

Upgrading Strategies for Industrial Infrastructures – Integration of Biorefineries in Existing Industrial Infrastructure

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Working document

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Summary

A key driver for the necessary sustainable development is the implementation of the BioEconomy, which is based on renewable resources to satisfy its energy and material demand of our society. The broad spectrum of biomass resources offers great opportunities for a comprehensive product portfolio to satisfy the different needs of a BioEconomy – food, feed, bioenergy, biofuels, chemicals, materials. The concept of biorefining guarantees the resource and energy efficient use of biomass resources. The IEA Bioenergy Task 42 “Biorefining” has the following definition on biorefinery: “*Biorefining is the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, and materials) and bioenergy (biofuels, power and/or heat)*”. Currently many different biorefinery concepts are developed and already implemented which play a key role in establishing a BioEconomy. The purpose of the work is to analyse the possible integration of biorefineries in the existing industrial infrastructure. This information assists industry, decision makers and investors in their strategies to invest and integrate resource efficient biomass uses in the infrastructure of a future BioEconomy. Based on the activities of the 11 participating countries (A, AUS, CA, DK, FR, G, I, J, NL, US) the IEA Task 42 identified and assessed the current status and development potential of “energy-driven” biorefineries and “product-driven” biorefineries. The 14 most interesting “energy-driven” biorefinery concepts until 2025 and their value chains, including the integration and deployment options in industrial infrastructures, are analyzed. The classification and description of existing infrastructure in combination with the available biomass resources and (future) market needs shows the matching points for a cost and resource efficient roll out of the BioEconomy by implementing various biorefineries.

The main conclusions are

- A classification of different biorefineries and existing industrial infrastructure is possible via the 4 features: platforms, products, feedstocks, processes
- IEA Bioenergy Task 42 “Biorefinery” selected the 14 most interesting “Biofuel-driven Biorefineries” until 2025 and published them in a brochure
- To analyse the possible integration of biorefineries in the existing industrial infrastructure a systematic characterisation of the infrastructure with 10 industry sectors and 31 subsectors was developed.
- The existing industrial infrastructure is described based on the 4 features – feedstock, platforms, products and processes.
- The opportunity to integrate a biorefinery into existing industrial is characterised by the type and amount of common features, where the feedstock and the platforms are more relevant for efficient integration than the platforms and processes.
- The most relevant features for integration are the feedstock and the products and are ranked the following:
 - Feedstocks & products \geq platforms \geq processes
 - Feedstocks: very strong

- Products: very strong
- Platforms: strong
- Processes: possible
- A case study for this integration approach was performed in Austria by applying this approach to 232 existing sites in the 10 industrial sectors.. The following “hot spots” for favourable integration opportunities for the 14 biofuel-driven biorefineries were identified:
 1. pulp&paper and wood industry to additionally produce transportation biofuels and biochemicals on 12 sites;
 2. food&feed industry to additionally produce bioenergy carriers on 60 sites,
 3. chemical industry to integrate biogenic resources to produce biobased chemicals on 20.
 4. Conventional oil refinery to integrate biofuel production on 1 sites
- With these results the most promising industry sectors for upgrading towards biorefining are identified. The next steps will be to analyse and assess the individual opportunities of the relevant sectors via stakeholder involvement.
- The results assist various stakeholders in finding their position on biorefining in a future biobased economy while minimizing unexpected technical, economic and financial risks.



1 Aim of the work

A key driver for the necessary sustainable development is the implementation of the BioEconomy, which is based on renewable resources to satisfy its energy and material demand of our society. The broad spectrum of biomass resources offers great opportunities for a comprehensive product portfolio to satisfy the different needs of a BioEconomy. The concept of biorefining guarantees the resource and energy efficient use of biomass resources. The IEA Bioenergy Task 42 “Biorefining” has the following definition on biorefinery: *“Biorefining is the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, and materials) and bioenergy (biofuels, power and/or heat)”*.

Currently many different biorefinery concepts are developed and already implemented which play a key role in establishing a BioEconomy. The purpose of the work is to analyse the efficient integration of biorefineries in existing industrial infrastructure. This information assists industry, decision makers and investors in their strategies to invest and integrate resource efficient biomass uses in the infrastructure of a future BioEconomy (Figure 1).

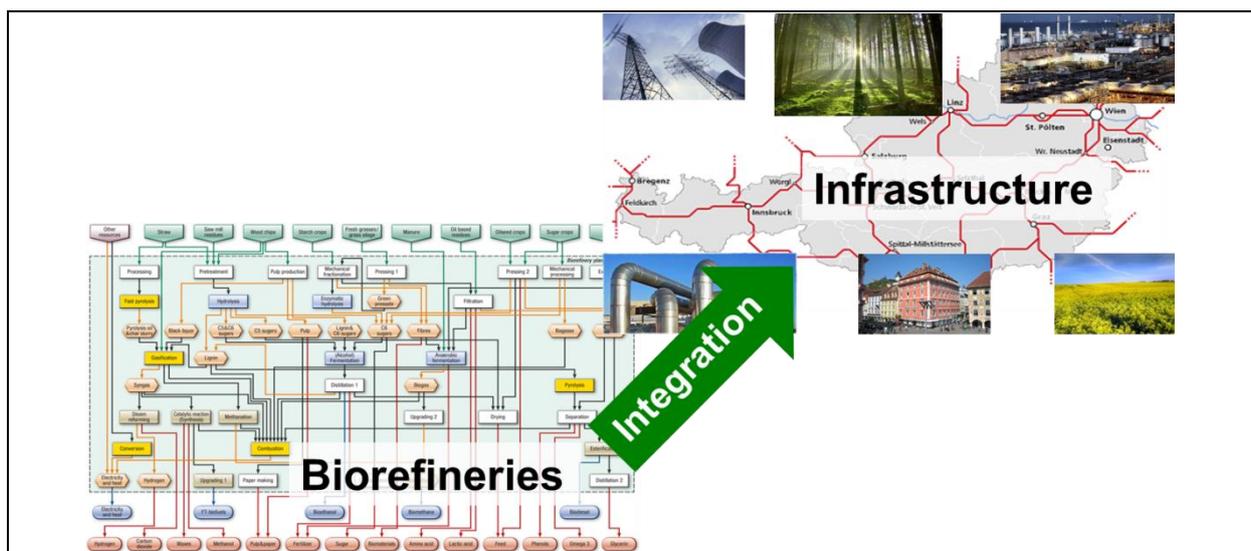


Figure 1: Upgrading strategies for industrial infrastructures to a BioEconomy

2 Approach

Based on the activities of the 11 participating countries (A, AUS, CA, DK, FR, G, I, J, NL, US) the IEA Task 42 identified and assessed the current status and development potential of “energy-driven” biorefineries and “product-driven” biorefineries. So far the 14 most interesting “energy-driven” biorefinery concepts until 2025 and their value chains, including the integration and deployment options in industrial infrastructures, are analyzed. The selected energy driven biorefineries are designed to produce large volumes of liquid and/or gaseous road transportation biofuels co-producing

marketable bioproducts. The expectation is that the bioproducts provide additional revenue streams environmental benefits that reduce the production costs and environmental impacts of road transportation biofuels.

The identification of the upgrading opportunities of existing industrial infrastructure towards biorefineries in the Biobased Industry is done the following way (Figure 3):

- The biorefineries are described based on their 4 features (platforms, products, feedstock and processes) (Figure 2) and their “Biorefinery Fact Sheets”
- The existing industrial infrastructures are described based on their 4 features (platforms, products, feedstock and processes)
- Identification of the same features of a biorefinery and of the existing industrial infrastructure
- Case study: verification of this approach by application to the Austrian Situation as an example.

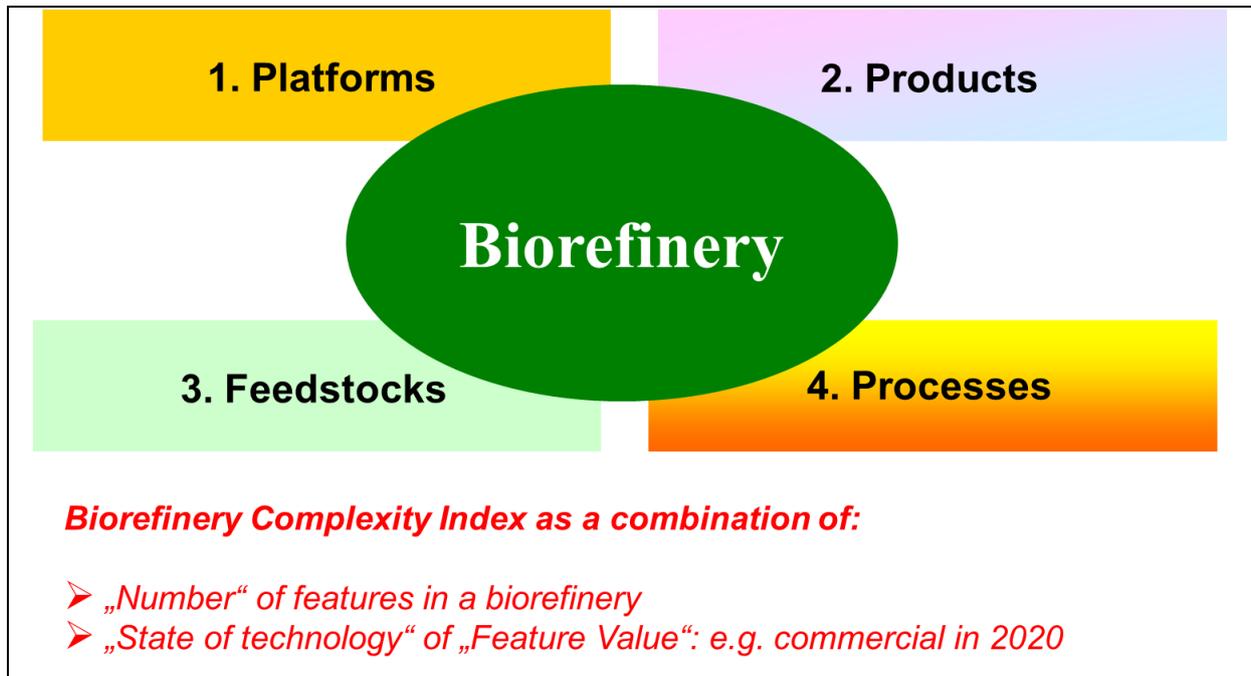


Figure 2: Classification system of a biorefinery with the 4 features – platforms, products, feedstocks and processes (based on Cherubini et al. 2009)

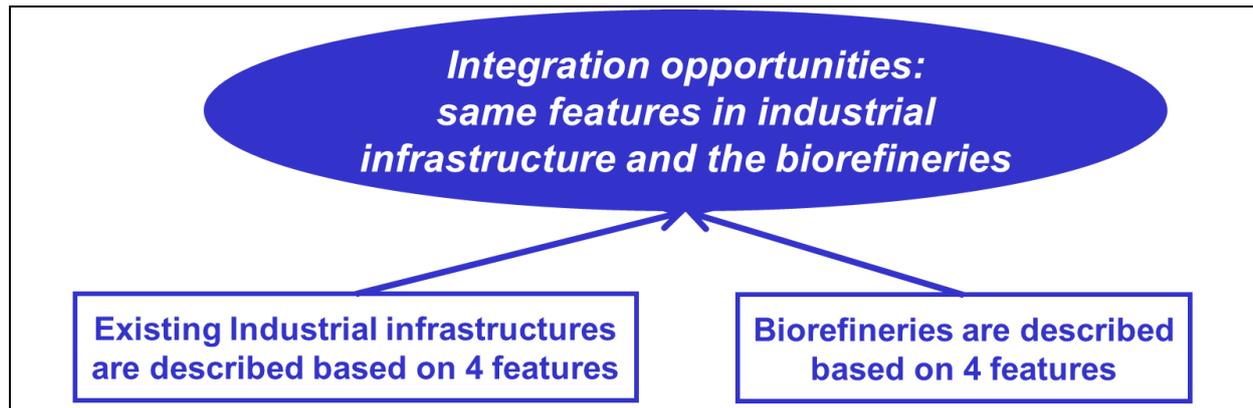


Figure 3: Identifying upgrading opportunities towards biorefineries in the Biobased Industry

The most promising energy driven biorefinery concepts are presented in the following list using the classification nomenclature of IEA Bioenergy Task 42 (Jungmeier et al. 2013), for which the integration opportunities are assessed (Figure 4):

- Commercial scale energy driven biorefineries:
 - “1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin and feed“
 - “1-platform (oil) biorefinery using oil based residues&oilseed crops for biodiesel, glycerin and feed“
 - “1-platform (C6 sugars) biorefinery using sugar&starch crops for bioethanol and feed“
 - “3-platform (C6 sugars, bagasse, electricity&heat) biorefinery using sugar cane for bioethanol, electricity, heat, sugar and fertilizer”
- Demonstration scale energy driven biorefineries:
 - „4-platform (C6 sugars, C5 sugars, lignin, electricity&heat) biorefinery using straw for bioethanol, electricity, heat and feed“
 - “3-platform (C5&C6 sugars, 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 and manure for biomethane, amino acid, 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, C5&C6 sugars, lignin, syngas, electricity&heat) biorefinery using starch crops and straw for bioethanol, FT-biofuels, feed, electricity and heat“
- Conceptual energy driven biorefineries:
 - “2-platform (electricity&heat, syngas) biorefinery using wood chips for FT-biofuels, electricity, heat and waxes with steam gasification“
 - “3-platform (pyrolysis oil, syngas, electricity&heat) biorefinery using straw for FT-biofuels and methanol with oxygen gasification“

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- “4-platform (pulp, syngas, electricity&heat) biorefinery using wood chips for FT-biofuels, electricity, heat and pulp“
- “5-platform (C6&C5 sugars, lignin&C6 sugars, 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“.

In the whole development process a critical review and discussion of the approach and results was done by the members of IEA Task 42 from the participating countries and relevant stakeholders during internal meetings, stakeholder workshops and international conferences e.g. European Biomass Conference (see chapter references).



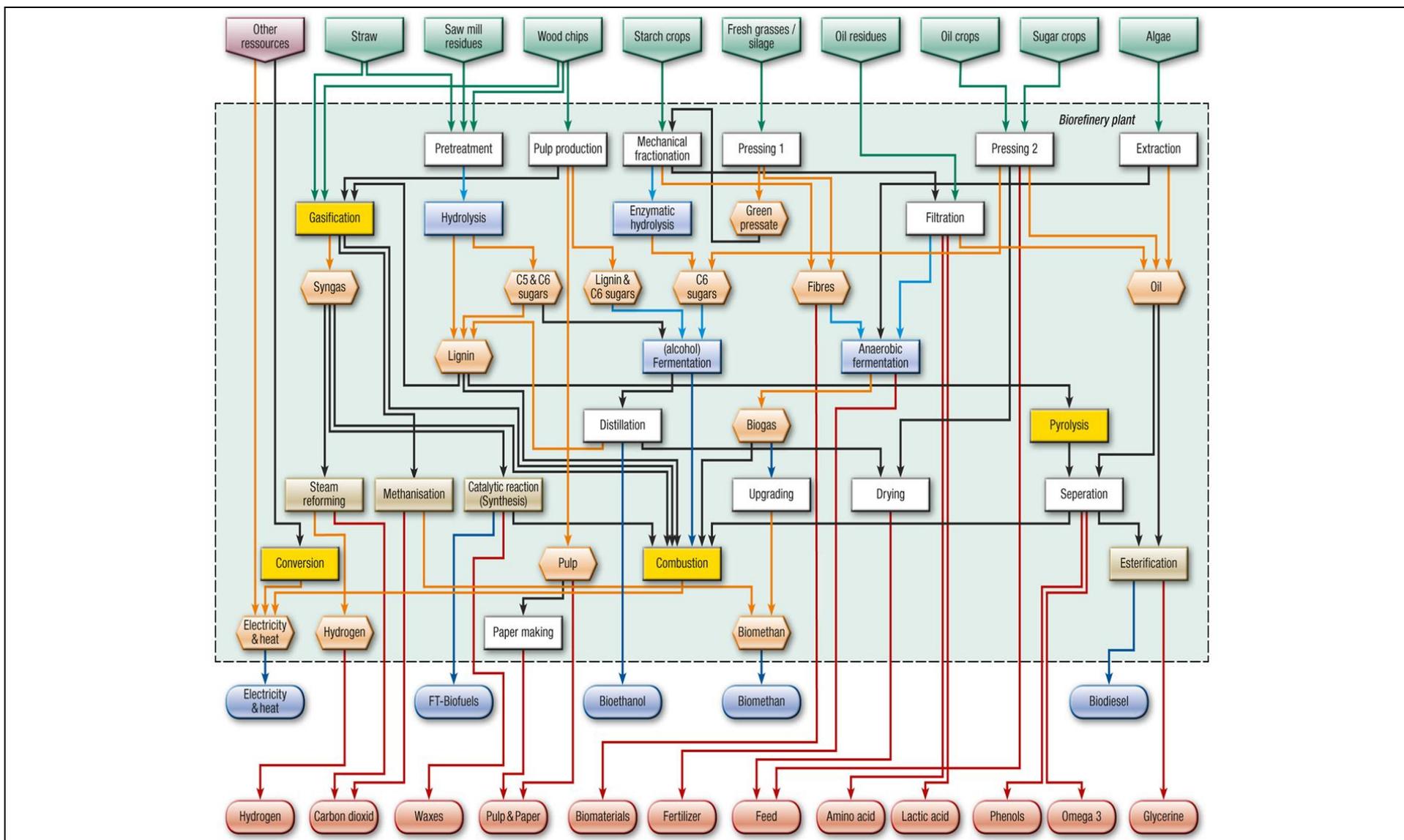


Figure 4: the 14 most promising biofuel-driven biorefineries until 2025 (Jungmeier et al. 2013)

3 Characteristics of the existing industrial infrastructure

The existing industrial infrastructure was classified into 10 different industry sectors with 31 subsectors shown in [Figure 5](#) (based on Buchsbaum 2014). Based on this systematic a database for the existing industrials infrastructure was built up in Austria as a first case example to verify this integration approach. In the case of Austria so far 232 existing industrial sites are described with their main characteristics based on the four features platform, product, feedstock and processes ([Figure 6](#)).

<p>1 Power and CHP plants</p> <ul style="list-style-type: none"> 1.1 heating plant 1.2 CHP plant <ul style="list-style-type: none"> 1.2.1 Biomass 1.2.2 fossil (oil, gas, coal) 1.2.3 waste <p>2 Biofuel facilities</p> <ul style="list-style-type: none"> 2.1 biodiesel facilities 2.2 bioethanol facilities <p>3 Oil refineries</p> <p>4 Pulp and paper industry</p> <ul style="list-style-type: none"> 4.1 pulp 4.2 paper 4.3 pulp and paper <p>5 Wood industry</p> <ul style="list-style-type: none"> 5.1 pellet facilities 5.2 wood based boards 5.3 saw mill <p>6 Biogas/Biomethane plants</p> <ul style="list-style-type: none"> 6.1 biogas CHP 6.2 biomethane 6.3 green refinery 	<p>7 Chemical industry</p> <ul style="list-style-type: none"> 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 <p>8 Waste treatment facilities</p> <ul style="list-style-type: none"> 8.1 sewage treatment plants 8.2 landfill gas facilities 8.3 composting plants <p>9. Food industry</p> <ul style="list-style-type: none"> 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 <p>10. Others</p>
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[Figure 5](#): Classification of existing industrial infrastructure in 10 sectors with 31 subsectors

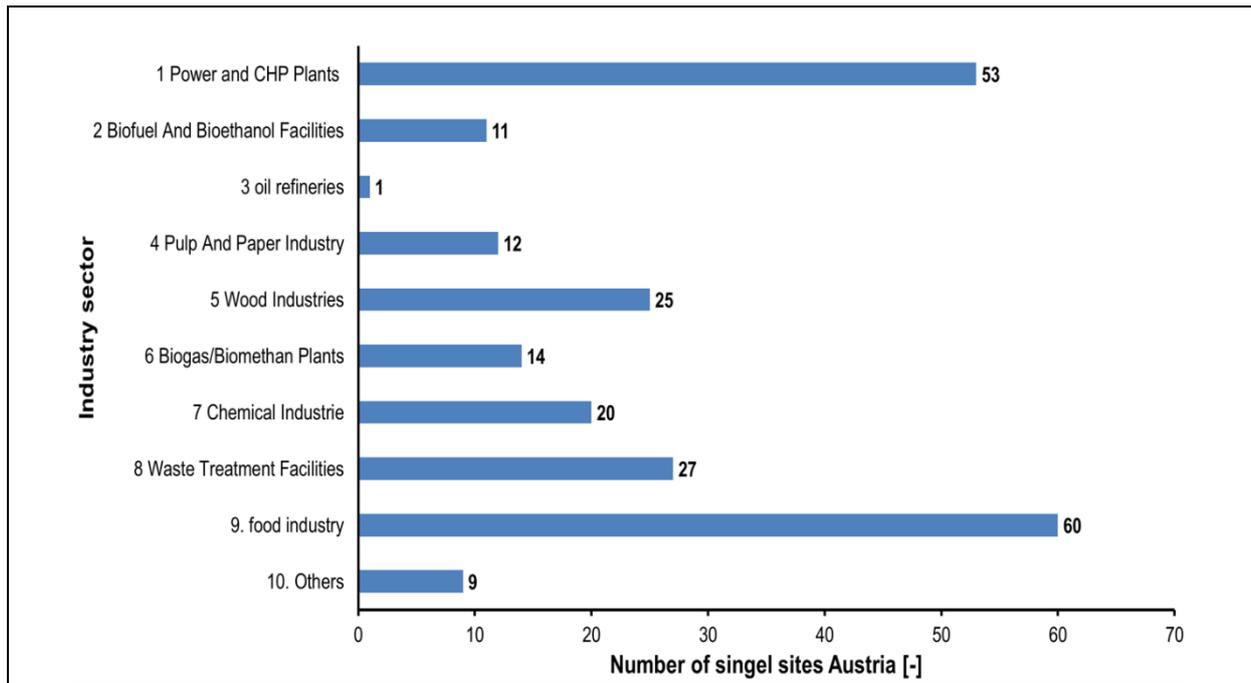


Figure 6: Database on the existing industrial infrastructure in Austria with 232 sites in the 10 industry sectors

4 Results

The results presented in this chapter show, which and how many features of the biorefinery are the same as the features of the existing industrial infrastructure. Two examples of a biorefinery for the possible integration in the existing infrastructure are given and then the overall integration opportunities for all 14 energy-driven biorefineries in the 31 industrial subsectors are shown and vice versa.

4.1 Example 1: Biodiesel from rape seed

In Figure 7 it is shown, how the biorefinery “1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin & feed” can be integrated in the 31 analyzed subsectors of existing infrastructure in Austria. The coverage is defined for each feature to be maximum 25% if all features of the biorefinery are the same as the feature of the considered industry. So a total coverage of 67% is reached in the biodiesel and vegetable oil industry, with the other industries the coverage with 8% to 25% is relatively low. And for most of the considered industries the coverage is 0%, which means that there is no reasonable integration opportunity.

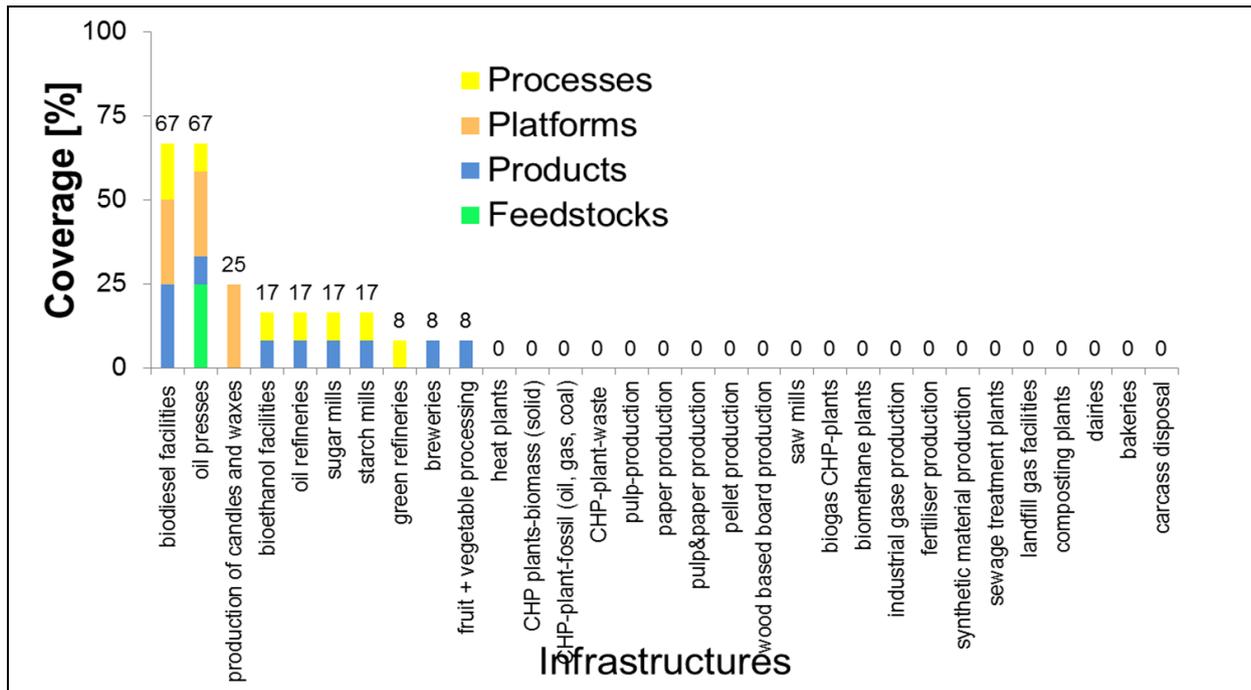


Figure 7: Example I: 1 Biorefinery (“1-platform (oil) biorefinery using oilseed crops for biodiesel, glycerin & feed”) and 31 Industry Subsectors

4.2 Example 2: Bioethanol from wood and black liquor

In Figure 8 it is shown, how the biorefinery “5-platform (C5&C6 sugars, lignin&C6 sugars, electricity&heat) biorefinery using saw mill residues, wood chips and sulphite liquor for bioethanol, pulp&paper, electricity and heat” can be integrated in the 31 analyzed subsectors of existing infrastructure in Austria. With coverage between 55% to 65% this biorefinery has very attractive opportunities to be integrated in the pulp, paper and pulp&paper industry in Austria. Only 9 of the 31 industry sectors have no coverage with this biorefinery where the other 19 sectors have an integration opportunity with coverage between 4% up to 37%.

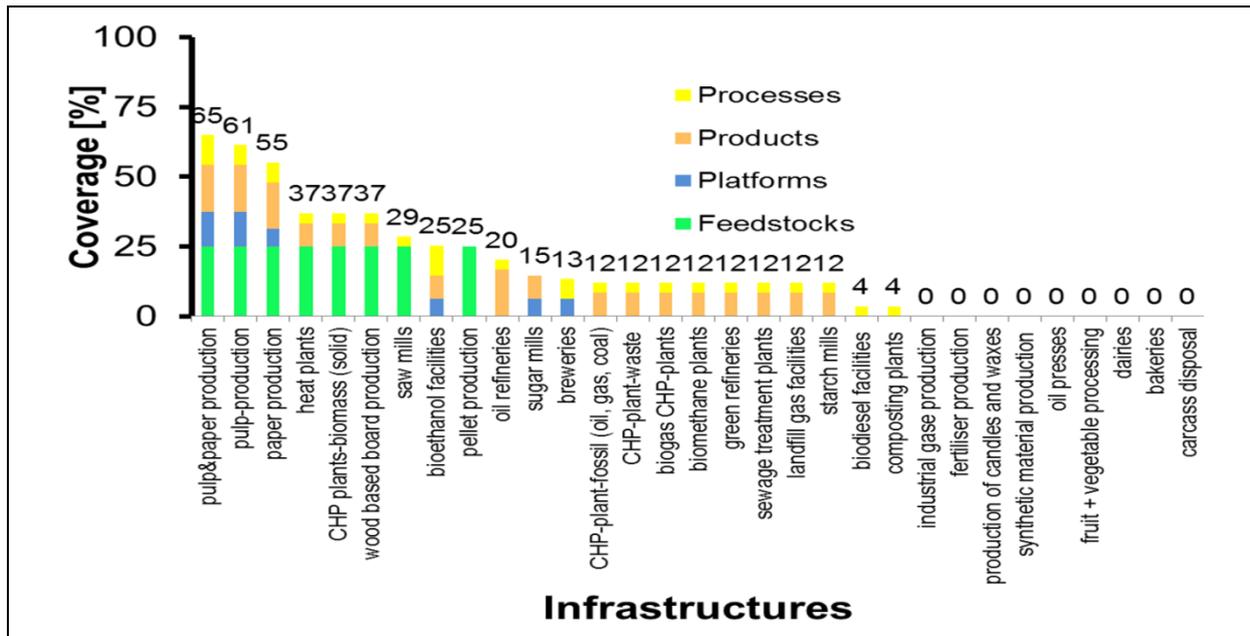


Figure 8: Example II: 1 Biorefinery (“5-platform (C5&C6 sugars, lignin&C6 sugars, electricity&heat) biorefinery using saw mill residues, wood chips and sulphite liquor for bioethanol, pulp&paper, electricity and heat”) and 31 Industry Subsectors

4.3 14 biorefineries in 10 industry sectors

In Figure 9 the index of the upgrading opportunities of the 31 industrial subsectors towards the 14 energy-driven biorefineries are shown. The index for upgrading is between 4% up to 28%, where the feedstock and the products offer the most attractive opportunities to integrate an energy-driven biorefinery.

In Figure 10 the index of the integration opportunities of the 14 energy-driven biorefineries into the 31 industrial subsectors are shown. The index for the integration is between 8% up to 28%, where the feedstock and the products offer the most attractive integration opportunities.

The following “hot spots” for favourable integration opportunities for the 14 biofuel-driven biorefineries were identified:

5. pulp&paper and wood industry to additionally produce transportation biofuels and biochemicals on 12 sites;
6. food&feed industry to additionally produce bioenergy carriers on 60 sites,
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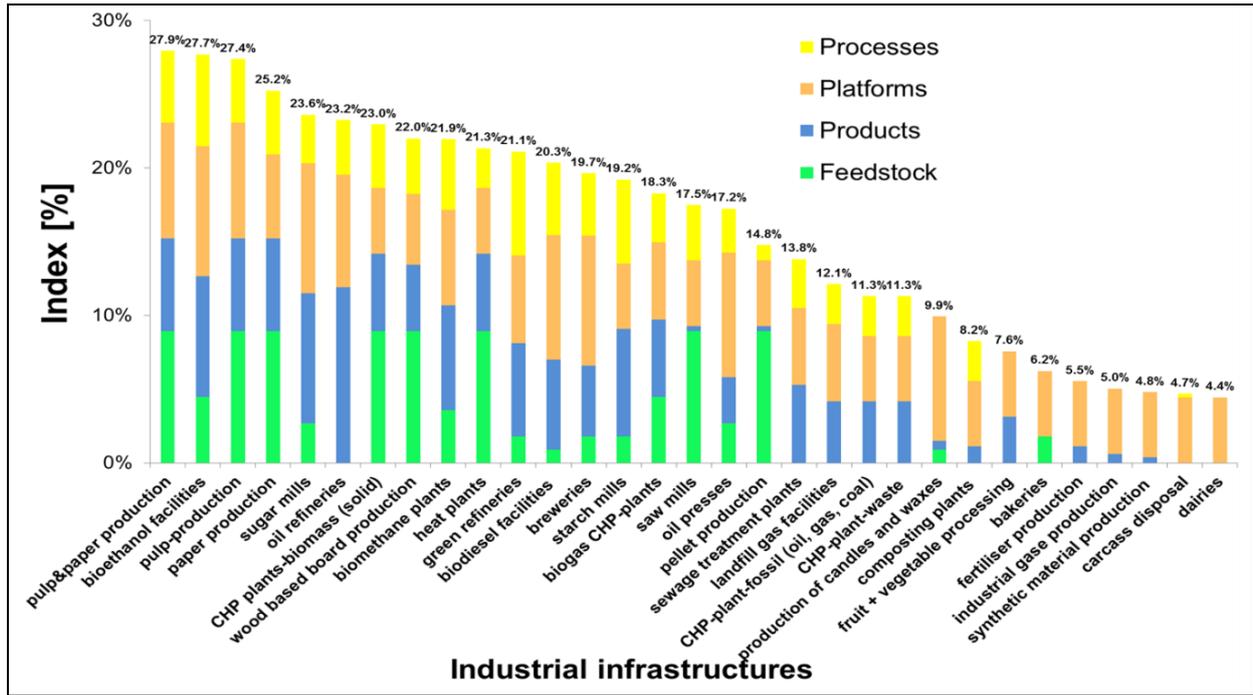


Figure 9: Index of the upgrading opportunities of the 31 industrial subsectors towards the 14 energy-driven biorefineries

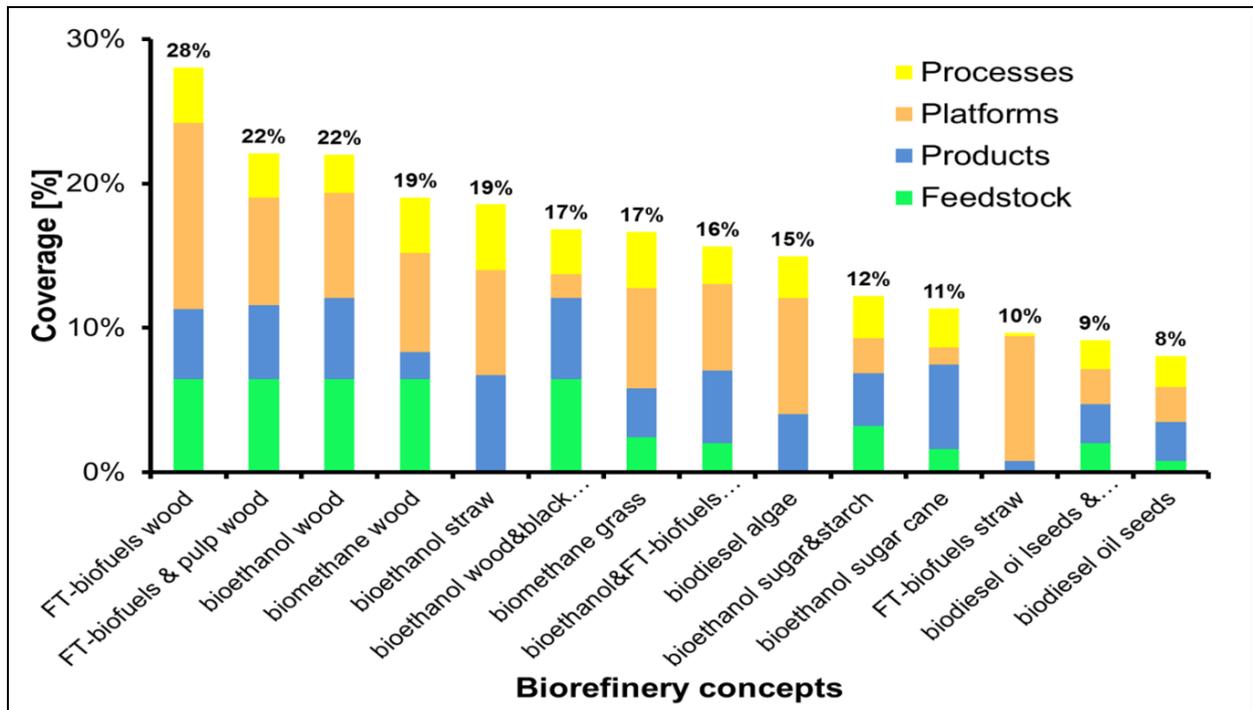


Figure 10: Coverage: 31 Industry Subsectors and 14 Biorefineries

5 Conclusions

The main conclusions are

- a classification of different biorefineries and existing industrial infrastructure is possible via the 4 features: platforms, products, feedstocks, processes
- IEA Bioenergy Task 42 “Biorefinery” has selected the 14 most interesting “Biofuel-driven Biorefineries” until 2025 and published them in a brochure
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- The opportunity to integrate a biorefinery into existing industrial is characterised by the type and amount of common features, where the feedstock and the platforms are more relevant for integration than the platforms and processes.
- The most relevant features for integration are the feedstock and the products and are ranked the following:
 - Feedstocks & products ≥ platforms ≥ processes
 - Feedstocks: very strong
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- A case study for this integration approach was performed in Austria by applying this approach to 232 existing sites in the 10 industrial sectors.. The following “hot spots” for favourable integration opportunities for the 14 biofuel-driven biorefineries were identified:
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6 References

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IEA Bioenergy Task 42 2013: G. Jungmeier, M. Hingsamer, R. van Ree, H. Joergenson, M. Wellisch, H. Stichnothe, R. Rauch, E. de Jong, I. De Bari: Biofuel-driven Biorefineries – A Selection of the most promising biorefinery Concepts to produce large volumes of road transportation biofuels by 2025, Report of IEA Bioenergy Task 42 “Biorefinery”, February 2013

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Jungmeier et al. 2014: G. Jungmeier, H. Stichnothe, I. de Bari, H. Jørgensen, R. Van Ree, E. de Jong, M. Wellisch, P. Walsh, G. Garnier, M. Klembara, Facts, Figures and Integration of Biorefineries in a Future Bioeconomy – Findings in IEA Bioenergy Task 42 “Biorefining”, Proceedings of the 22th European Biomass Conference, Hamburg 2014

This approach was presented and discussed at the following events:

- Facts, Figures and Integration of Biorefineries in a Future BioEconomy – Findings in IEA Bioenergy Task 42 “Biorefining”, 22th European Biomass Conference , Hamburg, Germany, June 23 – 27, 2013
- Facts&Figures of Biorefineries Integrated in the Pulp&Paper Industry – Case Studies in IEA Bioenergy Task 42 “Biorefining”, FUTURE.FORUM PAPER – The Austrian Paper Conference, June 4 – 5, 2014, Graz, Austria
- Value Chain Assessment of Biofuel-driven Biorefineries, 3rd European Biorefinery Training School, 7-10 July 2014, Budapest
- Approach for the Integration of Biorefineries in the Existing Industrial Infrastructures, Workshop @i-SUP2014, “The role of industry in a transition towards the BioEconomy in relation to biorefinery”, September 3, 2014 Antwerp/Belgium
- 10 aktuelle Highlights 2014 aus der Österreichischen Mitarbeit in der IEA Bioenergy Task 42 “Biorefining”, Produktion der Zukunft Stakeholderdialog Biobased Industry, Graz 22. September 2014
- The Possible Role of Wood-biorefining in a Biobased Industry, International Conference on Processing Technologies for the Forest and Bio-based Products Industries (PTF BPI) Kuchl, September 24 -26, 2014

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- Best of 2014 - Österreichische Mitarbeit in der IEA Bioenergy Task 42 “Biorefining”, bmvit Bioenergie Fachgespräch, Wien 21. November 2014

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