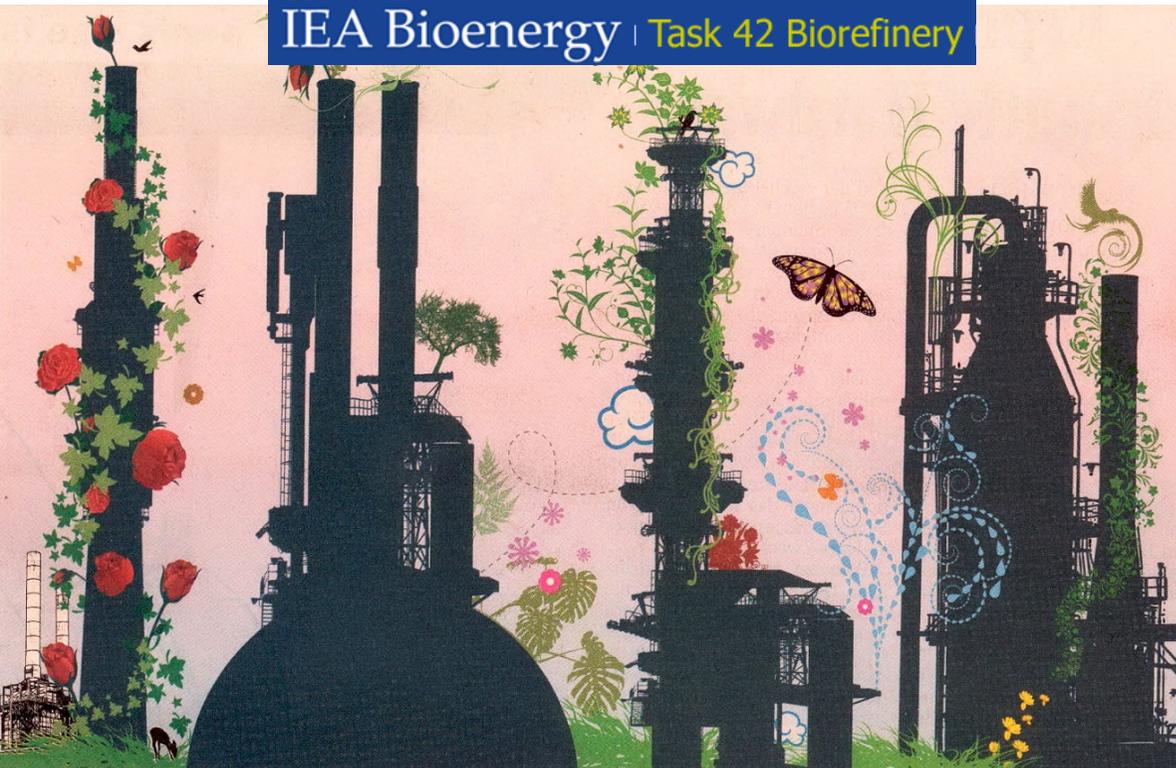


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IEA Bioenergy | Task 42 Biorefinery



Identifying and Assessing the Most Interesting Biofuel-driven Biorefineries Until 2025

Gerfried Jungmeier

H. Jørgensen, N. S. Bentsen, M. Mandl, R. Van Ree, E. de Jong, A. Departe, C. Philips, J.C. Pouet, I. Skiadas, P. Walsh, M. Wellisch, K. Piquette, T. Willke, I. de Bari, M. Klembara, G. Bullock, J. Tomkinson, O. Atac, G. Garnier

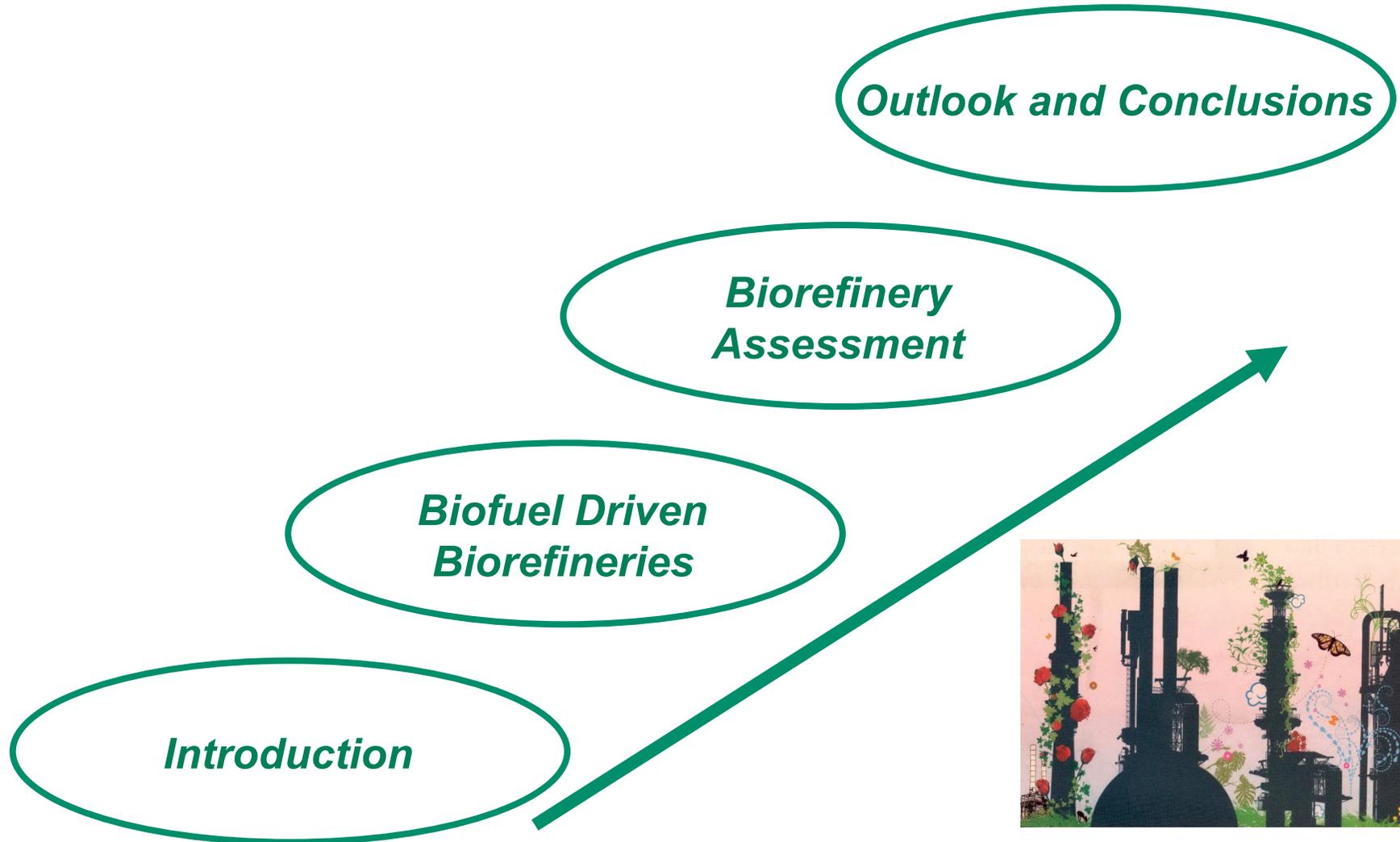
IEA Bioenergy Conference 2012,

November 13 – 15, 2012, Vienna, AUSTRIA

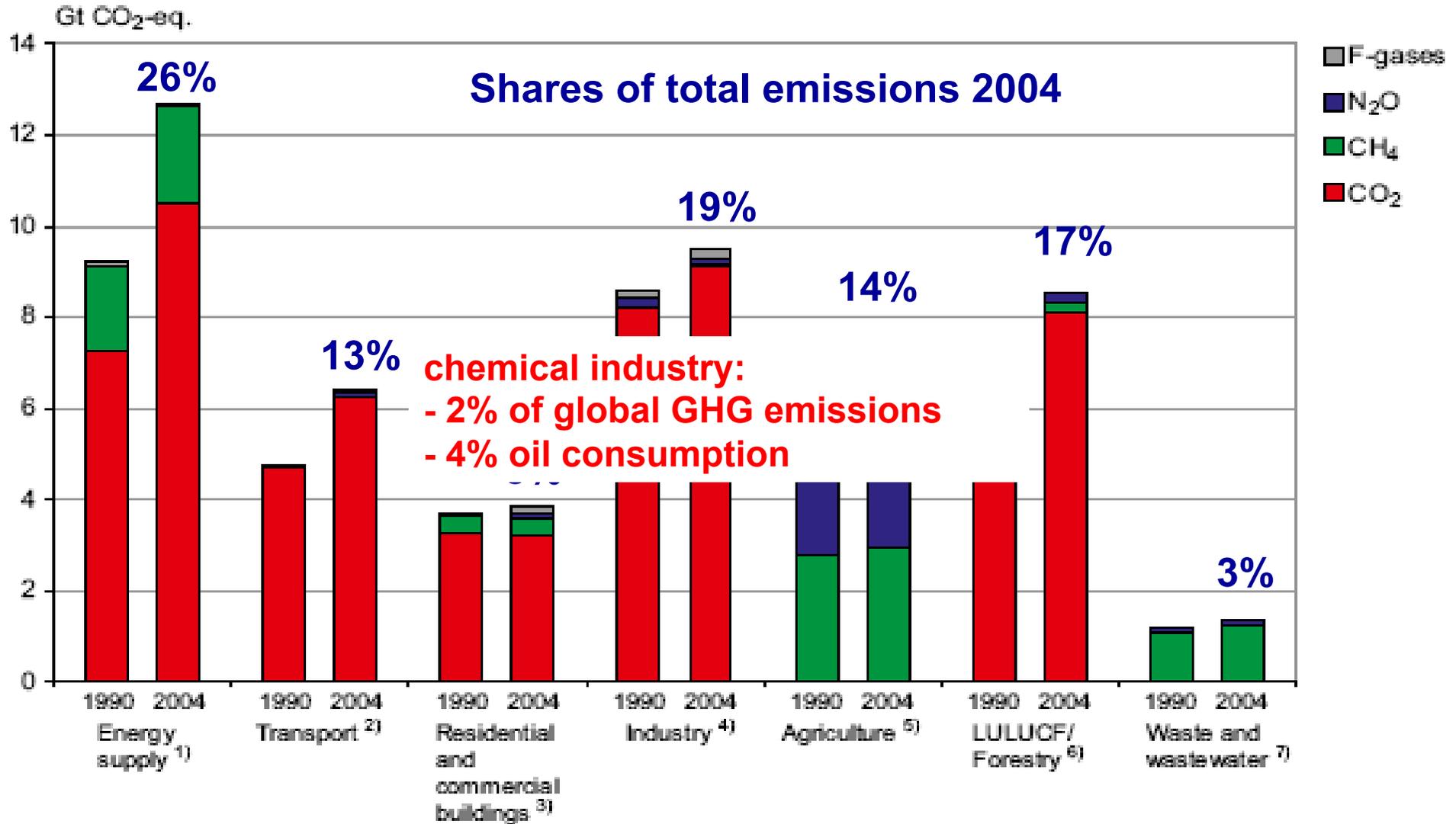
IEA FORSCHUNGS
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The Austrian participation in Tasks 42 of IEA Bioenergy is financed by the Federal Ministry for Transport, Innovation and Technology / Department for Energy and Environmental Technologies

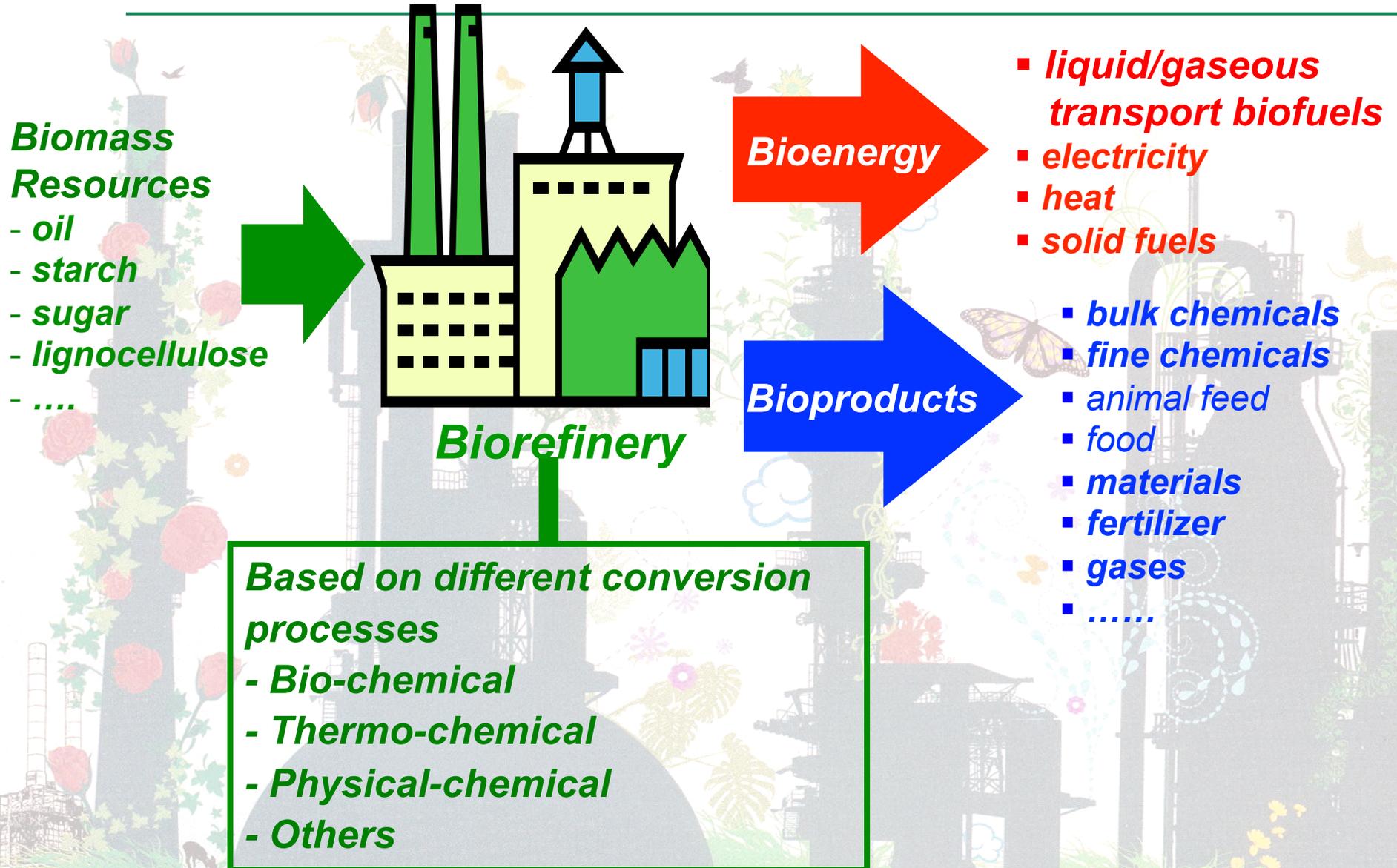
Outline



Development Greenhouse Gas Emissions per Sector 1990 - 2004



Scheme of a Biorefinery



Task 42 “What is a Biorefinery?”

“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 energetic and non-energetic 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

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

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1. Platforms

2. Products

Biorefinery

3. Feedstocks

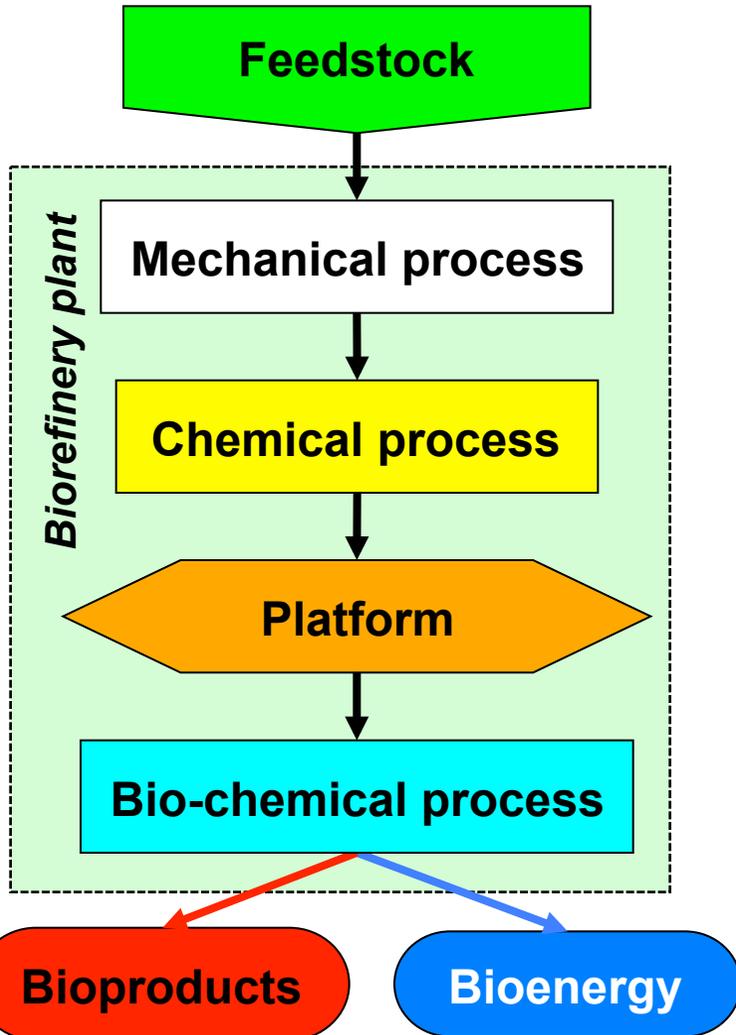
4. Processes

Naming:

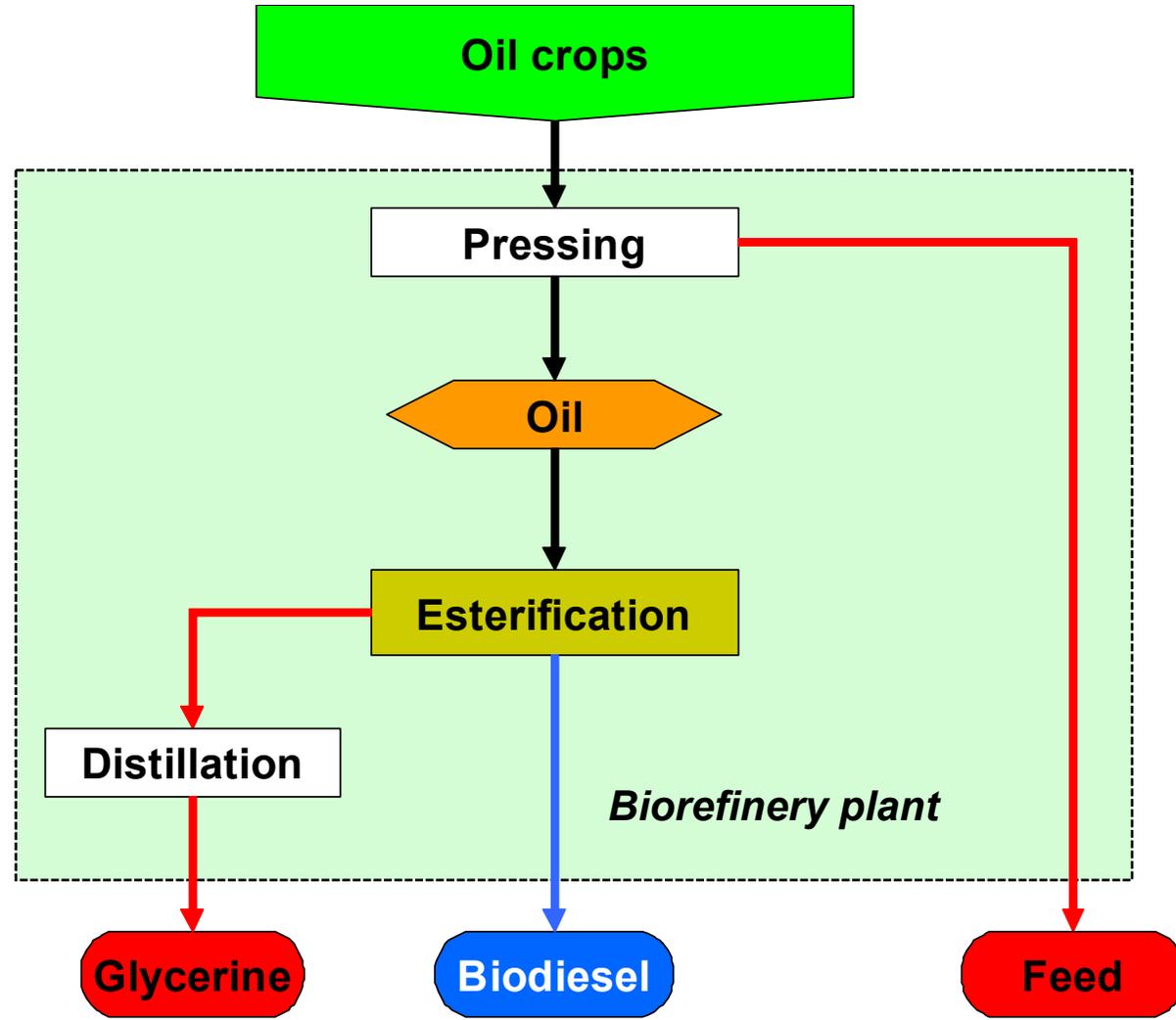
- *Number platforms (Name of platforms)/Feedstock/Products/Processes*
- *e.g. „A 1-Platform Biorefinery with Rape for Biodiesel, Animal Feed & Glycerine“*

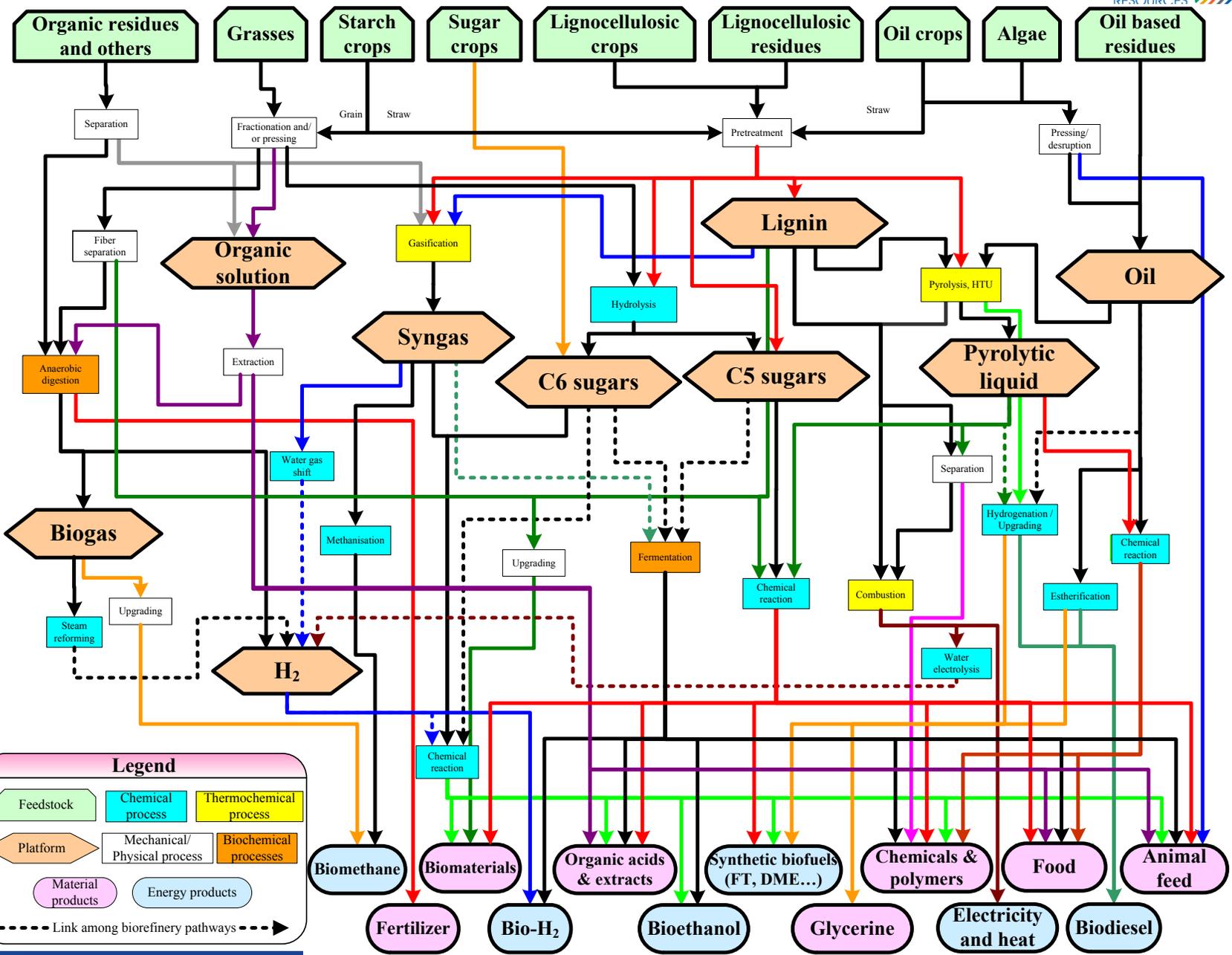
Application of Classification System

Generic System



Example





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

Legend

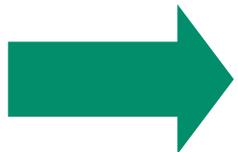
Feedstock	Chemical process	Thermochemical process
Platform	Mechanical/Physical process	Biochemical processes
Material products	Energy products	

--- Link among biorefinery pathways ---

What are “Biofuel Driven” Biorefineries?

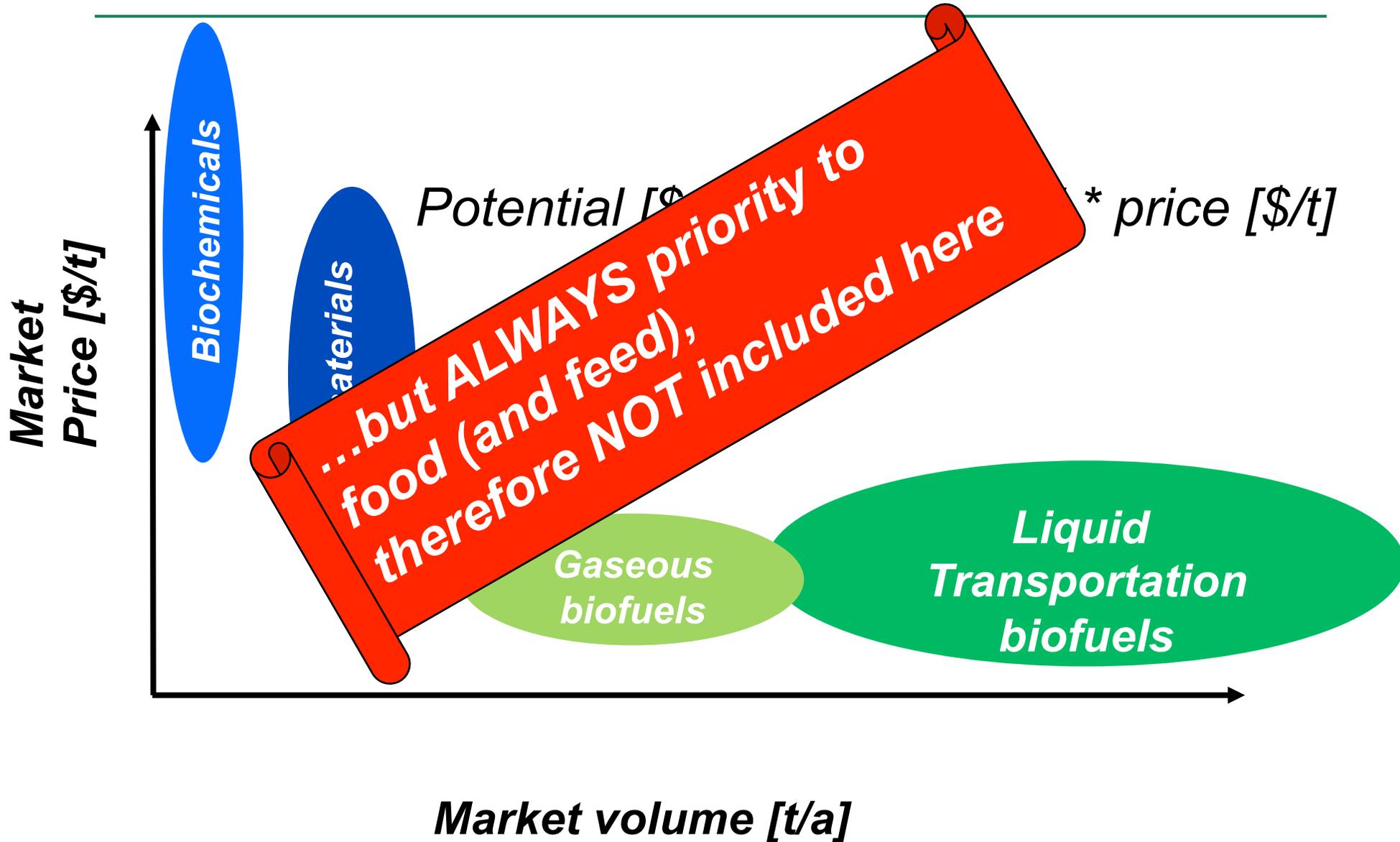
„A transportation biofuel driven biorefinery aims to produce huge volumes of liquid and/or gaseous transportation biofuels co-producing (high value) bio-chemicals and biomaterials“

- **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:

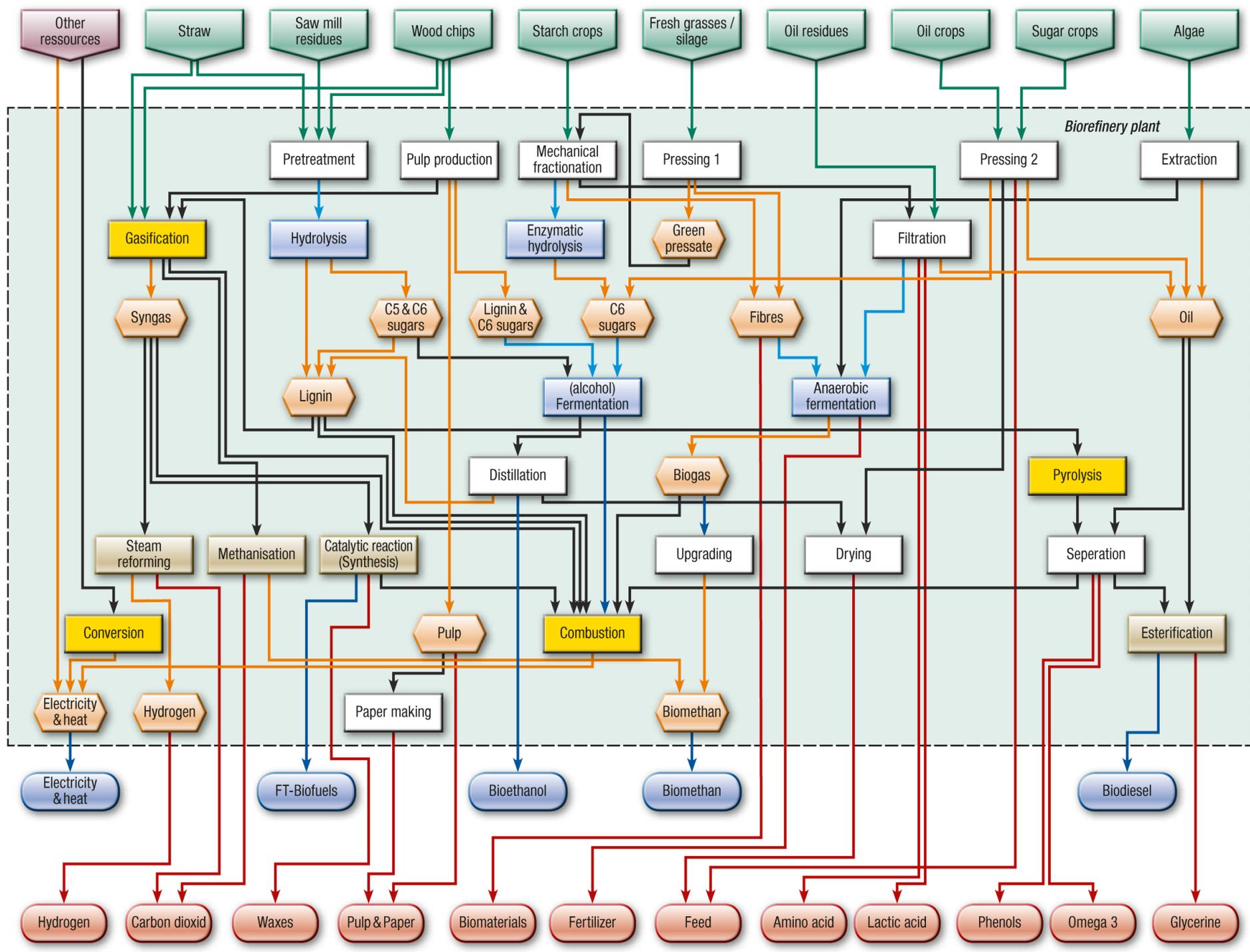
- ✓ Animal feed
- ✓ Glycerine
- ✓ Phenole
- ✓ Pulp/paper
- ✓ Amino acids
- ✓ Lactic acids
- ✓ Fertiliser
- ✓ Waxes
- ✓ Hydrogen
- ✓ Carbon dioxide

*) coproduction of electricity, heat and lignin pellets

The Most Interesting „Bioenergy-driven“ Biorefineries up to 2025

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1. “1-platform (oil) biorefinery using oil crops for biodiesel, glycerin and feed“
2. “1-platform (oil) biorefinery using oil based residues&oil crops for biodiesel, glycerin and feed“
3. “1-platform (C6 sugar) biorefinery using sugar&starch crops for bioethanol and feed“
4. “5-platform (biogas, biomethane, green pressate, fibers, electricity&heat) biorefinery using grass for biomet
lactic acid, biomaterials and fertilizer“
5. “2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-Biofuels, electricity, heat and v
with steam gasification“
6. “3-platform (pyrolyses oil, syngas, electricity&heat) biorefinery using straw for FT-biofuels and methano
oxygen gasification“
7. “3-platform (pulp, syngas, electricity&heat) biorefinery using wood chips for FT-biofuels, electricity, hea
pulp“
8. “3-platform (C6&C5 sugar, electricity&heat, lignin) biorefinery using wood chips for bioethanol, electricity
and phenols“
9. “4-platform (electricity&heat, hydrogen, biomethane, syngas) biorefinery using wood chips for biome
(SNG), hydrogen and carbon dioxide“
10. “4-platform (C6&C5 sugar, lignin&C6 sugar, electricity&heat) biorefinery using saw mill residues, wood
and sulfite liquor for bioethanol, pulp&paper, electricity and heat“
11. „4-platfrom (C6-, C5- sugars, lignin, electricity&heat) biorefinery using straw for bioethanol, electricity, hea
feed“
12. “5-platfrom (C6 sugars, C6&C5 sugar, lignin, syngas, electricity&heat) biorefinery using starch crops and
for bioethanol, FT-biofuels, feed, electricity and heat“
13. “4-platform (biogas, biomethane, oil, electricity&heat) biorefinery using algae for biodiesel, biomet
electricity heat and glycerin Omega 3 and fertilizer“



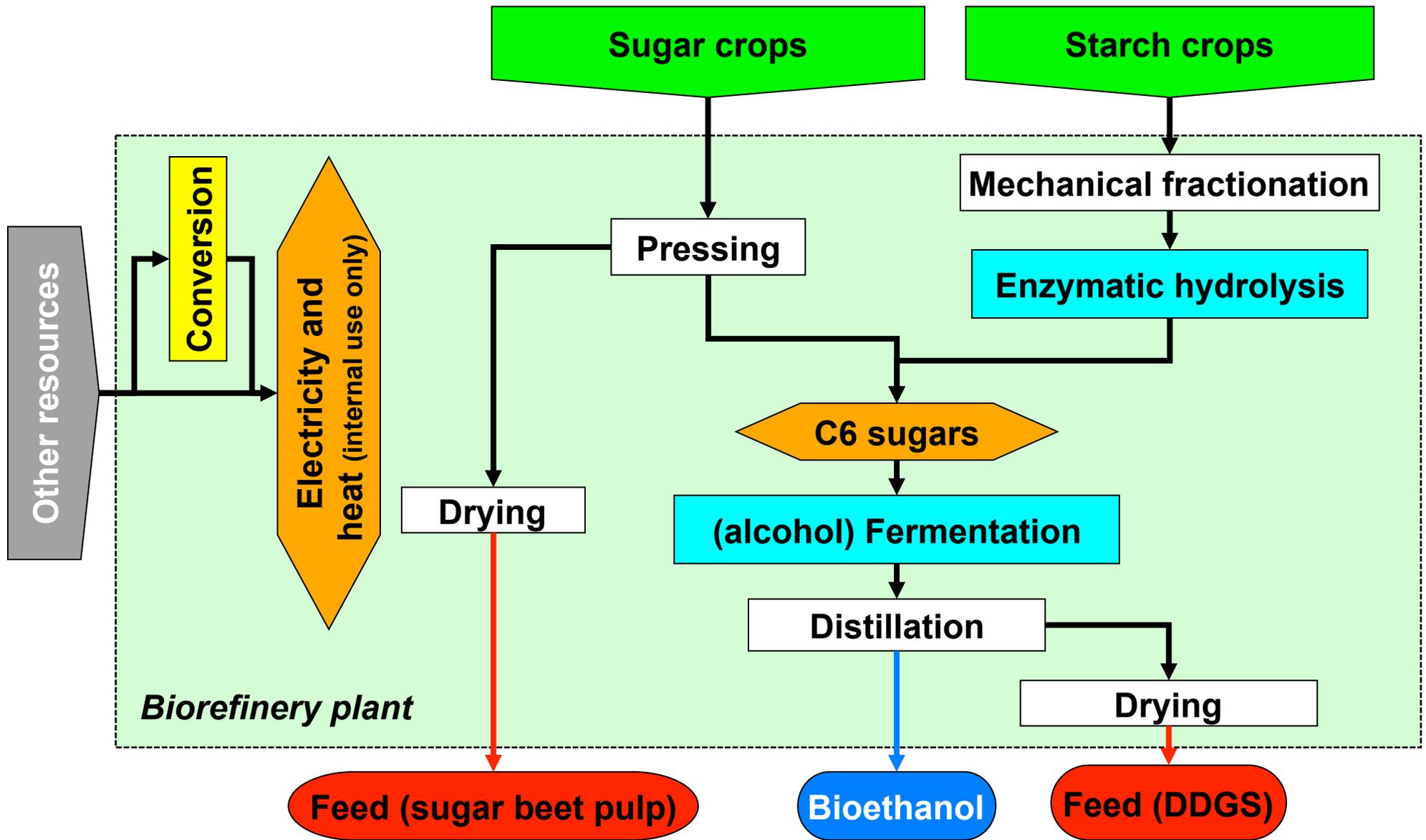
Implementation Perspectives of Energy Driven Biorefinery Concepts

- 
- **Commercial energy driven biorefineries**
 - ✓ state of the art
 - ✓ worldwide in commercial operation under current economic condition
 - **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 \geq 2020
 - **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 \geq 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“

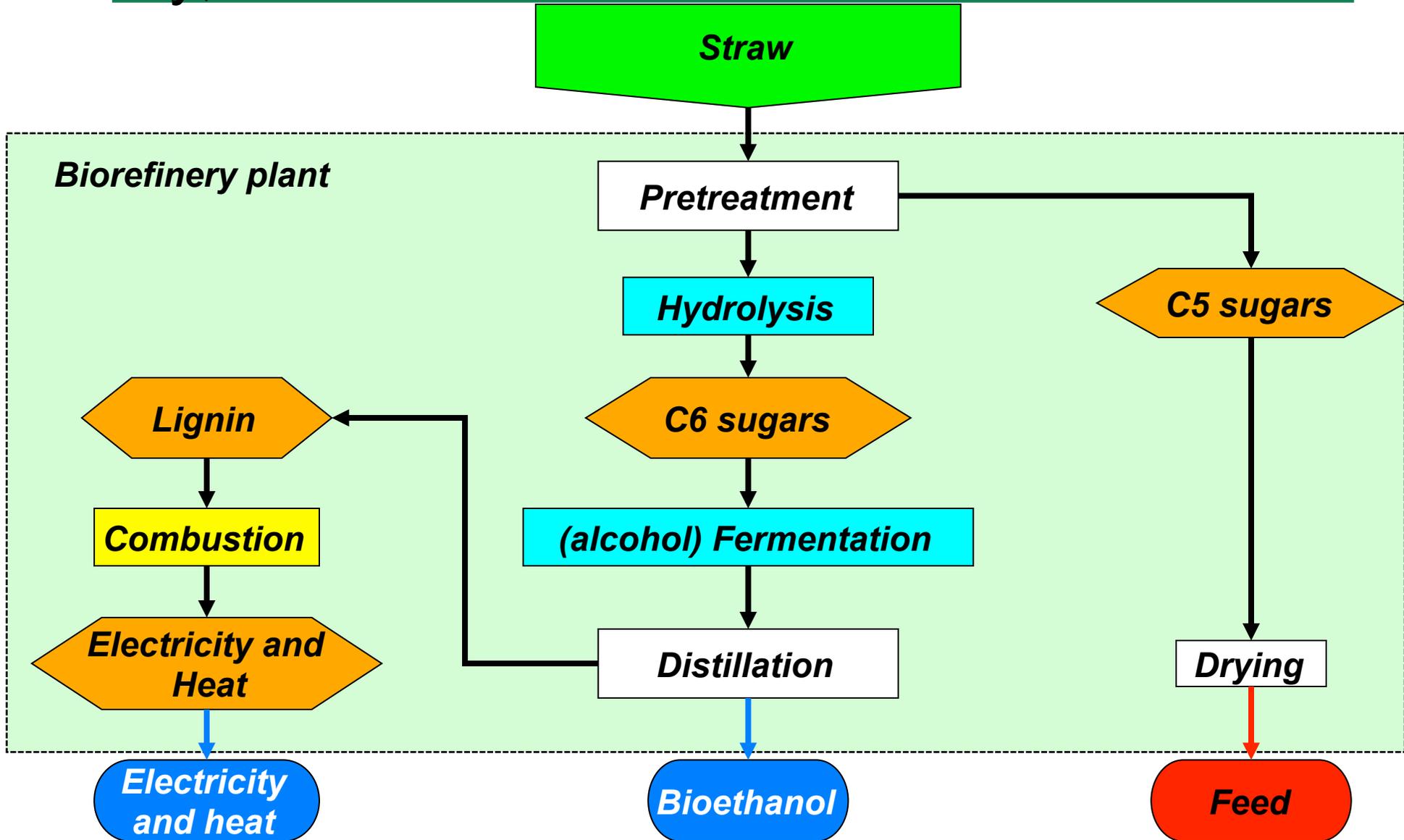
1-platform (C6 sugar) biorefinery using sugar&starch crops for bioethanol



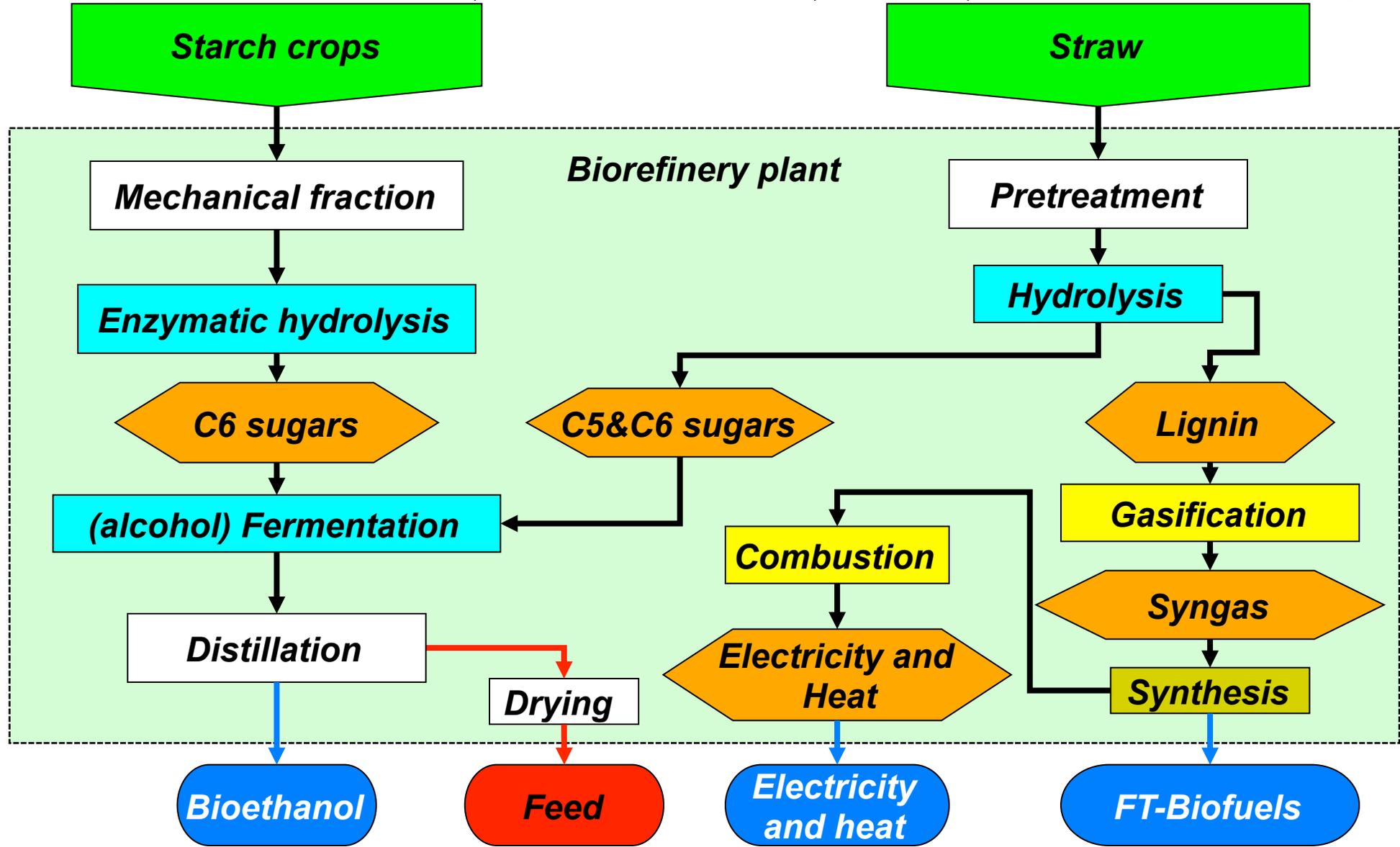
Demonstrated Energy Driven Biorefineries

- “4-platform (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-platform (C6 sugars, C6&C5 sugar, lignin, syngas, electricity&heat) biorefinery using starch crops and straw for bioethanol, FT-biofuels, feed, electricity and heat“

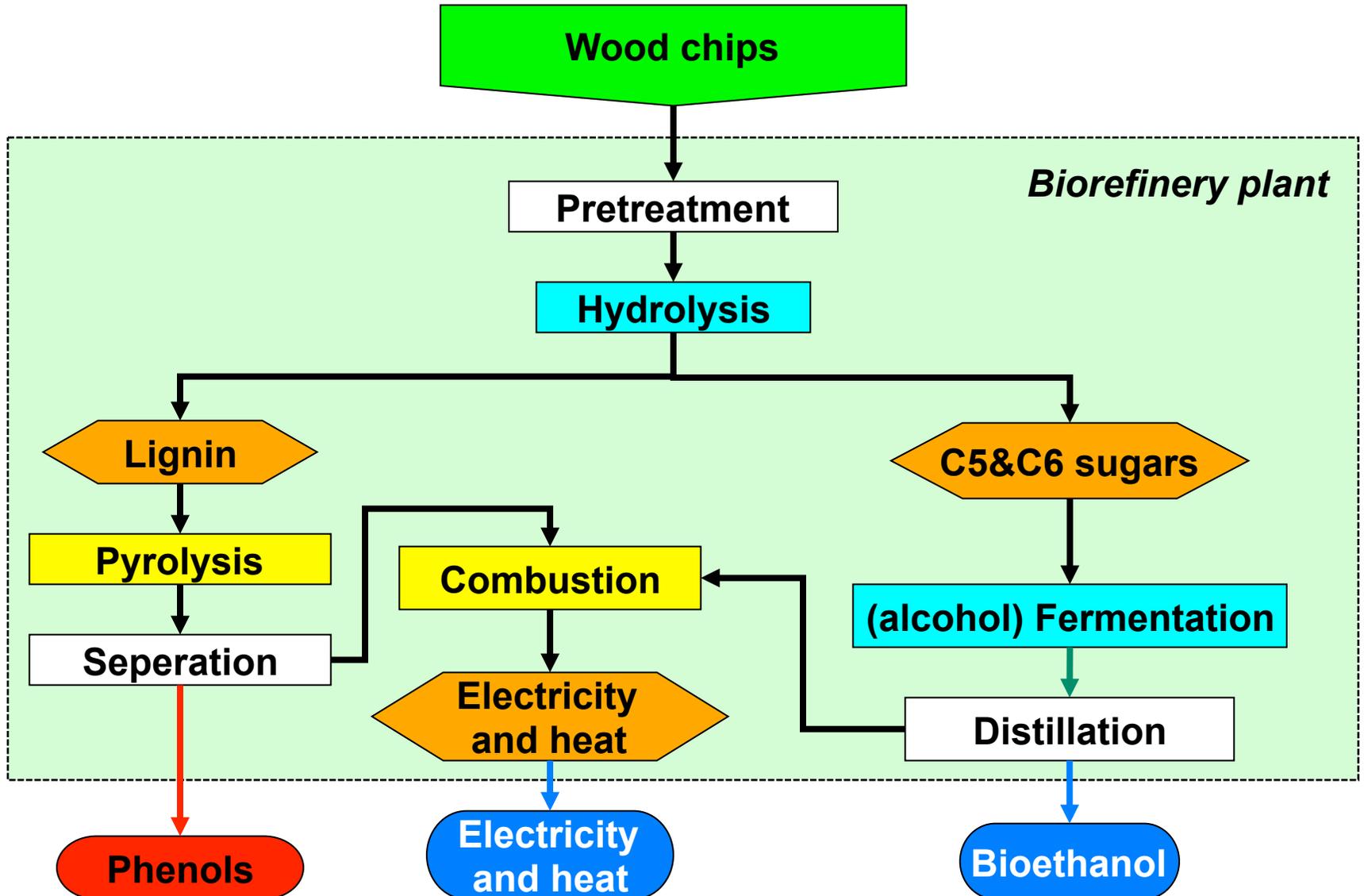
4-platform (C6-, C5- sugars, lignin, electr.&heat) biorefinery using straw for bioethanol, electricity, heat and feed



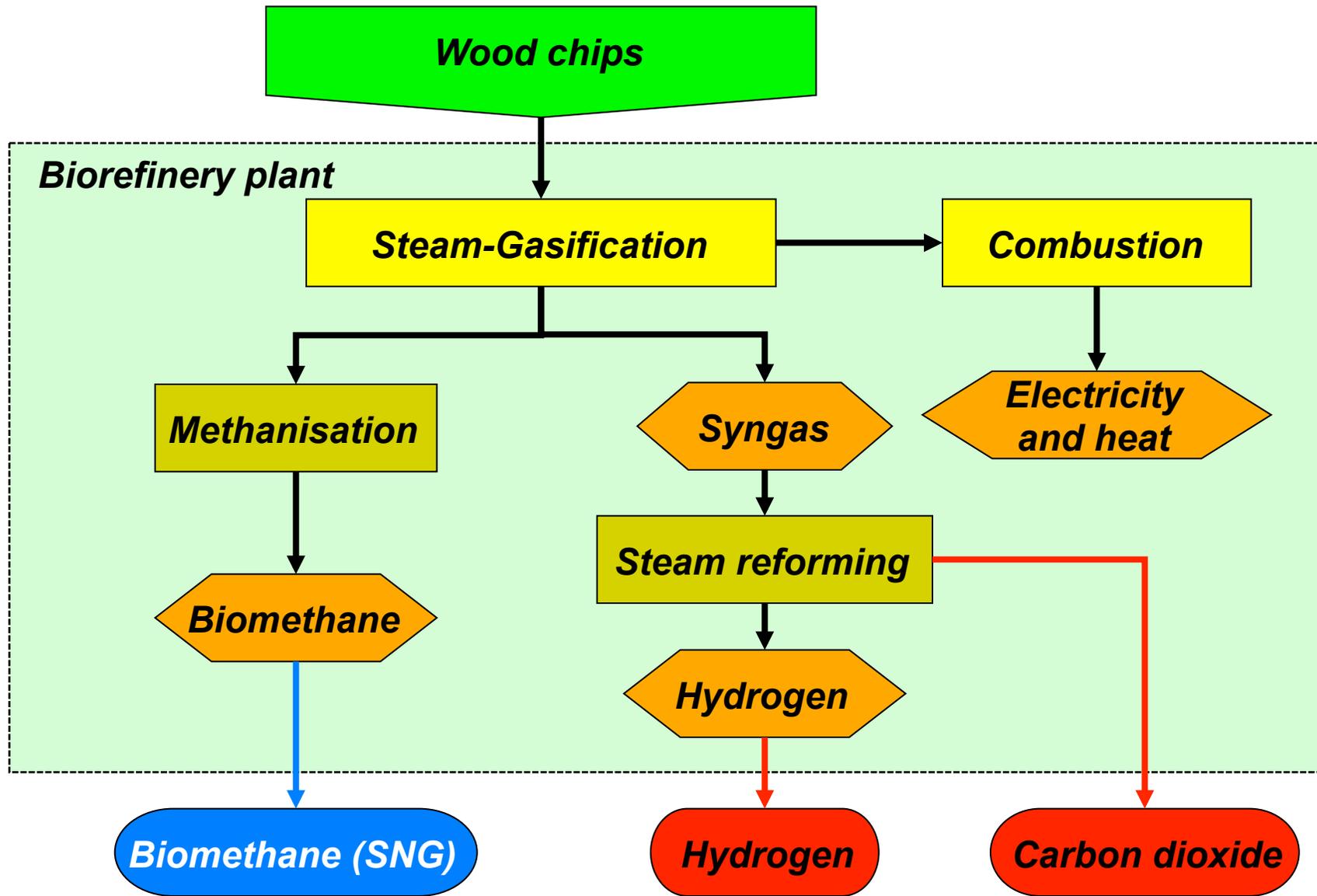
5-platform (C6 sugars, C6&C5 sugar, lignin, syngas, elec.&heat) biorefinery using starch crops and straw for bioethanol, FT-biofuels, feed, elec. and heat



3-platform (e&heat, lignin, C6&C5 sugar) biorefinery using wood chips for bioethanol



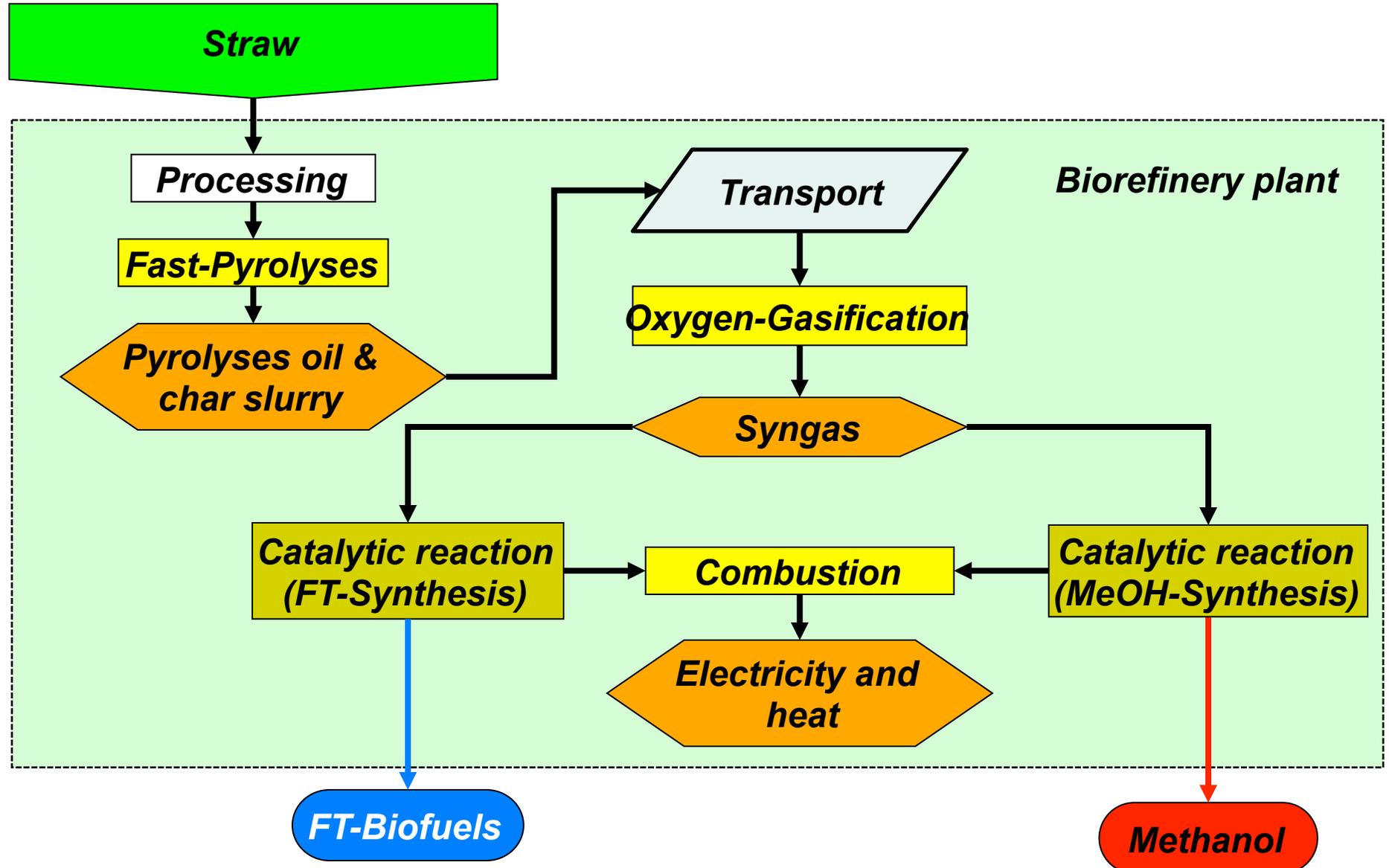
4-platform (electricity&heat, hydrogen, bio-methane, syngas) biorefinery using wood chips for biomethane (SNG), hydrogen and carbon dioxide



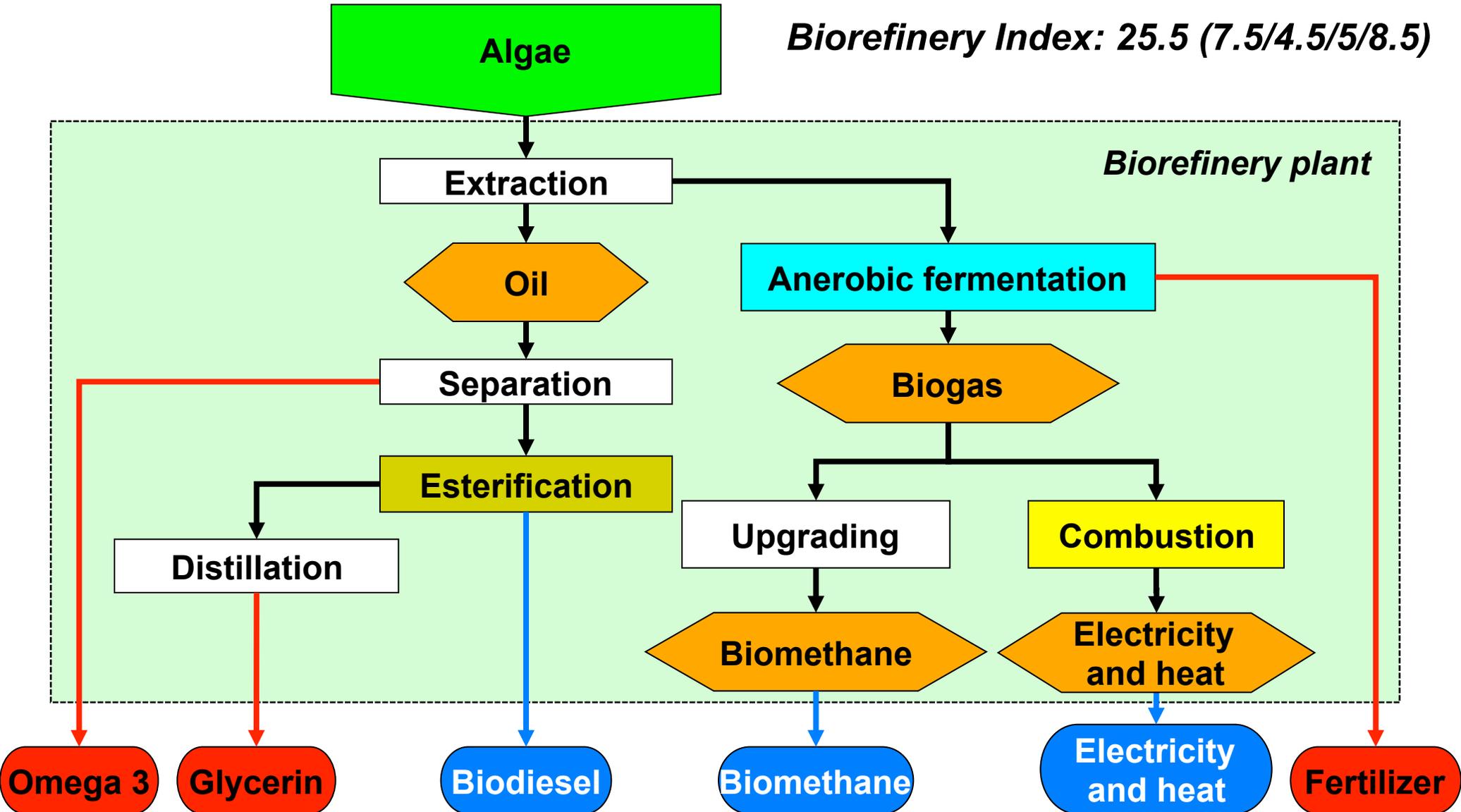
Conceptual Energy Driven Biorefineries until 2025

- “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“.

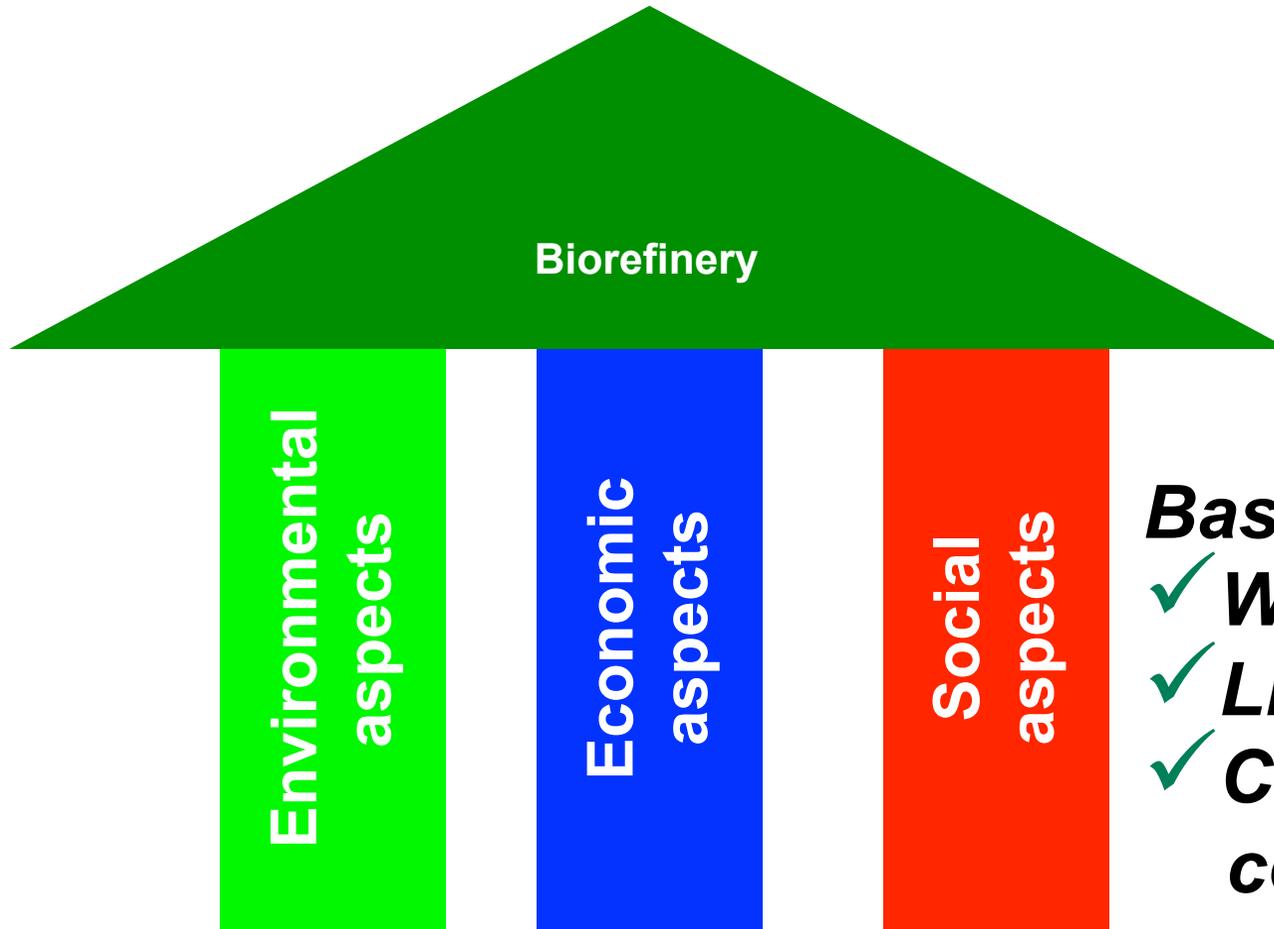
“3-platform (pyrolyses oil, syngas, elec.&heat) biorefinery using straw for FT-biofuels and methanol with oxygen gasification”



4-platform (biogas, biomethane, oil, el.&heat) biorefinery using algae for biodiesel



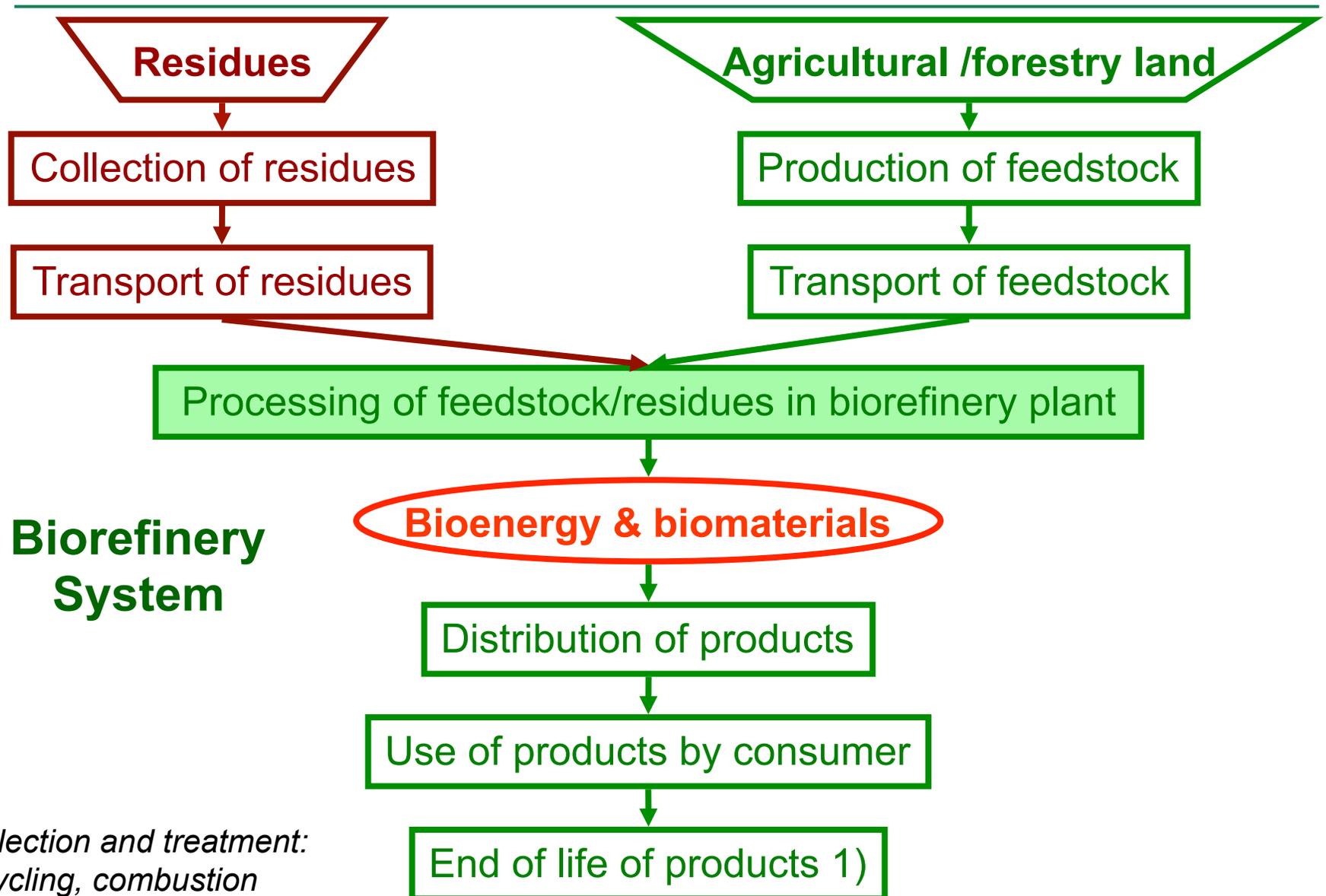
Sustainability Assessment of Biorefineries



Based on

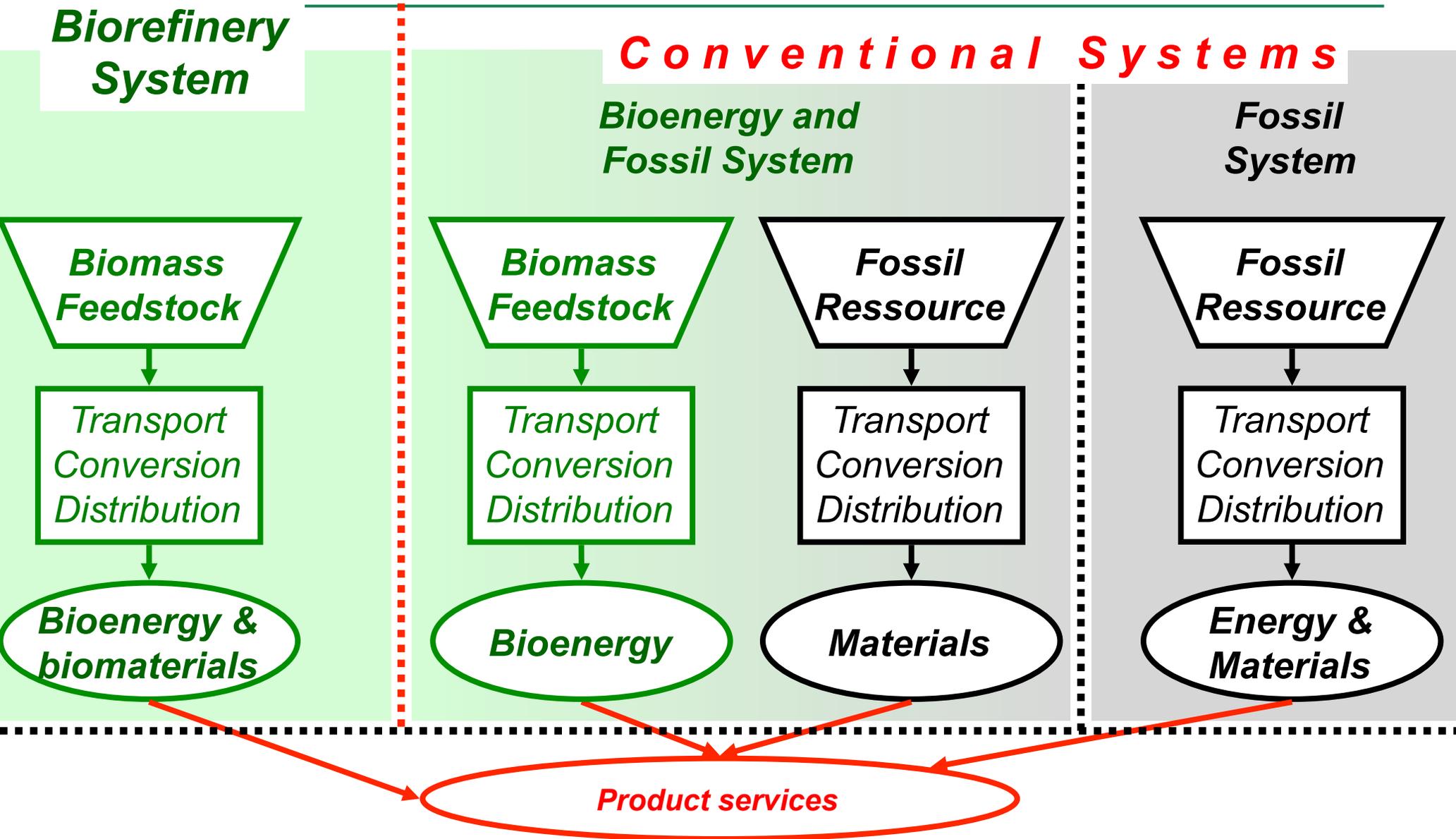
- ✓ ***Whole value chain***
- ✓ ***Life cycle***
- ✓ ***Comparison to conventional system***

Sustainability Assessment Based on “Value Chain of a Biorefinery”



1) Collection and treatment:
e.g. recycling, combustion

What are the „Conventional Systems“ for Comparison?



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

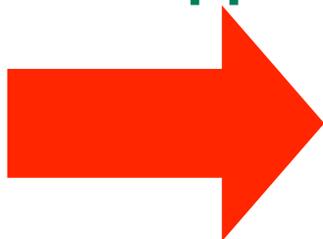
*) Bioethanol: 100.000 t/a
 **) Combined heat and power

Conventional systems

Basics of Comparing Biorefineries to “Conventional Systems”

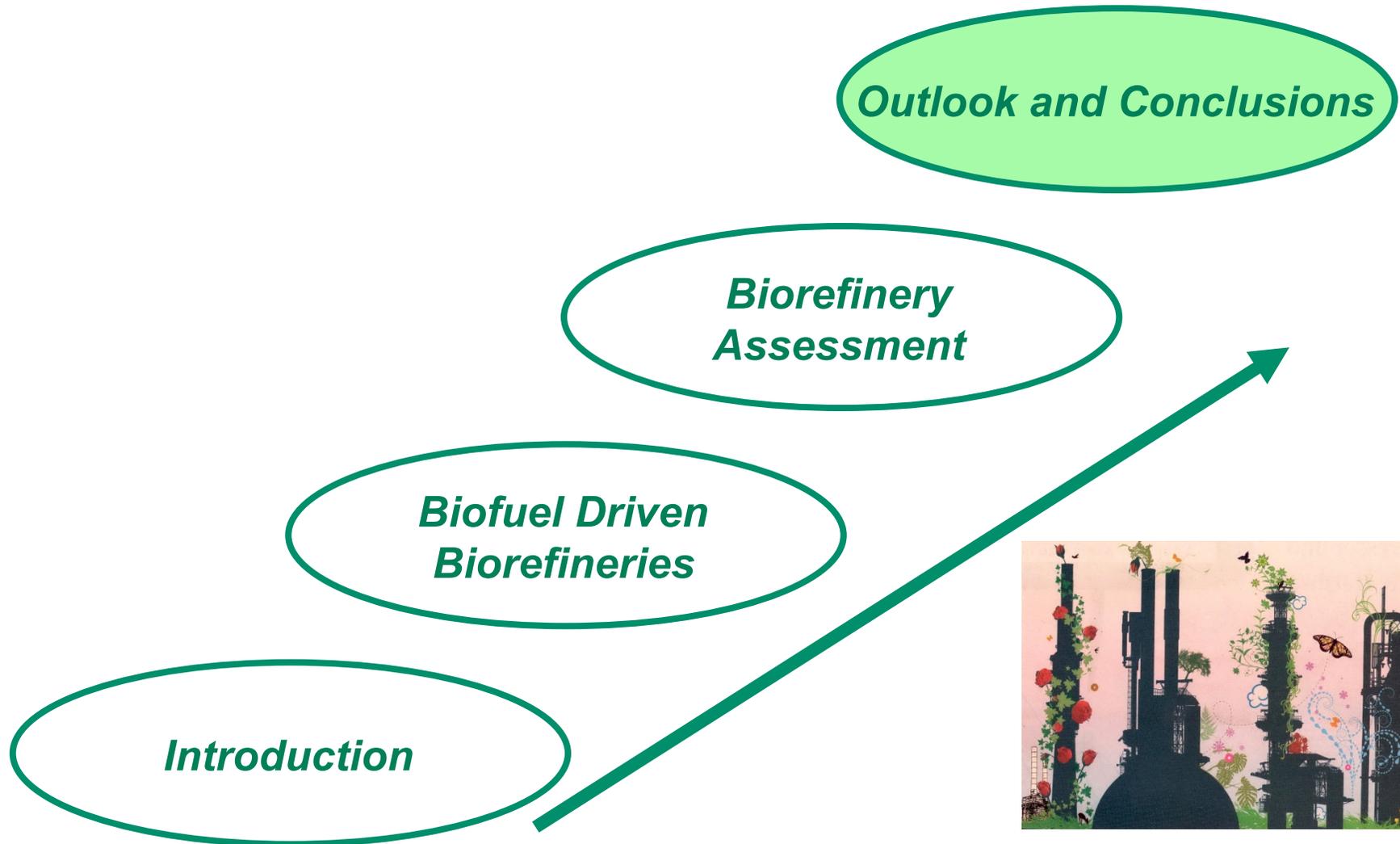
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- ✓ Same amount of products with same services
- ✓ Same amount and type of biomass must be considered
- ✓ Same amount of agricultural and forestry area used
- ✓ Whole chain approach e.g. life cycle, value chain



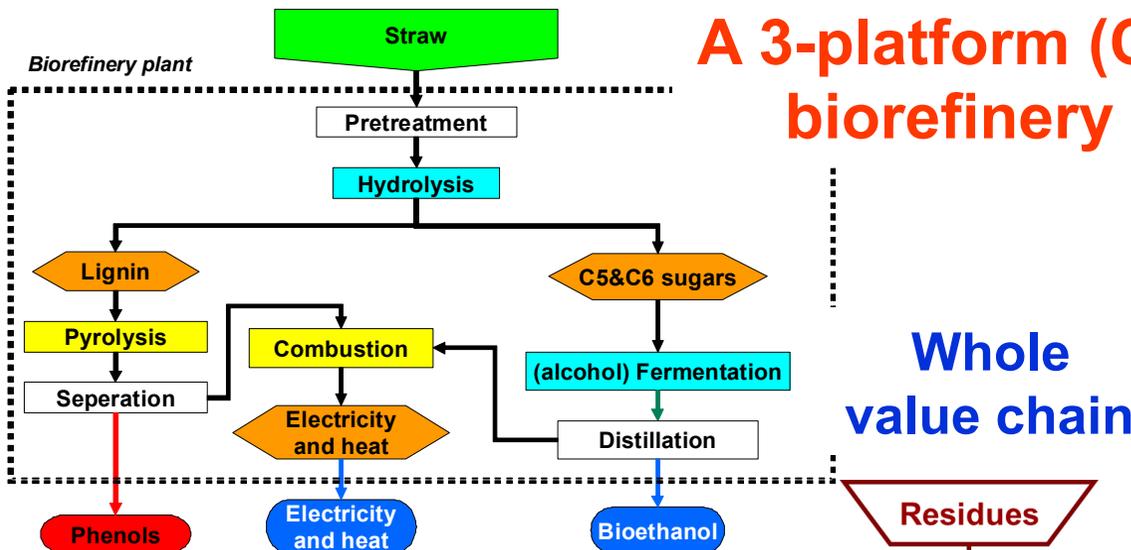
***Relevant for all aspects of sustainability:
economic, environmental and social***

Outline



Assessment of Biorefinery Concepts in a „Biorefinery Fact Sheet“

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



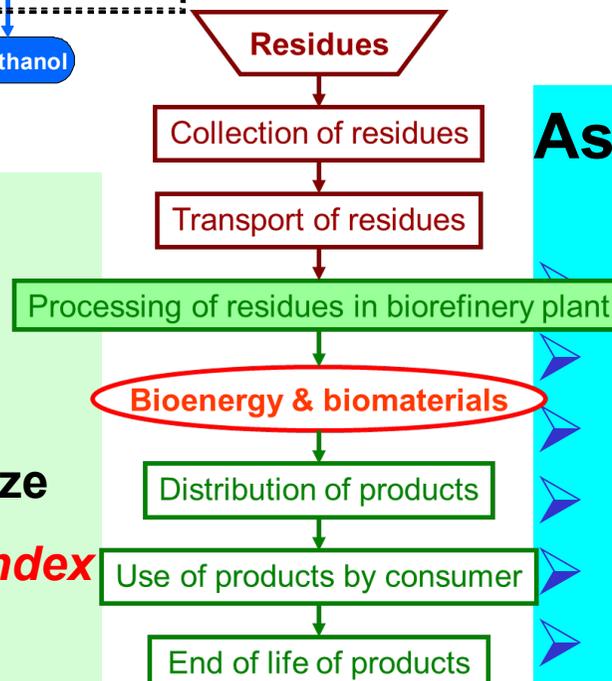
Description

text text

Characteristics

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

Whole 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

Conclusions&Outlook

Assessment&fact sheet of biorefinery concepts (100,000t/a) in IEA Task 42

Reference System includes fossil and biomass based systems → complex

Sustainability assessment based on “Whole Value Chain” compared to conventional systems

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

Selection of interesting “bioenergy-driven Biorefinery concepts by IEA Bioenergy Task 42 “Biorefinery”

Distinction between “Bioproduct-driven” and “Bioenergy-driven” biorefinery is essential in developing biorefinery concepts until 2020