BIOCHEMICALS

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Innovative Solutions
for Sustainability

Gaia Biorefiner Results

Screening the Environmental Sustainability of Bio-based Value Chains and Products

Crude Tall Oil (CTO) to Tall Oil Fatty Acids (TOFA)
Crude Soybean Oil to Soybean Oil Fatty Acids

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What is Gaia Biorefiner?

Screening the sustainability of bio-based products

Gaia Biorefiner screens the environmental sustainability of bio-based products and value chains. It enables comprehensive sustainability benchmarking of innovations and solutions in areas like biofuels, biochemicals and biomaterials. With Gaia Biorefiner, companies and investors can identify the most resource-efficient and advanced solutions, focus investments and ensure that the benefits of bio-based technologies and products are fully realized.

Why have we developed Gaia Biorefiner?

Bioeconomy is a rapidly evolving field, where novel value chains and concepts are developed and commercialized based on growing demand and global drivers. Sustainability is one of the main drivers of this development, but assessing sustainability is becoming very complex. Many sustainability issues, such as origin of biomass feedstock and related land use issues, are specific for bio-based value chains. Yet companies need practical tools for screening of business ideas and investment opportunities in terms of sustainability.

What does Gaia Biorefiner screen and how?

Gaia Biorefiner highlights the most critical sustainability related issues of emerging value chains. It is an indicator-based tool which includes main aspects of environmental sustainability and builds on globally recognized methodology, classification criteria and data sources. The results are presented in an easy-to-understand and visual way.

What is the benefit of Gaia Biorefiner?

Gaia Biorefiner combines an in-depth understanding of the new value chains and material cycles of bioeconomy with most valid understanding on the sustainability issues. By doing that, it offers a novel opportunity to screen different raw materials, locations, technologies, processes, and product options easily. In addition it enables benchmarking alternative value chains. The results can be used, for example, for selecting the most beneficial options for investments and further RDI as well as planning actions to mitigate highlighted sustainability risks.

How do we understand bioeconomy?

Bioeconomy covers all the products, processes, and technologies that use biomass as their main raw material. As well, services related to these areas are included. Our main focus is on emerging bioeconomy including biofuels, biochemicals, and biomaterials.

Main points of Gaia Biorefiner

- Critical sustainability aspects of bio-based products highlighted and benchmarked to alternatives
- Applicable to biofuels, biochemicals and biomaterials
- Efficient screening of important sustainability aspects with solid methodological basis
- Ability to screen efficiently complex value chains

Four easy steps to screen the sustainability of your value chain

1. Select the product and value chain to be screened
2. Select alternative value chains
3. Locate the value chains geographically
4. Provide value chain specific data if available

Case Description

Case name

Crude Tall Oil (CTO) to Tall Oil Fatty Acids (TOFA)

Value chain

Forestry (Finland, Russia, Sweden, Estonia, USA) > Kraft pulping (Finland, Russia, Sweden, Estonia, USA) > CTO > CTO distillation (Finland) > TOFA > End market (Germany)

Production capacity

48 000 t/year

Energy sources

The distillation plant is in close connection to the neighbouring pulp mill. Excess steam is received from the pulp mill. Electricity and heat is produced in the pulp mill CHP plant (fuel: biomass) and heat is produced at plant (fuel: head and pitch from distillation).

Co-products

TOR (Tall Oil Rosin) and Fortop600

Reference group

Gaia Biorefiner evaluates the quantitative indicators against a product specific reference group. Of the four product sub-categories (*Main bulk chemicals, Intermediate bulk chemicals, Fine Chemicals and Pharmaceuticals*), Intermediate Bulk Chemicals is chosen as the sub-category corresponding to the end product TOFA/ Soybean Oil FA. The reference group for Intermediate Bulk Chemicals is made of 20 common intermediate bulk chemicals (biomass based and petrochemical) and five oleochemicals. If the value calculated for the value chain is among the top 15%, the indicator gives the result competitive advantage. If the value calculated for the value chain is among the middle 70%, the indicator gives the result neutral.
If the value calculated for the value chain is among the bottom 15%, the indicator gives the result potential risk. For 4.1 Land use intensity, the corresponding values are 10%/80%/10% and for 7.4 Waste per product ratio, 20%/60%/20%.

Alternative value chain

Soybean Oil to Soybean Oil Fatty Acids: Soybean cultivation (Brazil) > Soybean oil extraction (Brazil) > Crude soybean oil > Soybean oil Fatty Acids (Brazil) > End market (Germany)

Why this value chain is chosen as an alternative

Fatty acids from vegetable oils can be used for similar purposes as Tall Oil Fatty Acids (TOFA). Soybean oil is an established product and can, similar to TOFA, be used for printing ink, oil paints and surfactants production. Current production volume is 42,3 million tonnes, of which 1.7 million tonnes is used as oleochemicals.

Energy sources

Electricity is assumed to be average grid electricity for Brazil. Heat is produced from combustion of natural gas. No heat recovery or area surplus is assumed.

Data sources for value chain data

TOFA

Ecoinvent database (see attachment for details), Forchem

Gaia Dataset for Location Specific Data: Finland, USA, Sweden, Russia, Estonia

Soybean oil

Ecoinvent database (see attachment for details), USDA Soybean transportation guide 2011, ABIOVE, ASA-American Soybean Association

Gaia Dataset for Location Specific data: Brazil, Germany

Crude Tall Oil (CTO) to Tall Oil Fatty Acids (TOFA)

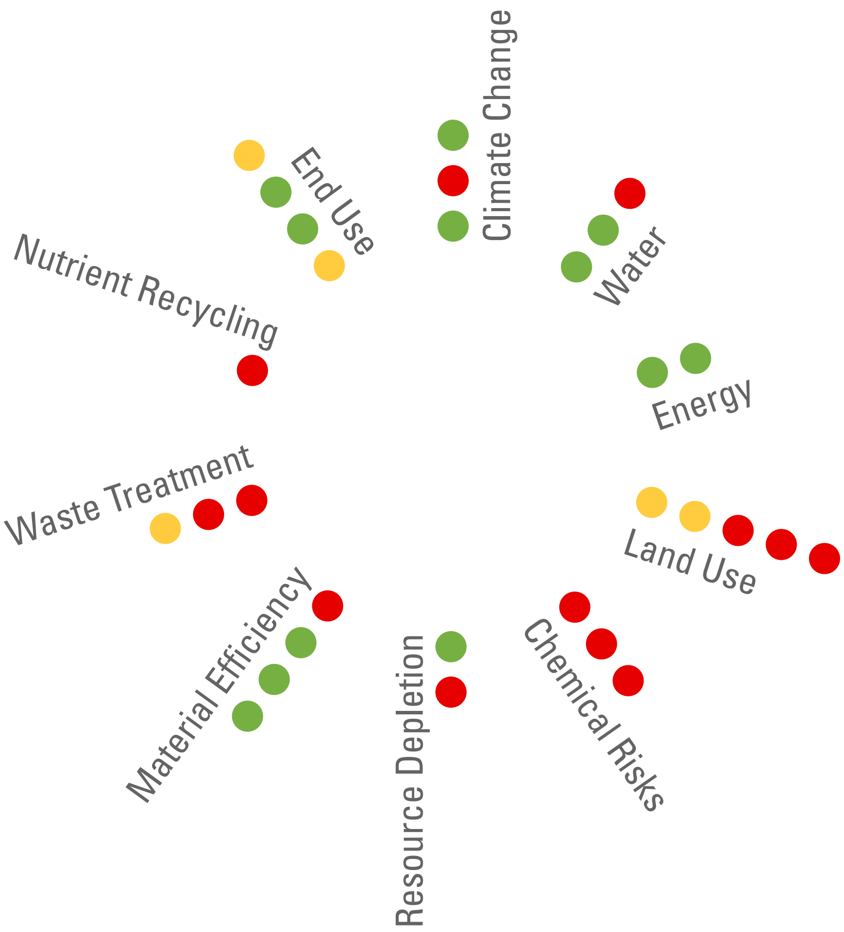
Potential competitive advantage

The value chain has several potential competitive advantages from an environmental sustainability view. Competitive advantages rise in all climate change indicators: GHG emissions from transport and GHG emissions from production and Carbon sequestration. The water scarcity in the region of production is low, and the share of renewable energy sources is high. The raw material production site provides ecosystem services, and there is no threat to food production, nor risks through indirect land use change. No threat to nutrients balance is raised by the production. Chemicals used in the production process provide no environmental hazard. Fossil intensity is low and material efficiency is high. The product has a competitive advantage in product functionality and biodegradability.

Potential risks

Potential risks are raised by solid waste treatment and waste gas treatment requirements

Crude Soybean Oil to Soybean Oil Fatty Acids



● Potential competitive advantage	● Neutral	● Potential risk

Potential competitive advantage

The value chain has competitive advantages from low GHG emissions from production and Carbon sequestration. The water scarcity in the region of production is low, and the share of renewable energy sources is high. Fossil intensity is low and material efficiency is high. The product has a competitive advantage in biodegradability.

Potential risks

There are several potential risks related to the value chain. Potential risks are raised by GHG emissions from transport due to long distances. Raw material production requires water and desalination. The production of raw material further poses threat to food production and biodiversity, risks through indirect land use change, threat to nutrients balance and is very mineral intensive, due to fertilizing. Processing chemicals are connected to environmental and health risks. Waste water treatment and waste gas treatment need special attention.

Results

	CRUDE TALL OIL TO TALL OIL FATTY ACIDS	SOYBEAN OIL TO SOYBEAN OIL FATTY ACIDS
1. CLIMATE CHANGE		
1.1 GHG emissions from production	● Small	● Small
1.2 GHG emissions from transport	● Small	● Remarkable. Long distance transport
1.3 Carbon sequestration in raw material production	● Significant positive impacts likely	● Significant positive impacts likely
2. WATER		
2.1 Water intensity	● Moderate. Mainly from raw material production: Kraft pulping	● Small
2.2 Water scarcity where produced	● No water scarcity	● Small
2.3 Desalination before production	● Desalination of other than ocean water. 44% of total water used in boiler in distillation step is desalinated	● Desalination of ocean water
3. ENERGY		
3.1 Energy intensity of production	● Moderate. 44% of energy intensity results from raw material production	● Small
3.2 Share of renewables in production energy	● Remarkable (over 50 %). Energy requirements are covered by pulp mill, which uses biomass as fuel	● Remarkable (over 50 %). High utilization of hydropower in Brazil
4. LAND USE		
4.1 Land use efficiency of raw material production	● Moderate land area needed	● Moderate land area needed
4.2 Land use synergies through ecosystem services	● Remarkable synergies. Forests provide significant ecosystem services while biomass is produced.	● Moderate synergies
4.3 Threat to food production from raw material production	● No threat	● Remarkable threat. Raw material is defined as food
4.4 Threat to biological diversity from raw material production	● No significant impacts	● Significant negative impacts. Produced on grasslands
4.5 Risks through indirect land use change	● No or minor risks. Global primary raw material (pine forests) production is not growing and not competing with food production	● High risks. Raw material is oil crop. Global primary raw material production is growing significantly in ways that would hamper biodiversity and food production (new areas are taken for cultivation)

Results

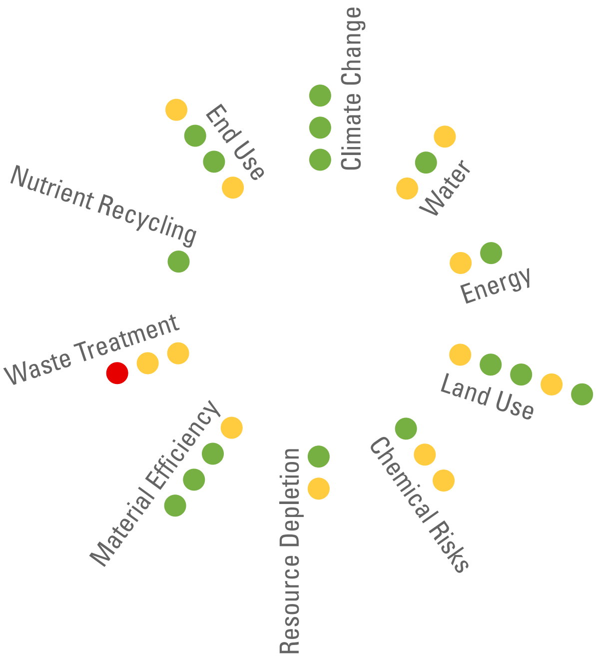
	CRUDE TALL OIL TO TALL OIL FATTY ACIDS	SOYBEAN OIL TO SOYBEAN OIL FATTY ACIDS
5. CHEMICAL RISKS		
5.1 Environmental hazard of production chemicals	● Not hazardous. Process chemicals not environmentally hazardous	● Highly environmentally hazardous. Hexane toxic to aquatic life with long lasting effects
5.2 Health hazard of production chemicals	● Environmentally hazardous. Sodium hydroxide causes severe skin burns and eye damage	● Highly hazardous to human health. Hexane is suspected of damaging fertility or the unborn child and may cause damage to organs through prolonged or repeated exposure
5.3 Safety hazard of production chemicals	● Moderate. Sodium hydroxide may be corrosive to metals and nitrogen gas under pressure may explode if heated	● Highly safety hazardous. Hexane is highly flammable liquid and vapour
6. RESOURCE DEPLETION		
6.1 Fossil intensity	● Small. Raw material is biomass and energy requirements are covered by pulp mill, which uses biomass as fuel.	● Small
6.2 Mineral intensity	● Using minerals	● Using extremely rare or large amounts of minerals. Fertilizer intensive process
7. MATERIAL EFFICIENCY		
7.1 Alternative uses of raw material	● Raw material could be used for other solutions.	● Raw material could be used as food for people
7.2 Main raw material utilization rate to products	● Over 80 %	● Over 80 %
7.3 Product type ratio	● Over 50 %	● Over 50 %
7.4 Waste per product ratio	● Less than 20 %	● Less than 20 %
8. WASTE TREATMENT		
8.1 Wastewater treatment	● Some treatment needed. Wastewater contains e.g. organic compounds that need to be treated	● Remarkable treatment needed. Wastewater contains reprotoxic hexane (suspected of damaging fertility or the unborn child)
8.2 Waste gas treatment	● Some treatment needed. Waste gas from raw material production contains sulfurous compounds	● Remarkable treatment needed.Waste gas contains reprotoxic hexane (suspected of damaging fertility or the unborn child)
8.3 Solid waste treatment	● Remarkable treatment needed. Green liquor sludge from raw material production is deposited to landfill	● Some treatment needed. Assumed that solid waste is suitable for normal waste disposal

Results

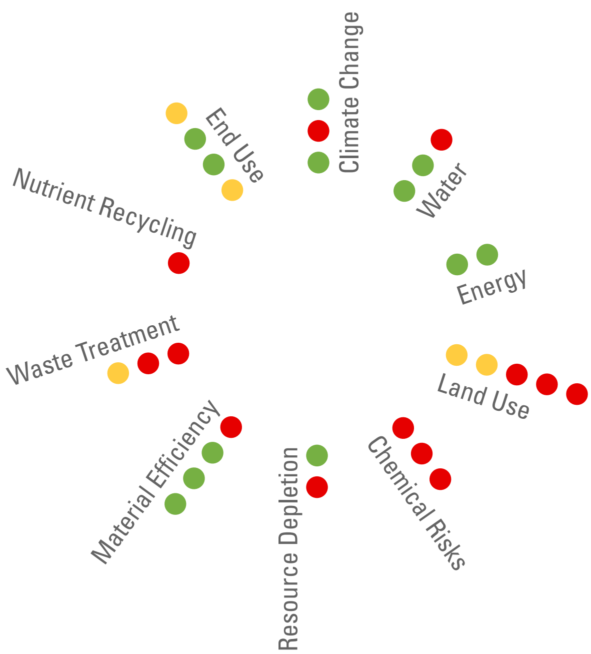
	CRUDE TALL OIL TO TALL OIL FATTY ACIDS	SOYBEAN OIL TO SOYBEAN OIL FATTY ACIDS
9. NUTRIENT RECYCLING		
9.1 Threat to nutrient balance from raw material production	● No threat. The nutrient balance in Finland is at EU average. This indicates that there is a risk for overnutrification. The raw material production process does not include fertilization, agriculture or livestock production and therefore this is irrelevant.	● Remarkable threat. Country is suffering from nutrients depletion and coastline is eutrophicated
10. END USE		
10.1 Storage properties	● Moderate sensitivity to surroundings	● Moderate sensitivity to surroundings
10.2 Risks related to use and disposal	● The product is not hazardous	● The product is not hazardous
10.3 Biodegradability	● Biodegradable	● Biodegradable
10.4 Product functionality	● TOFA is slightly better than the comparative product soybean oil when used in paints and coatings, as the reactivity is higher and drying time is shorter.	● For use in ink and lubricants, the functionality of the comparative end products is the same.

Environmental sustainability of the value chain of TOFA compared to the value chain of Soybean Oil Fatty Acids

Crude Tall Oil (CTO) to Tall Oil Fatty Acids (TOFA)



Crude Soybean Oil to Soybean Oil Fatty Acids



Potential competitive advantage | Neutral | Potential risk

Tall Oil Fatty Acids (TOFA) can replace the use of Soybean Oil Fatty Acids in paint, ink and lubricants production. The indicator based sustainability analysis shows that the value chain for the production of TOFA has several advantages from an environmental point of view. The only potential risk found in the analysis is related to solid waste treatment from the raw material production step, sulphate pulping. The production of Soybean Oil Fatty Acids has somewhat fewer advantages and also includes many potential risks, mainly related to raw material production and land use. The climate change indicators indicate that both value chains have a low impact on climate change due to GHG emissions from processing and raw material production. The production of TOFA occurs closer to the market, which results in lower GHG emissions from transport and gives competitive edge compared to Soybean Oil Fatty Acids. The production of TOFA's raw material crude tall oil is however water and energy intensive. Nevertheless, high use of renewable energy sources gives potential competitive edge and the high water intensity is not critical at the specific production locations as fresh water is not scarce in the production areas. The value chain for TOFA production raises no land use alerts, while these are raised in the value chain for Soybean oil production. Chemicals used in TOFA production have moderate or no hazards for environment, health and safety, while high risk chemicals are used in Soybean oil production. Use of fossil materials is low for both cases, but mineral intensity is higher in the value chain for Soybean oil production due to intensive fertilizer usage. TOFA production is very material efficient and the raw material crude tall oil is non-edible. On the contrary the raw material Soybean is edible and thus an alert is raised in the alternative uses of raw material indicator. Waste treatments raise alert in both value chains. Regarding nutrient balance raw material for TOFA is produced from unfertilized forests and does not change the nutrient balance of N, P and K as much as agricultural production of soybean oil. Soybeans for soybean oil production are produced in areas where nearby waters are eutrophicated and soil is nutrient depleted.

Contact Details

Tiina Pursula
Project Director
tiina.pursula@gaia.fi
+358 40514 9507

Maija Aho
Project Manager
maija.aho@gaia.fi
+358 44541 7444

Gaia Consulting Ltd, Bulevardi 6 A FI-00120 Helsinki, Finland

Gaia Biorefiner Team


Tiina Pursula


Maija Aho


Ida Rönnlund


Piia Pessala


Laura Hakala


Niina Hokkanen


Jatta Aho


Anu Vaahtera


Erkka Ryynänen

Gaia Consulting Ltd

Gaia Biorefiner is created and provided by Gaia Consulting. We are a leading sustainability consultancy. In addition to bioeconomy, our areas of expertise include sustainability, energy, climate change and environment, as well as risk management and innovation. We provide our clients with profound and multi-disciplinary know-how, and a cross-disciplinary approach to meet challenges with uncompromised high quality and reliability.

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