Assessing Biorefineries Using Wood for the BioEconomy – Current Status and Future Perspective of IEA Bioenergy Task 42 "Biorefining"

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ABSTRACT

The 11 member countries (A, AUS, CA, DK, G, I, IR, J, NL, NZ, USA) of IEA Bioenergy Task 42 "Biorefining" state: "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)". Woods with its various assortments offers great opportunities for a broad product portfolio. The purpose is to assess various biorefineries using wood in a future BioEconomy based on the assessment framework developed by Task 42. The assessment covers technical, economic, environmental, social, infrastructural integration, implementing and R&D issues relevant for the realization of biorefinery concepts using wood.

The 5 most interesting "biofuel-driven" bio-refinery concepts until 2025 based on wood (e.g. wood chips, saw mill, bark) were analyzed in their value chains to produce transportation biofuels and biochemicals. The life cycle based assessment is developed to cover issues from the production, operation and end of life phase.

The assessment of the 5 wood biorefineries is done in the "Biorefinery Fact Sheet" including technology readiness level, biorefinery classification, Biorefinery Complexity Index, economic assessment, environmental assessment, social assessment, sustainability assessment with SLCA and implementation in existing industrial infrastructure.

The results assist various stakeholders in finding their position on biorefining in a future biobased economy while minimizing unexpected technical, economic and financial risks by significantly contributing to the development of a BioEconomy.

KEYWORDS

Assessment, BioEconomy, Biorefinery, Sustainability, Technology Readiness Level, Wood

INTRODUCTION

The 11 member countries (A, AUS, CA, DK, G, I, IR, J, NL, NZ, USA) of IEA Bioenergy Task 42 "Biorefining" state: "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)" [1]. Woods with its various assortments offers great opportunities for a broad product portfolio. The purpose is to assess various biorefineries using wood for in a future BioEconomy based on the assessment framework developed by Task 42. The assessment covers technical, economic, environmental, social, infrastructural integration, implementing and R&D issues relevant for the realizations of biorefinery concepts using wood. [2], [3], [4]

APPROACH

The 5 most interesting "biofuel-driven" bio-refinery until 2025 concepts based on wood (e.g. wood chips, saw mill, bark) were analyzed in their value chains to produce transportation biofuels and biochemicals. These 5 wood based biorefineries are [5]:

1. "2-platform (syngas, electricity&heat) biorefinery using wood chips for FT-Biofuels, electricity, heat and waxes with steam gasification"
2. "3-platform (pulp, syngas, electricity&heat) biorefinery using wood chips for FT-biofuels, electricity, heat and pulp"
3. "3-platform (C6 & C5 sugar, lignin, electricity&heat) biorefinery using wood chips for bioethanol, electricity, heat and phenols"
4. "4-platform (hydrogen, biomethane, syngas, electricity & heat) biorefinery using wood chips for biomethane (SNG), hydrogen and carbon dioxide"
5. "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"

Additionally also a "product-driven" biorefinery - "3-platform (black liquor, pulp, electricity&heat) biorefinery using wood chips for pulp, paper, turpentine, tall oil, bark, electricity and heat" - was analyzed to experience, if the assessment procedure can be applied to all types of biorefineries (Figure 1) [6]. The life cycle based assessment is developed to cover issues from the production, operation and end of life phase:

1. biorefinery classification and assessing the "Technology Readiness Level (TRL: 1 – 9)".
2. Life Cycle Costing (LCC) for economic aspects.

3. Life Cycle Assessment (LCA) for environmental aspects.
4. Screening of social aspects in a Social Life Cycle Assessment (sLCA).
5. Integration of these aspects in Life Cycle Sustainability Assessment (LCSA)
6. Identification of attractive industry sectors ("Hot Spots") to integrate these biorefineries
7. Highlighting R&D demand for commercialization until 2015.
8. Concluding on the possible future role in a BioEconomy.

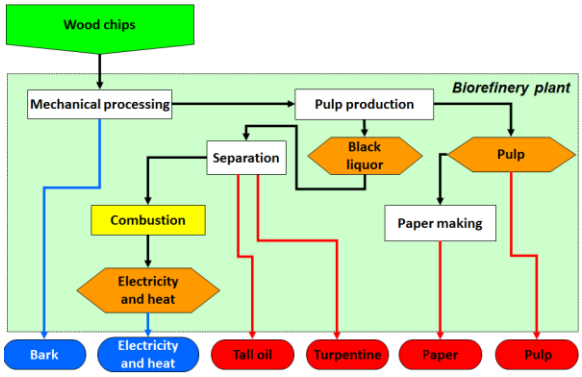

Figure 1: The biorefinery classification scheme for the "3-platform (black liquor, pulp, electricity&heat) biorefinery using wood chips for pulp, paper, turpentine, tall oil, bark, electricity and heat" [7], [9]

RESULTS AND DISCUSSION

The assessment of the 5 wood biorefineries is done in the "Biorefinery Fact Sheet" including:

- Technology: Description and assessment of technology readiness level for involved process technologies [8]
- Biorefinery classification of IEA task 42 with the 4 features: platforms, products, feedstock, processes [7]
- Biorefinery complexity Index as indicator for the overall complexity and development status [8]
- Economic assessment with LCC: investment, operation costs, revenues, market potential [9]
- Environmental assessment with LCA: GHG and fossil energy saving, area demand, [9]
- Social assessment with sLCA: labour created, social acceptance, labour conditions, health risk
- Sustainability assessment with SLCA: 3-dimensional functionality (environmental, economic and social issues)
- Implementation in existing industrial infrastructure: e.g. wood biorefinery integrated in the p&p industry [10]

The "Biorefinery Fact Sheets" consist of three parts (Figure 2):

1. Part A: Biorefinery plant
2. Part B: Value chain assessment and
3. Annex: Methodology of sustainability assessment and data

In Part A the key characteristics of the biorefinery plant are described by giving compact information on

- classification scheme,
- description of the biorefinery,
- mass and energy balance,
- share of costs and revenues.

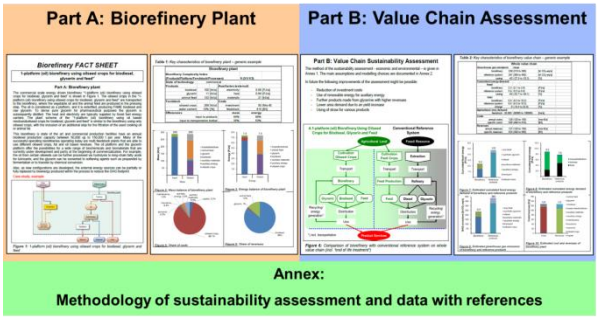

Figure 2: The three parts of the "Biorefinery Fact Sheet" [9]

In Part B the sustainability assessment based on the whole value chain of the biorefinery plant is described by giving compact information on

- system boundaries,
- reference system,
- cumulated primary energy demand,
- greenhouse gas emissions and
- costs and revenues.

In the Annex of the "Biorefinery Fact Sheet" the main data for the sustainability assessment are documented.

One important aspect is the choice of the reference system to produce the same products as the biorefinery plant and the basics of comparing a biorefinery to the reference system.

Based on these sheets an easy comparison of the different biorefinery systems is possible. The "Biorefinery Fact Sheet" assists various stakeholders in finding their position on biorefining in a future biobased economy. Continuously new "Biorefinery Fact Sheets" are made for various biorefineries of interest in one of the IEA Bioenergy Task 42 member country.

The classification and description of existing infrastructure in combination with the available biomass resources and (future) market needs shows the matching points for a resource efficient roll out of the BioEconomy by implementing various biorefineries. Examples for identified "hot spots" by coproducing high value products like food, feed, biochemicals and biomaterials are [10]:

1) pulp&paper and wood industry to additionally produce transportation biofuels and biochemicals;

2) food&feed industry to additionally produce bioenergy carriers,

3) chemical industry to integrate biogenic resources to produce biobased chemicals.

In the following an example for the assessment procedure is give with a "3-platform (C5&C6 sugars, electricity&heat, lignin) biorefinery using wood chips for bioethanol, electricity, heat and phenols" (Figure 3).

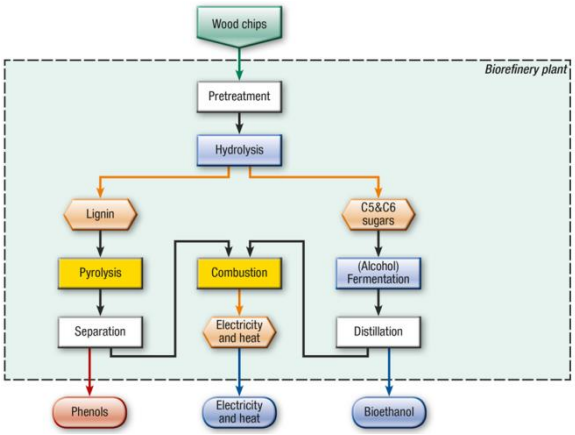

Figure 3: 3-platform (C5&C6 sugars, electricity&heat, lignin) biorefinery using wood chips for bioethanol, electricity, heat and phenols [8], [9]

In Figure 4 the assessed Biorefinery Complexity Profile of 33 (8/1/6/18) is shown. In this biorefinery the following features are involved:

- three platforms of which one (lignin) has a feature complexity of 4, one (C5 & C6 sugars) has a feature complexity of 3 and one (electricity & heat) of 1
- one feedstock with a feature complexity of 1
- three products of which the phenol has a feature complexity of 4 and the other products of 1 and
- seven processes with a feature complexity between 4 and 1.

In Figure 5 the mass and in Figure 6 the energy balances are shown. In Figure 7 the comparison of the biorefinery with the conventional reference system on whole value chain (incl. "end of life management") is shown, for which the environmental assessment is done - GHG emission in Figure 8 and cumulated primary energy demand in Figure 9. In Figure 10 the cost and revenues of biorefinery plant are shown.

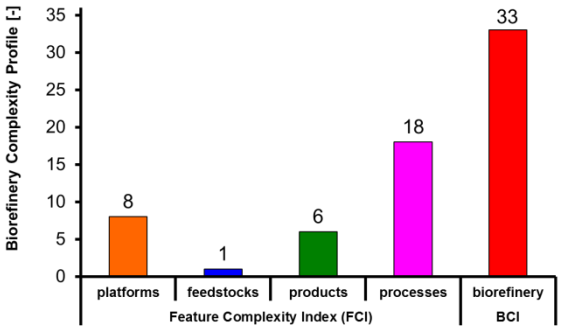

Figure 4: Biorefinery Complexity Profile 33 (8/1/6/18) of biorefinery example [8]

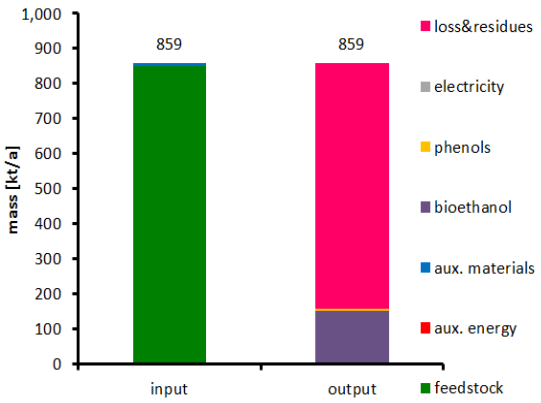

Figure 5: Mass balance of biorefinery example [9]

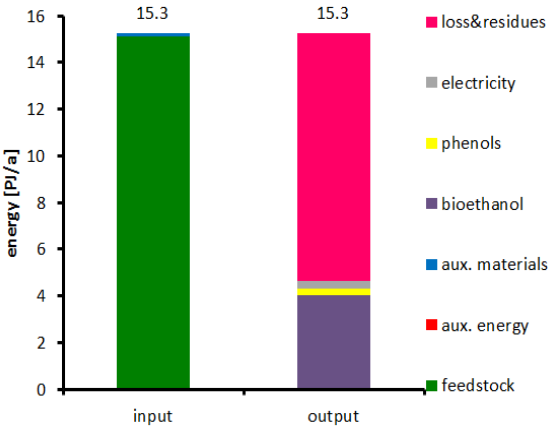

Figure 6: Energy balance of biorefinery example [9]

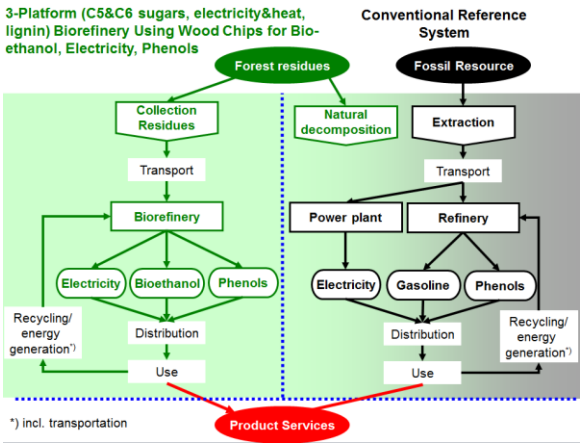

Figure 7: comparison of the biorefinery with the conventional reference system on whole value chain [9]

CONCLUSIONS

The results assist various stakeholders in finding their position on biorefining in a future biobased economy while minimizing unexpected technical, economic and financial risks by significantly contributing to the development of a BioEconomy. So the IEA Bioenergy Task 42 "Biorefining" deals with the analysis and distribution of strategic relevant information of value chains of biorefineries to support the implementation of a BioEconomy with a focus on:

- Assessing the major market deployment aspects for integrated biorefineries
- Supporting the industry by setting their position in a future BioEconomy
- Analysing optimal sustainable biomass valorisation approaches for Food and Non-Food applications
- Preparing policy advice on needs for implementation

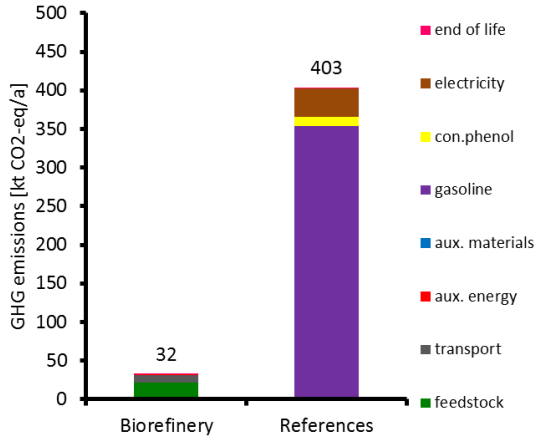

Figure 8: Estimated greenhouse gas emissions of biorefinery example and reference products [9]

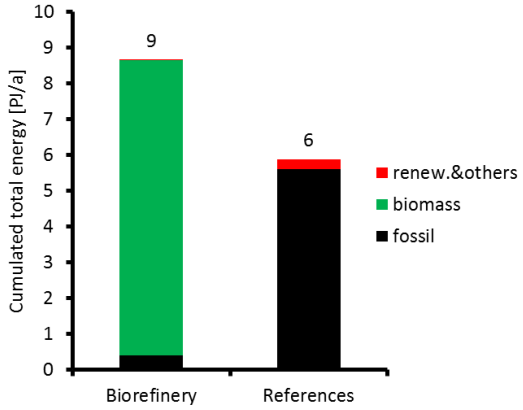

Figure 9: Estimated cumulated primary energy demand of biorefinery example and reference products [9]

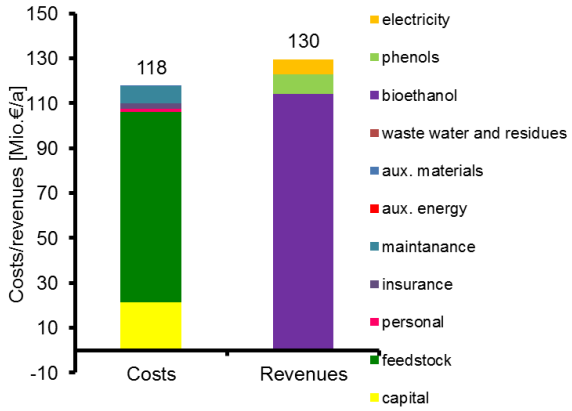

Figure 10: Estimated cost and revenues of biorefinery plant [9]

ACKNOWLEDGEMENTS

http://www.iea-bioenergy.task42-biorefineries.com/

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