gaia
Innovative Solutions
for Sustainability

Gaia Biorefiner

Framework and Methodology

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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

Framework

Gaia Biorefiner is based on Gaia's extensive experience and understanding on the sustainability of bio-based value chains. It is based on internationally recognized and well established frameworks, and updated regularly with reference data reflecting the technology development. The framework itself is transparent, and indicators are tailored to fit specific product categories in biofuels, biochemicals, and biomaterials.

Our method of evaluating the sustainability of a specific value chain is to study the value chain both with respect to its geographical location and the inputs and outputs of the value chain. Reference values are used to understand how the value chain compares to other similar products. Well-recognized institutions such as FAO, Eurostat, EU, IPCC, OECD, UN, and WWF are used in defining the framework and reference values.

Gaia Biorefiner includes three main product categories: biochemicals, biomaterials, and biofuels. Each product category has subcategories and each subcategory is connected to a specific reference group. Issues such as energy intensity, water intensity, fossil intensity and raw material intensity increase with the degree of refinement and value adding steps. By comparing products that belong to a certain product subcategory, it can be ensured that the products are competing in the right league.

The results of the screening point out the potential competitive advantages and sustainability risks in the value chains.

Indicators

Gaia Biorefiner screens the environmental sustainability of products and technologies and their entire value chains based on ten indicator groups. The most important sustainability indicators are included providing a comprehensive and useful view on the most critical sustainability issues of the value chains.

The value of each indicator is evaluated based on raw material, process, location and transport data. In the quantitative indicators, the result is screened against a reference group and in the qualitative indicators against indicator specific alert lists and sustainability criteria. The indicator can give three levels of results: green indicating a possible competitive edge, red indicating a possible alert, and yellow being between these classes.

Indicators

1. CLIMATE CHANGE	2. WATER	3. ENERGY	4. LAND USE
1.1 GHG emissions from production	*2.1 Water intensity*	*3.1 Energy intensity of production*	*4.1 Land use efficiency of raw material production*
1.2 GHG emissions from transport	*2.2 Water scarcity where produced*	*3.2 Share of renewables in production energy*	*4.2 Land use synergies through ecosystem services*
1.3 Carbon sequestration in raw material production	*2.3 Water purification before production*		*4.3 Threat to food production from raw material production*
	2.4 Desalination before production		*4.4 Threat to biological diversity from raw material production*

5. CHEMICAL RISKS	6. RESOURCE DEPLETION	7. MATERIAL EFFICIENCY	8. WASTE TREATMENT
5.1 Environmental hazard of production chemicals and intermediates	*6.1 Fossil intensity*	*7.1 Alternative uses of raw material*	*8.1 Wastewater treatment*
5.2 Health hazard of production chemicals and intermediates	*6.2 Mineral intensity*	*7.2 Main raw material utilization rate to products*	*8.2 Waste gas treatment*
5.3 Safety hazard of production chemicals and intermediates		*7.3 Product type ratio*	*8.3 Solid waste treatment*
		7.4 Waste per product ratio	

9. NUTRIENT RECYCLING	10. END USE
9.1 Threat to nutrient balance from raw material production	*10.1 Storage properties*
	10.2 Risks related to use and disposal
	10.3 Biodegradability
	10.4 Product functionality

Indicators

1. CLIMATE CHANGE	
is one of the grand global challenges of our time. The need to reduce the greenhouse gas emissions is immediate. Biobased value chains have impact on greenhouse gas emissions both directly and indirectly. For a balanced analysis both need to be taken into account.	**1.1 GHG EMISSIONS FROM PRODUCTION** The indicator describes the greenhouse gas emissions of the production compared to other comparable products in kg CO2 equivalents per kg of product. Both energy used for processing and direct greenhouse gas emissions from processing are included throughout the value chain. This indicates carbon intensity of the processing technology. Selection of processing technology is one of the key means available to reduce greenhouse gas emissions.
	1.2 GHG EMISSIONS FROM TRANSPORT The indicator describes the greenhouse gas emissions from transportation in the value chain compared to other comparable products in kg CO2 equivalents per kg of product. Raw material, intermediate products and end product logistics are included. This indicates the carbon intensity of transportation, taking into account both transportation means and distances. Greenhouse gas emissions can be reduced by utilizing as local raw materials and production concepts as possible. However, product groups differ strongly on possibilities to do so, therefore the issue must be analyzed relative to the product category in question.
	1.3 CARBON SEQUESTRATION IN RAW MATERIAL PRODUCTION One of the potential advantages of biomass-based products from climate change perspective is the ability of biomass to bind carbon, both directly in actual growing biomass stock and indirectly in the soil. This carbon sequestration potential must be assessed on a reasonable time horizon: both time elapsed for binding of the actual carbon stock to be utilized and time required for re-binding of the equivalent carbon stock are relevant. In this indicator, scope is on raw material production. Additional carbon sequestration potential lies also in advanced processing technologies, which utilize greenhouse gases as process inputs.

Indicators

2. WATER *is one of the most important resources for life. Fresh water availability is limited in many parts of the world, and it is not evenly spread across the globe leaving millions of people without sufficient water for their daily needs. Climate change and population growth further increase the need for efficient use of water. Production of biomass-based products can be water intensive, so special care must be taken when selecting raw materials, production technologies and production locations.*	**2.1 WATER INTENSITY** The indicator describes how much water is used in raw material production and processing in litres of water per kg of product, compared to other comparable products. Water required for irrigation, processing and cooling purposes are included. Selection of water-efficient raw materials and processing technologies is one of the key means to reduced impact on water resources. However, for specific product groups only certain feedstocks and technologies are possible. Therefore the indicator compares the water intensity to other comparable products. Use of water for irrigation in biomass cultivation is also included in this indicator.
	2.2 WATER SCARCITY WHERE PRODUCED The indicator describes the scarcity of fresh water resources in the production regions of the value chain in question, indicating the general risk for water resource overuse in the region. The approach is to look at the ratio of regional blue water footprint (based on consumption) to regional blue water availability. Selection of production locations with low risk of water scarcity is crucial especially for water intensive processes.
	2.3 DESALINATION BEFORE PRODUCTION The indicator describes if salt content of processing input water is that high that water desalination is needed before using the water in processing. Need for desalination indicates resource consumption in form of e.g. energy, chemicals and infrastructure/facilities. If desalination is linked to closed water circulation in production, it is not included in this indicator, as direct consumption of energy and chemicals in the processing are included in other indicators.

Indicators

3. ENERGY *Global energy demand is constantly growing at the same time when adverse effects of energy production and use on climate change, natural resource scarcity and environment need to be minimized. Energy efficiency is therefore one of the key design criteria of production concepts, and sustainable renewable energy sources are promoted as well to minimize the greenhouse gas emission and natural resource scarcity impacts of energy production and use.*	3.1 ENERGY INTENSITY OF PRODUCTION The indicator describes the energy efficiency of the value chains and products by comparing their energy consumption (kWh of energy per kg of product) to other comparable products. Energy used in the raw material procurement and processing as well as in refining the product are included. Energy efficiency of production is related to the technology chosen for production and thus this indicator guides towards using BAT or better. 3.2 SHARE OF RENEWABLES IN PRODUCTION ENERGY The indicator describes the share of renewable energy sources in processing throughout the value chain in % of the total energy consumption. Energy used in the raw material procurement and processing as well as in refining the product are included.
4. LAND USE *Land is a limited resource. There is an increasing pressure to use land effectively. Land used for food and feed production and communities purposes increases constantly due to global population growth. However, land is required for several other crucial purposes as well: primary biomass production as production feedstock, providing the crucial ecosystem services and for binding of carbon.*	4.1 LAND USE EFFICIENCY OF RAW MATERIAL PRODUCTION The indicator describes how much land is needed for primary raw material production in hectares per ton of product. The indicator result depends on the primary raw material in question and its production location. For biomass raw materials the land area required for producing the annual biomass increment utilized as processing input is estimated. For fossil raw materials a comparable approach is being used. The quantitative land use efficiency is especially crucial for such raw materials, the production of which does not allow synergistic use of the land for other purposes. 4.2 LAND USE SYNERGIES THROUGH ECOSYSTEM SERVICES This indicator describes whether the land area used for primary raw material production is simultaneously beneficial for other synergistic purposes, such as providing of ecosystem services like nutrient recycling, air purification and recreation. These synergistic uses balance the quantitative land use efficiency, making certain quantitatively low-efficiency biomass sources beneficial taking into account the synergistic benefits provided.

Indicators

4. LAND USE *Land is a limited resource. There is an increasing pressure to use land effectively. Land used for food and feed production and communities purposes increases constantly due to global population growth. However, land is required for several other crucial purposes as well: primary biomass production as production feedstock, providing the crucial ecosystem services and for binding of carbon.*	**4.3 THREAT TO FOOD PRODUCTION FROM RAW MATERIAL PRODUCTION** The indicator describes whether the raw material production is a threat to the food production in the local scale (country level). This is the case when the raw material production takes place in a country where undernourishment is recorded and raw material production is linked to food chain. Indirect threat to food chain through global land use development is not covered here, but in indicator 4.5 Risks through indirect land use change.
	4.4 THREAT TO BIOLOGICAL DIVERSITY FROM RAW MATERIAL PRODUCTION The indicator describes if raw material is produced in areas that are identified as rich in biodiversity indicating potential threat e.g. through directly destroying such ecosystems or indirectly impacting their status and development.
	4.5 RISKS THROUGH INDIRECT LAND USE CHANGE The indicator addresses emissions and threat to food production and biodiversity from indirect land use change. Utilization of certain raw materials can lead to adverse effects elsewhere, as the overall global consumption of the raw material increases and new land areas are taken into use for biomass production. These effects can be particularly harmful when raw material production happens in areas with biodiversity hot spots, land with high carbon stock or which are particularly important for global food production.
5. CHEMICAL RISKS *Chemicals are used in our everyday life in numerous ways. In addition to their beneficial qualities, they posses also negative properties that result in a risk to the environment, health and safety.*	**5.1 ENVIRONMENTAL HAZARD OF PRODUCTION CHEMICALS AND INTERMEDIATES** The indicator describes the environmentally hazardous properties of the production chemicals indicating potential risks for adverse environmental impacts. Risk estimates are based on the seriousness of the hazardous properties of the chemicals.
	5.2 HEALTH HAZARD OF PRODUCTION CHEMICALS AND INTERMEDIATES The indicator describes the health hazardous properties of the production chemicals indicating potential risks for adverse health impacts. Risk estimates are based on the seriousness of the hazardous properties of the chemicals.
	5.3 SAFETY HAZARD OF PRODUCTION CHEMICALS AND INTERMEDIATES The indicator describes the physical hazardous properties of the production chemicals and intermediates indicating potential safety risks. Risk estimates are based on the seriousness of the hazardous properties of the chemicals.

Indicators

6. RESOURCE DEPLETION *is one of the global challenges. Fossil resources and minerals are used at an increasing rate as global population grows and standards of living rise in the emerging economies. Bio-based value chains and increased use of recycled materials should help in resolving these issues.*	**6.1 FOSSIL INTENSITY** The indicator describes how much fossil resources are used as raw material, transport fuel or energy source in the production of a particular product (in kg fossile material per kg product) compared to a group of comparable products. It indicates choices made in relation to raw material type, production energy source and production logistics. **6.2 MINERAL INTENSITY** The indicator describes whether mineral intensive steps are included in the value chain. Both raw material production (fertilizer use in cultivation) and processing (direct use of minerals and use of mineral-derived process chemicals) are included in the analysis. Mineral intensity can be minimized through selection of raw material and processing technology.
7. MATERIAL EFFICIENCY *As global resource usage rises and several resources are becoming scarce, material efficiency is a top priority. Material efficiency covers the efficient use of resources in the value chain. The more efficiently the resources can be utilized, the fewer primary resources are required in producing the product. Often material efficiency is beneficial also in minimizing of adverse environmental impacts.*	**7.1 ALTERNATIVE USES OF RAW MATERIAL** The indicator describes whether there is alternative uses for the raw material in food production or elsewhere. Food production is prioritized use. Established alternative uses must be taken into account as well when assessing overall justification for raw material utilization. If there is no other established uses, and the raw material would otherwise be waste, the overall impact on the material efficiency is positive. **7.2 MAIN RAW MATERIAL UTILIZATION RATE TO PRODUCTS** The indicator describes how much of the main raw material ends up in products (in %, tn product / tn main raw material). In material efficient production concepts nearly all fractions are utilized for sellable products, indicating efficient utilization of production side streams. The analysis is done on mass basis, i.e. the bioenergy products are assessed based on mass of biofuel produced. **7.3 PRODUCT TYPE RATIO** The indicator describes the ratio of different product types, i.e. comparing the share of material products versus energy products (%). The assessment takes into account the general prioritized status of material uses over energy uses. However the assessment is relative to the product group in question, i.e. in case of energy products material products are not absolutely prioritized, but side products capturing the material value are considered beneficial. **7.4 WASTE PER PRODUCT RATIO** The indicator estimates the likely need for wastewater treatment for liquid waste formed in processing. The indicator indicates the use of resources such as energy, chemicals and infrastructure/facilities for adequate wastewater treatment.

Indicators

8. WASTE TREATMENT *is needed for unwanted liquid, gaseous and soild outputs of production. They reduce overall material efficiency, may cause negative environmental impacts, and their treatment needs resources. Thus they should be avoided in all the value chains.*	8.1 WASTEWATER TREATMENT The indicator estimates the likely need for wastewater treatment for liquid waste formed in processing. The indicator indicates the use of resources such as energy, chemicals and infrastructure/facilities for adequate waste-water treatment.
	8.2 WASTE GAS TREATMENT The indicator estimates the likely need for treating the gaseous waste from processing indicating the use of treatment resources such as energy, chemicals and infrastructure/facilities.
	8.3 SOLID WASTE TREATMENT The indicator estimates the likely need for and type of treatment for solid waste indicating the use of treatment resources such as energy, chemicals and infrastructure/facilities.
9. NUTRIENT RECYCLING is becoming increasingly important as many fossil mineral sources are becoming scarce, global demand for food grows and nutrients are currently utilized inefficiently in many value chains. It is highly important to identify raw materials and production methods which may cause threat to nutrient recycling and promote ways to improve nutrient recycling.	9.1THREAT TO NUTRIENT BALANCE FROM RAW MATERIAL PRODUCTION The indicator indicates potential local adverse changes in nutrient balance in the environment. It is based on raw material production type and meth-ods, and the local nutrient balance resulting from cultivation and livestock.

Indicators

10. END USE *covers the last part of the value chain. The characteristics and functionality of the product, the life span of the product, recyclability, the characteristics of the waste that is formed from it and how it needs to be handled, are all important sustainability issues. These need to be compared to comparable products responding to similar end use need.*	**10.1 STORAGE PROPERTIES** The indicator points out the potential problems with keeping the product from reacting due to the impact of the surroundings. The properties are compared to similar products. In terms of sustainability, reduced storage properties may adversely impact resource efficiency. Indirect resource utlization, such as for additive chemicals or special materials, is also increased if storage requirements are demanding.
	10.2 RISKS RELATED TO USE AND DISPOSAL The indicator describes the hazards that are related to the product properties indicating risks related to end use and resource consumption in form of e.g. specific equipment in using the product (e.g. PPE) or facilities and energy in disposing the product.
	10.3 BIODEGRADABILITY The indicator indicates if the product is biodegradable or not. Biodegradability can provide advantage in disposal, but also be a risk for end use e.g. in high moisture conditions. However these risks are included in indicator 10.4 product functionality.
	10.4 PRODUCT FUNCTIONALITY The indicator indicates if the functionality of the product is better, similar, or worse than comparable end product(s) for similar end uses. Product functionality is linked to sustainability e.g. through resource efficiency and environmental impacts.

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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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