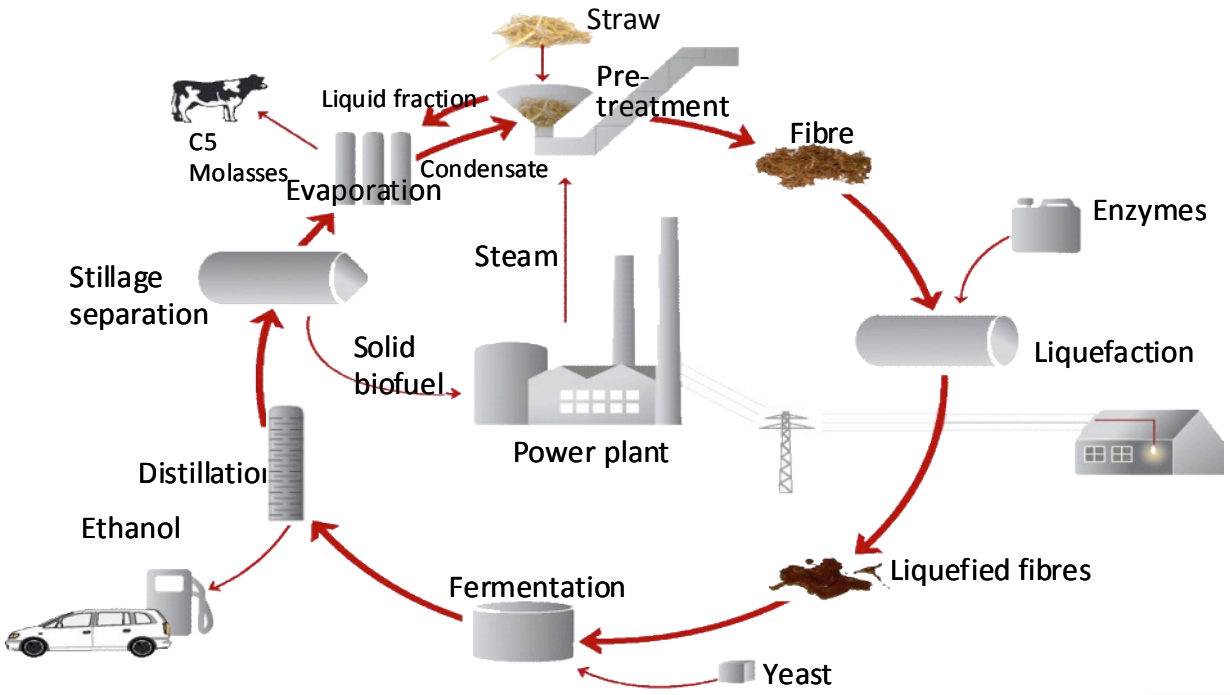
Based on

- ✓ ***Whole value chain***
- ✓ ***Life cycle***
- ✓ ***Comparison to conventional system***

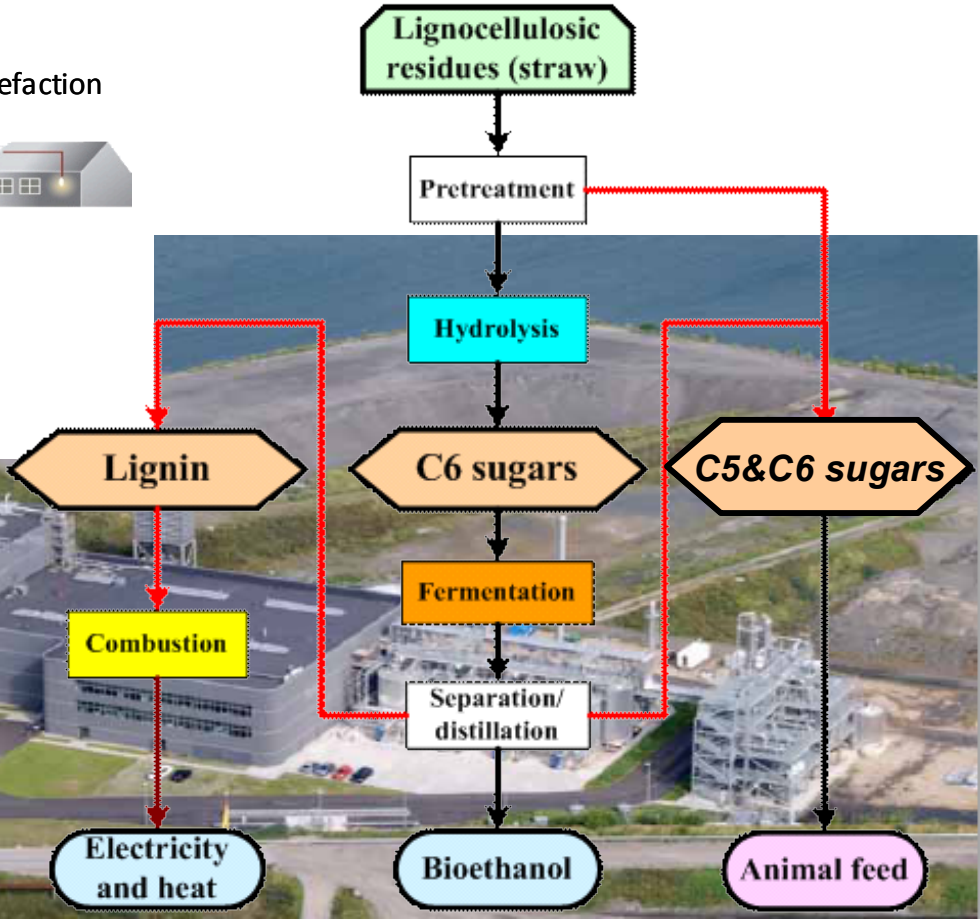
What are the „Conventional Systems“ for Comparison?



Case 1: Demonstration Plant IBUS Biorefinery Denmark



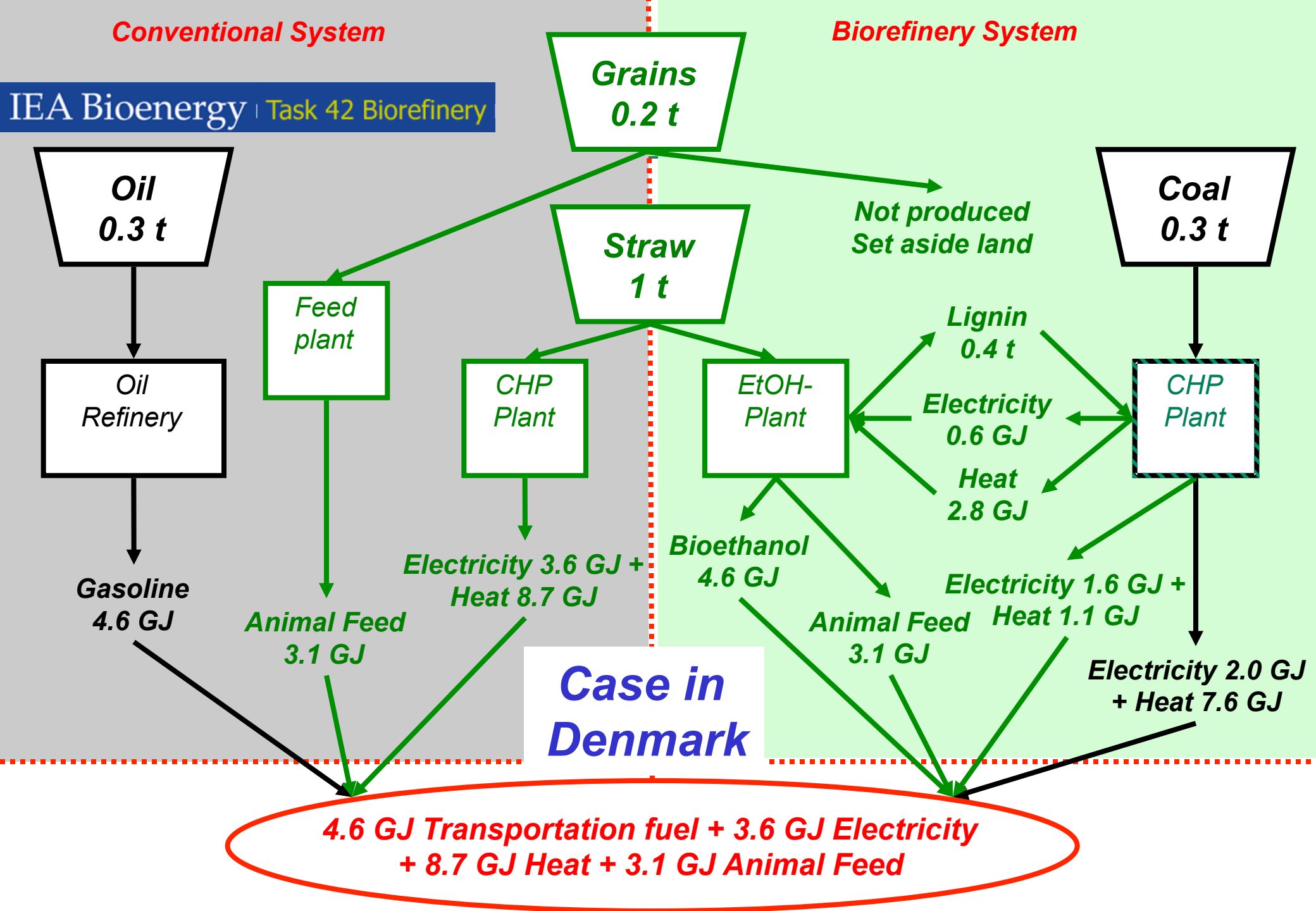
„A Three Platform Biorefinery with Straw for Bioethanol – C6&C5 Sugars and Lignin“



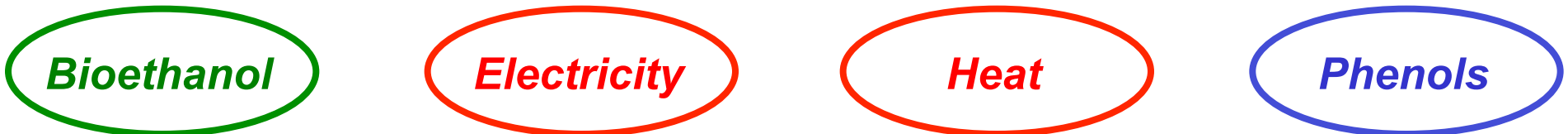
IEA Bioenergy | Task 42 Biorefinery

DONG energy

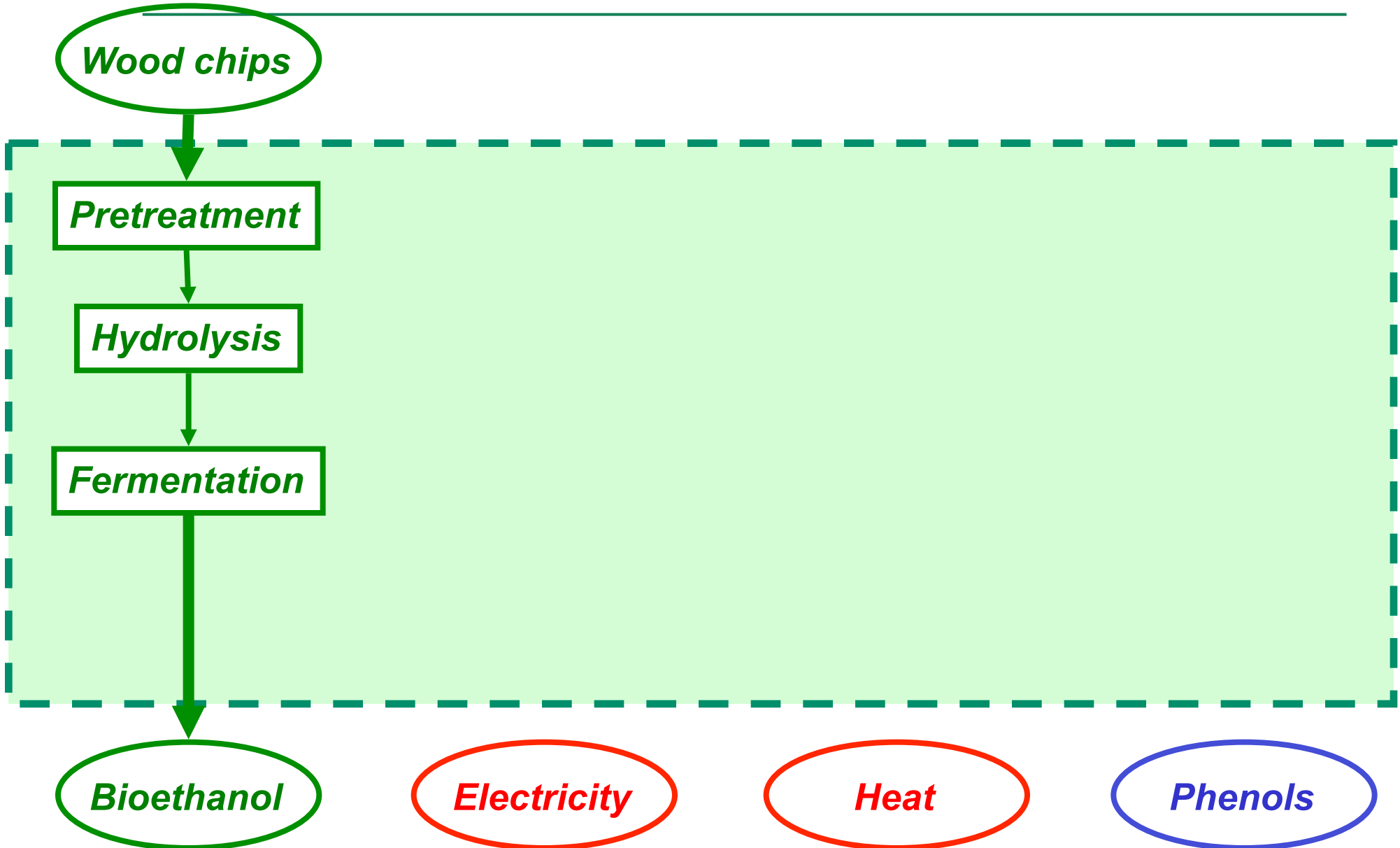
Inbicon


Conventional System
Biorefinery System
IEA Bioenergy | Task 42 Biorefinery
Grains
0.2 t
Oil
0.3 t
Straw
1 t
Not produced
Set aside land
Coal
0.3 t
Feed
plant
Oil
Refinery
CHP
Plant
EtOH-
Plant
Lignin
0.4 t
Electricity
0.6 GJ
Heat
2.8 GJ
CHP
Plant
Gasoline
4.6 GJ
Animal Feed
3.1 GJ
Electricity 3.6 GJ +
Heat 8.7 GJ
Bioethanol
4.6 GJ
Animal Feed
3.1 GJ
Electricity 1.6 GJ +
Heat 1.1 GJ
Electricity 2.0 GJ
+ Heat 7.6 GJ
Case in
Denmark
4.6 GJ Transportation fuel + 3.6 GJ Electricity
+ 8.7 GJ Heat + 3.1 GJ Animal Feed

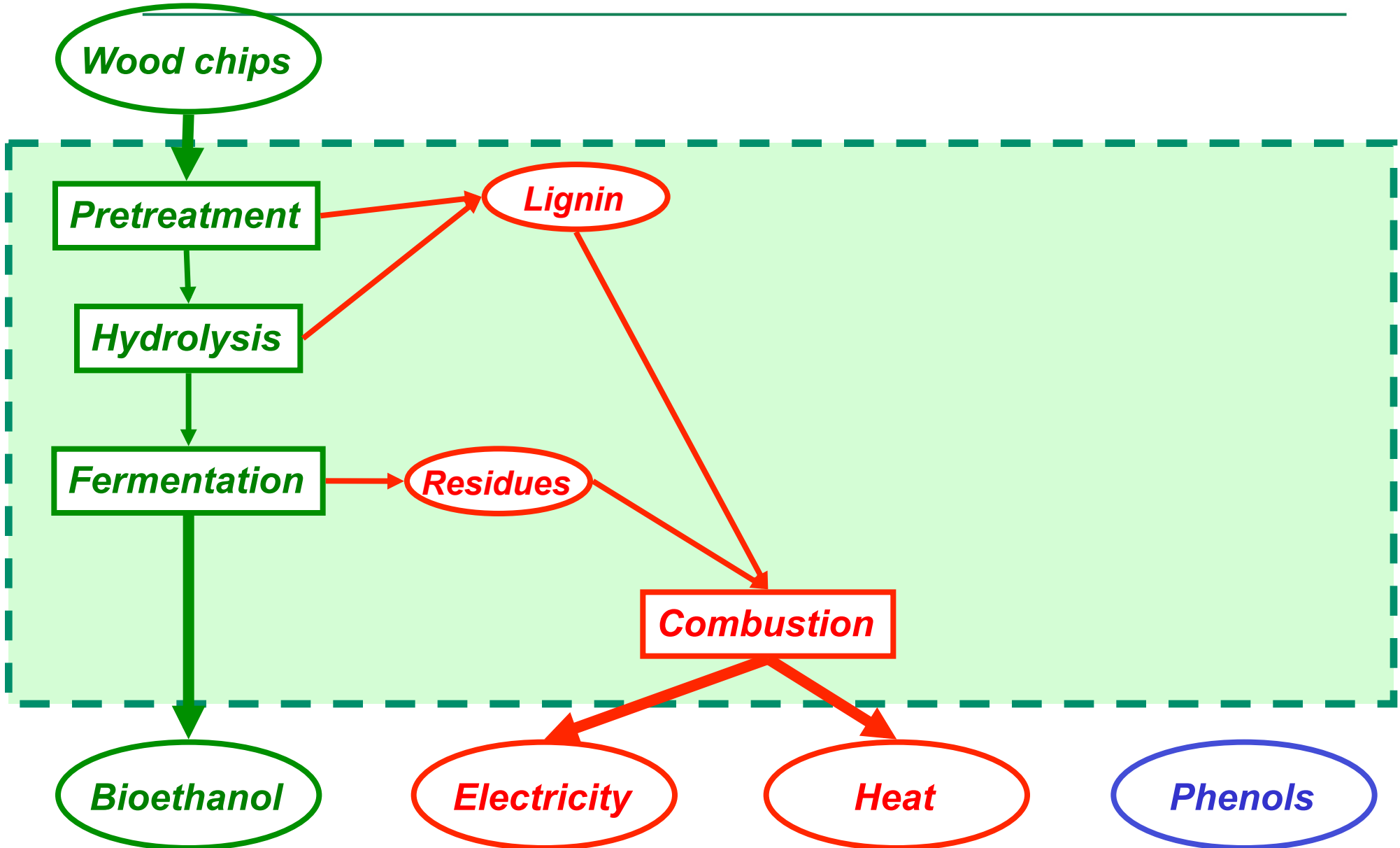
Case 2:
Wood Bioethanol Biorefinery



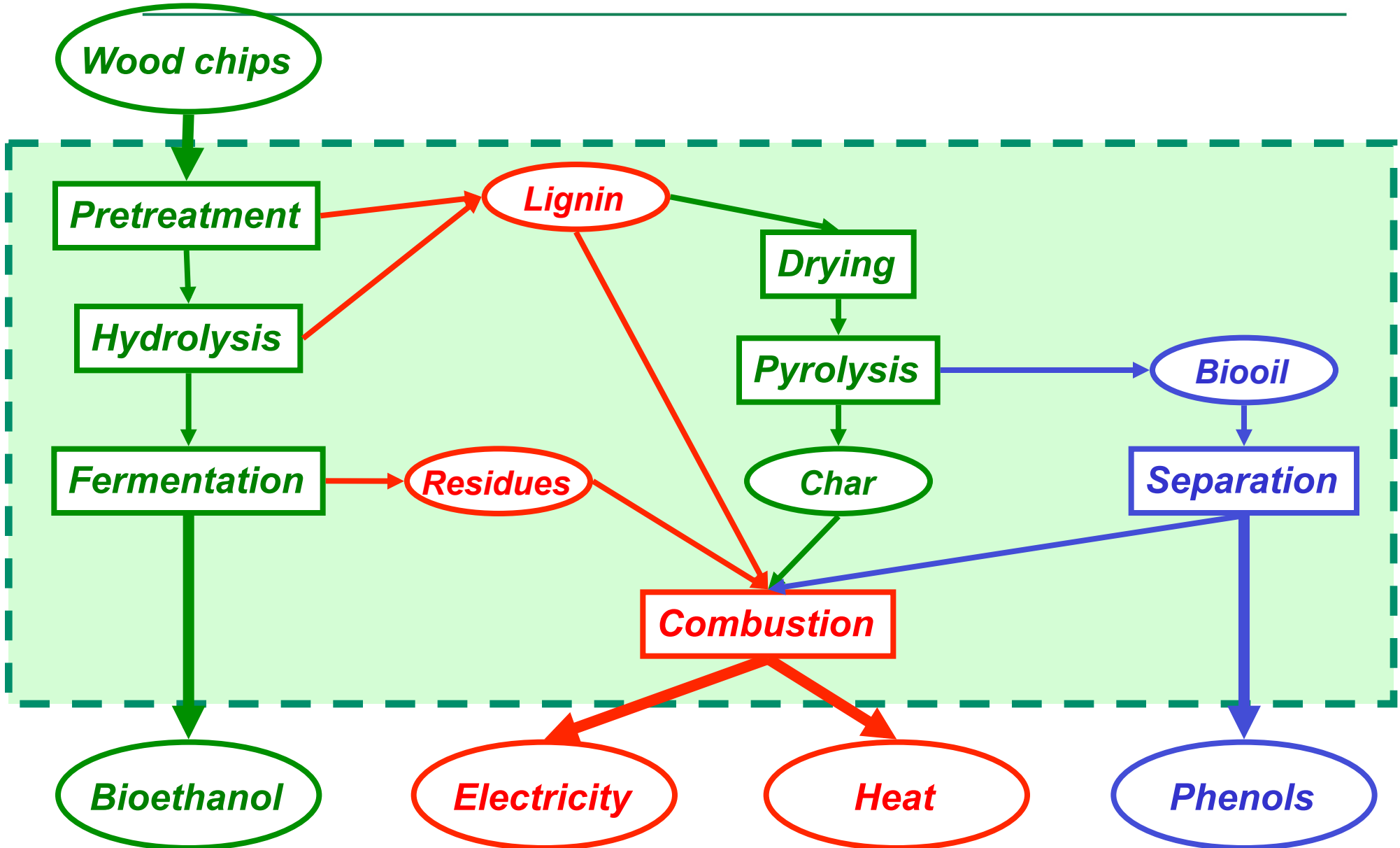
Case 2:
Wood Bioethanol Biorefinery



Case 2:
Wood Bioethanol Biorefinery



Case 2
Wood Bioethanol Biorefinery



Example: Conventional Systems for Comparison

Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			

*) Bioethanol: 100.000 t/a

**) Combined heat and power

Example: Conventional Systems for Comparison

Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			
Wood polygeneration, con. phenols	wood			oil

*) Bioethanol: 100.000 t/a

**) Combined heat and power

Example: Conventional Systems for Comparison

Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			
Wood polygeneration, con. phenols	wood			oil
Wood CHP **), gasoline, con. phenols	wood		gasoline	oil

*) Bioethanol: 100.000 t/a

**) Combined heat and power

Example: Conventional Systems for Comparison

Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			
Wood polygeneration, con. phenols	wood			oil
Wood CHP **), gasoline, con. phenols	wood		gasoline	oil
Wood heating, natural gas, gasoline, con. phenols	wood	natural gas	gasoline	oil

*) Bioethanol: 100.000 t/a

**) Combined heat and power

Example: Conventional Systems for Comparison

Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			
Wood polygeneration, con. phenols	wood			oil
Wood CHP **), gasoline, con. phenols	wood		gasoline	oil
Wood heating, natural gas, gasoline, con. phenols	wood	natural gas	gasoline	oil
Fossil reference system	oil	natural gas	gasoline	oil

*) Bioethanol: 100.000 t/a

**) Combined heat and power

Example: Conventional Systems for Comparison

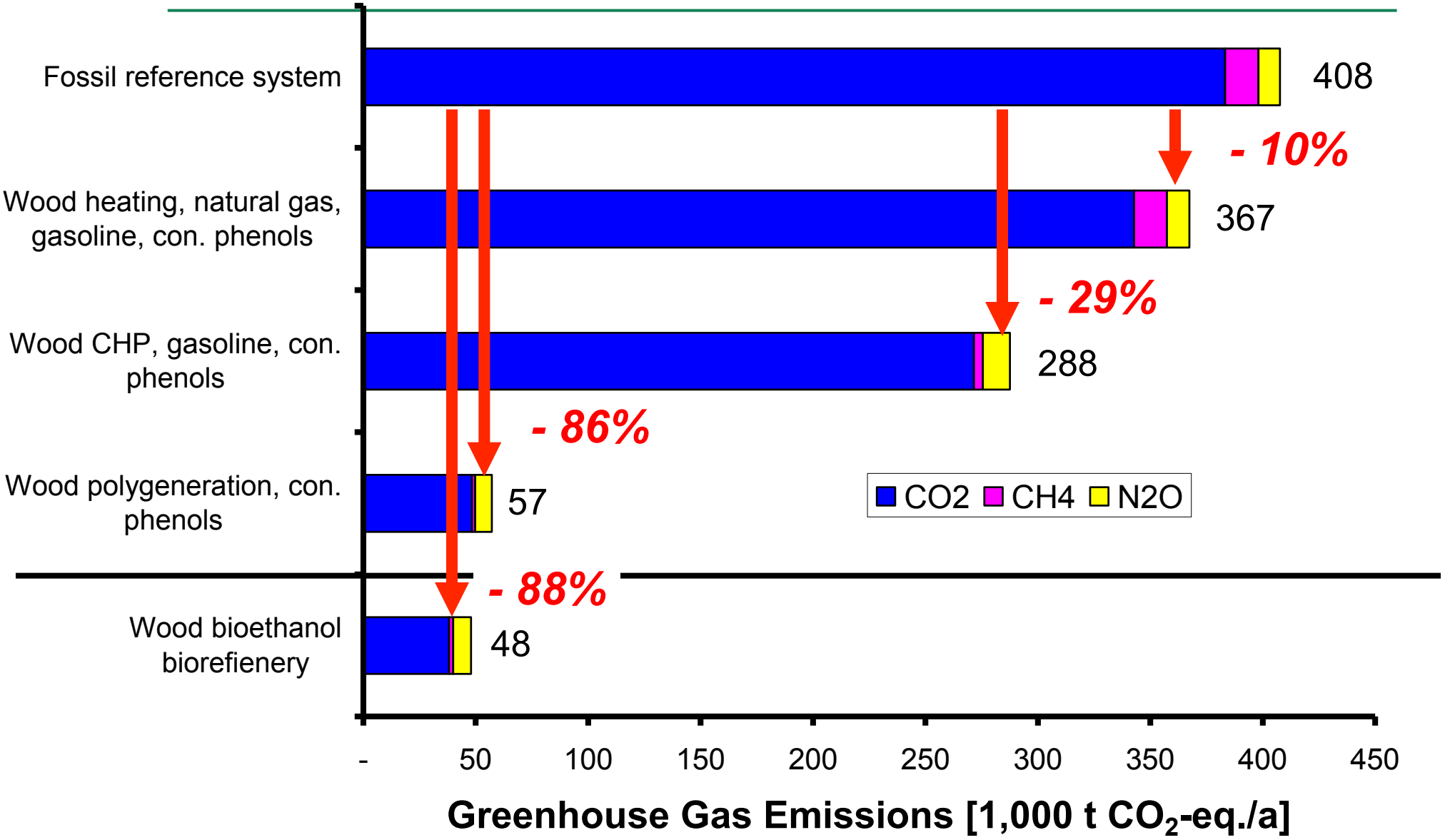
Compared Systems	Product services			
	Heat	Electricity	Transportation service *)	Phenols
	110 GWh/a	175 GWh/a	1,000 Mio. km/a	5,600 t/a
Wood bioethanol biorefinery	wood			
Wood polygeneration, con. phenols	wood			oil
Wood CHP **), gasoline, con. phenols	wood		gasoline	oil
Wood heating, natural gas, gasoline, con. phenols	wood	natural gas	gasoline	oil
Fossil reference system	oil	natural gas	gasoline	oil

*) Bioethanol: 100.000 t/a

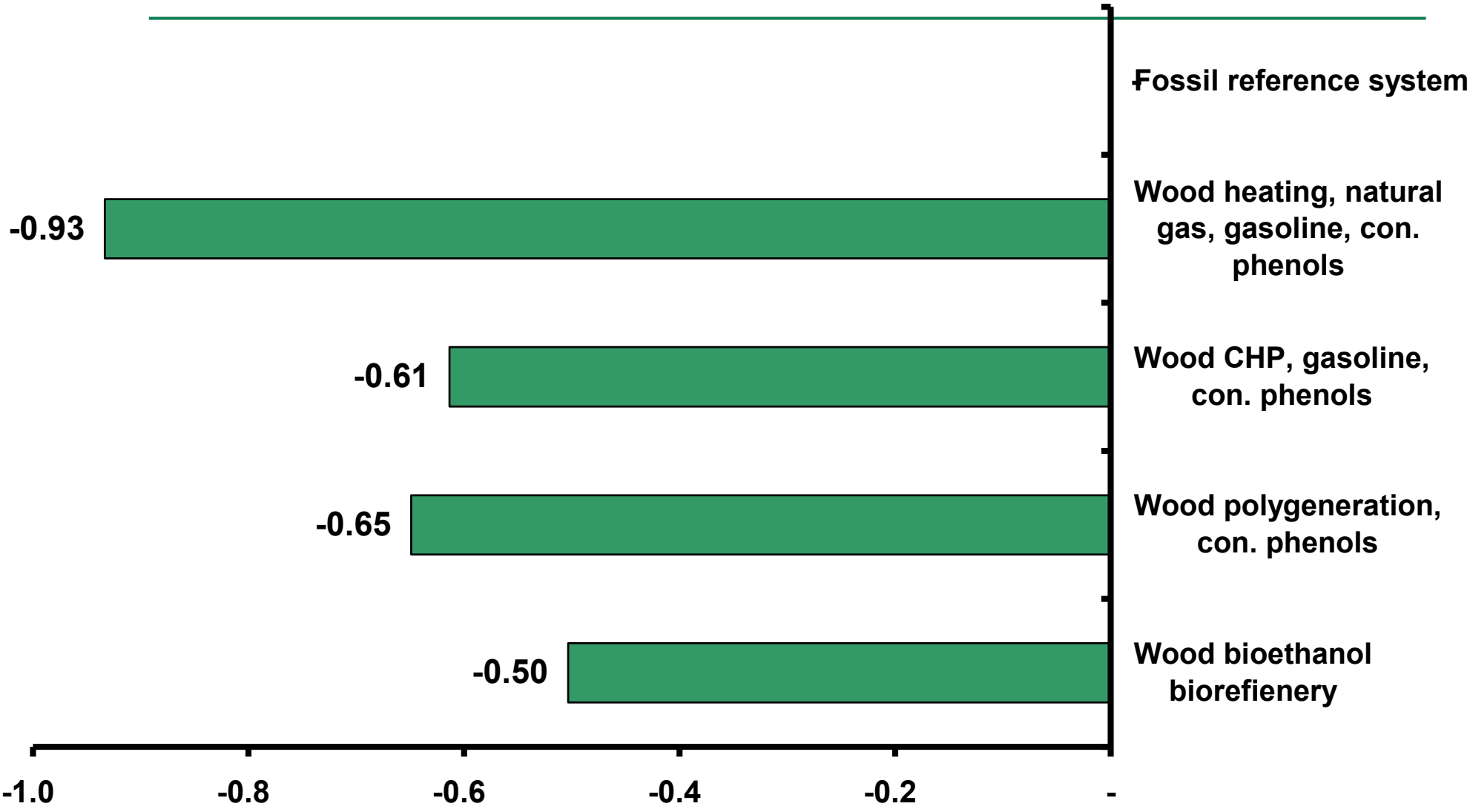
**) Combined heat and power

Conventional systems

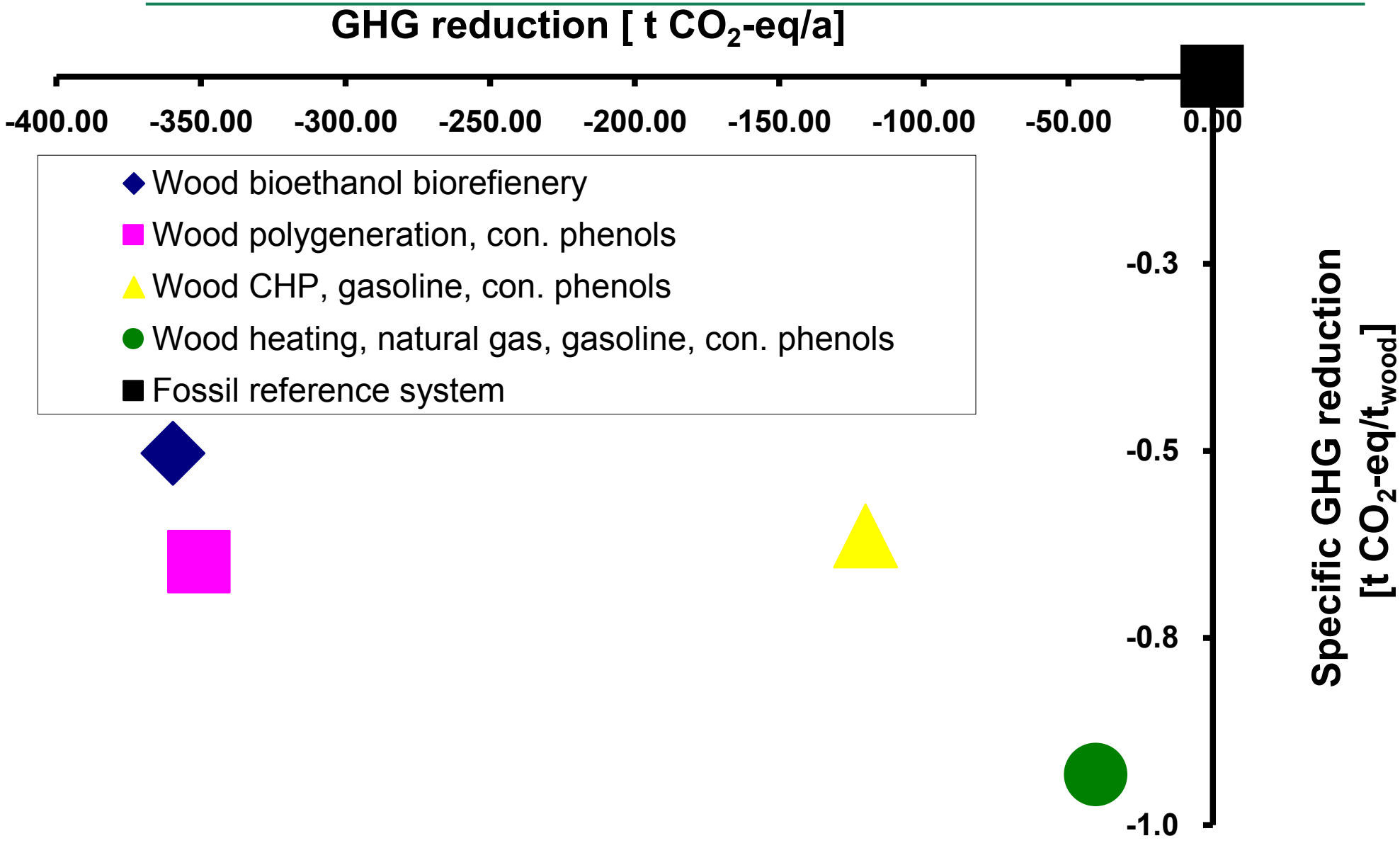
Annual Greenhouse Gas Emissions



Specific Greenhouse Gas Reduction



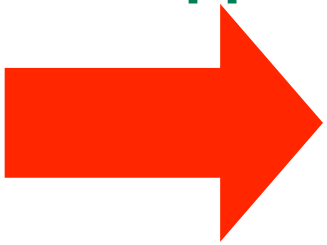
Indicator for Environmental Evaluation: Trade Off



Basics of Comparing Biorefineries to "Conventional Systems"

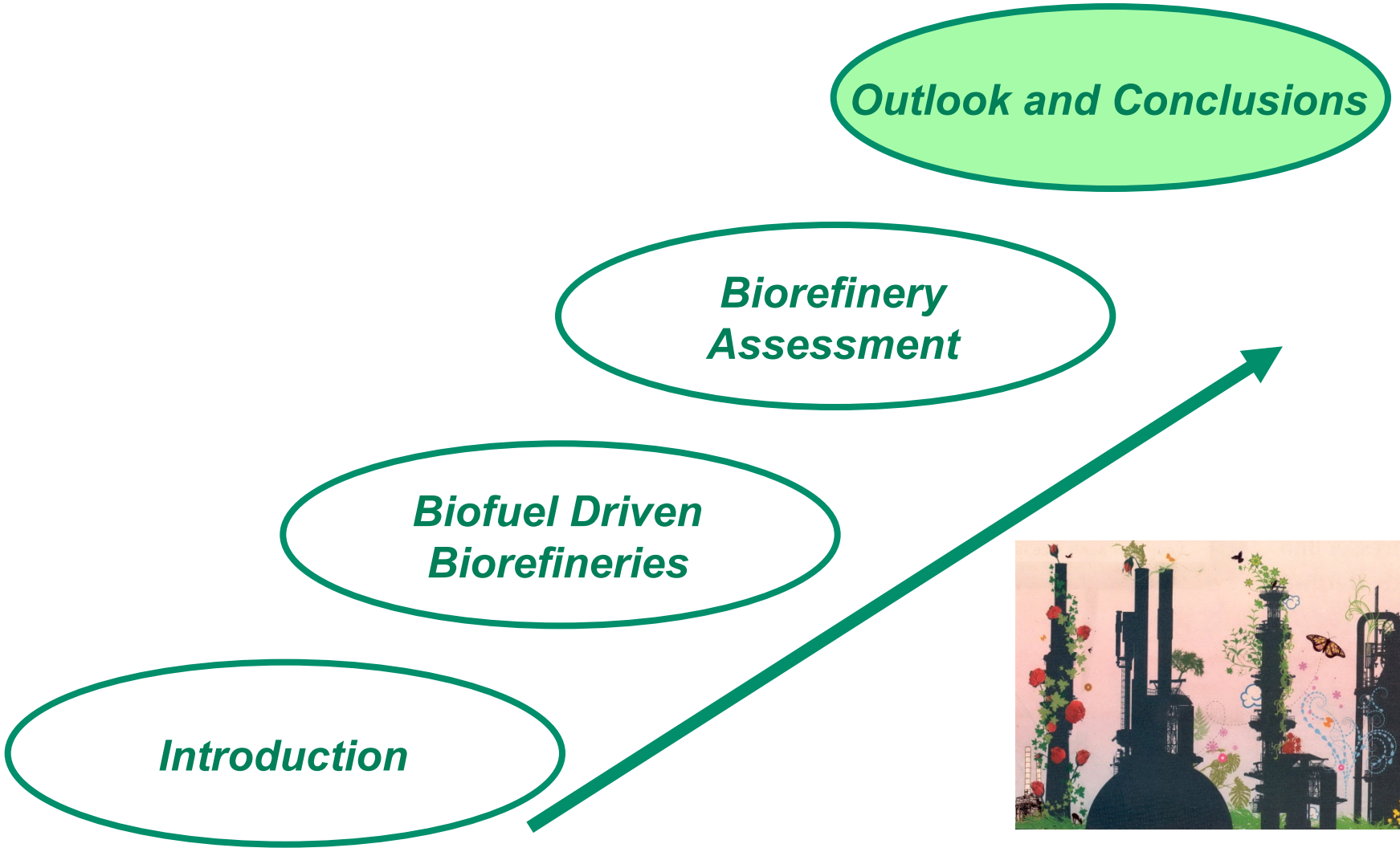
IEA Bioenergy | Task 42 Biorefinery

- ✓ **Same amount of products with same services**
- ✓ **Same amount and type of biomass must be considered**
- ✓ **Same amount of agricultural and forestry area used**
- ✓ **Whole chain approach e.g. life cycle, value chain**

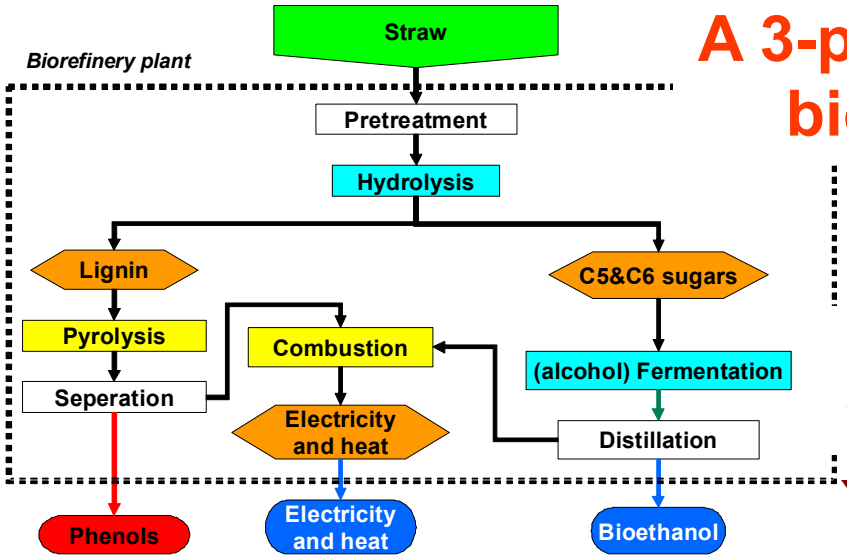


Relevant for all aspects of sustainability: economic, environmental and social

Outline


Outlook and Conclusions
Biorefinery Assessment
Biofuel Driven Biorefineries
Introduction

„Biorefinery Fact Sheet“ Assessment of Biorefinery Concepts

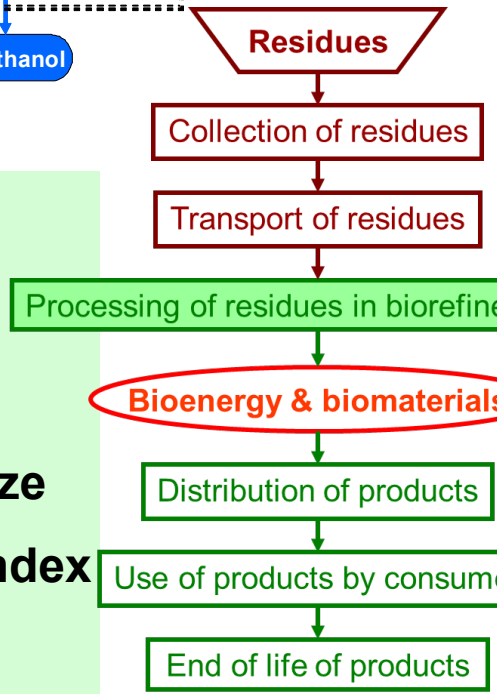


A 3-platform (C6&C5 sugar, el.&heat, lignin) biorefinery using straw for bioethanol

Description

text text text text text text text text text text text text text text text text text text text text

Whole value chain



Characteristics

- State of technology
- Demoplant e.g. Denmark
- (possible) Commercial size
- Biorefinery Complexity Index
- Full Value Chain

Assessment for 100,000 t/a transportation fuel

- Energy balance
- Material balance
- GHG reduction
- Fossil energy reduction
- Investment costs
- Costs of transportation biofuel

www.IEA-Bioenergy.Task42-Biorefineries.com

JOANNEUM RESEARCH RESOURCES

IEA Bioenergy | Task 42 Biorefinery |

type your search | search | extended search

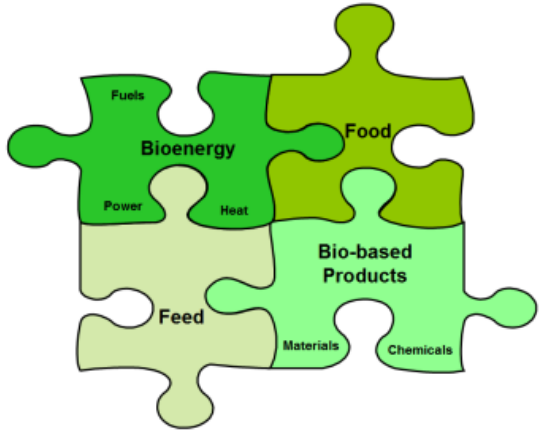
Home | News | Agenda | Members | Activities | Publications | Country Reports | Database | Contact | Links Members Area

You are not logged in

Go To
Database
Members Area

Aims of IEA Bioenergy Task 42

The framework of the activities of IEA Bioenergy Task 42 is the sustainable processing of biomass into a spectrum of Biobased Products and Bioenergy.



The aims of Task 42 are:

1. Assess the worldwide position and potential for biorefineries.
2. Gather new insights for the simultaneous production of human food, animal feed, chemicals, materials, fuels, power and/or heat from biomass in a socially and environmentally acceptable and economically profitable way.

>> More about IEA Bioenergy and Task 42 partners

Country Reports »

Biorefinery Database »

Agenda
No events found.

Conclusions

„Biorefinery Fact Sheets“
in progress IEA Bioenergy Task 42

Indicators for environmental evaluation
in specific and /absolut terms necessary

***Reference system** includes fossil and biomass based systems → might become complex*

***Life cycle assessment** (LCA) is applicable to biorefinery systems*

***Transportation fuels**: biodiesel, bioethanol, FT-biofuel, biomethan from biogas and SNG (synthetic natural gas)*

*Selection of interesting **“Bioenergy driven Biorefineries”** until 2025 by IEA Bioenergy Task 42 “Biorefinery”*

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

Your Contact

Gerfried Jungmeier

JOANNEUM RESEARCH Forschungsgesellschaft mbH.

RESOURCES – Institute for Water, Energy and Sustainability

Energy Research Group

Elisabethstraße 18

A-8010 Graz

AUSTRIA

+43 316 876-1313

www.joanneum.at/eng

gerfried.jungmeier@joanneum.at