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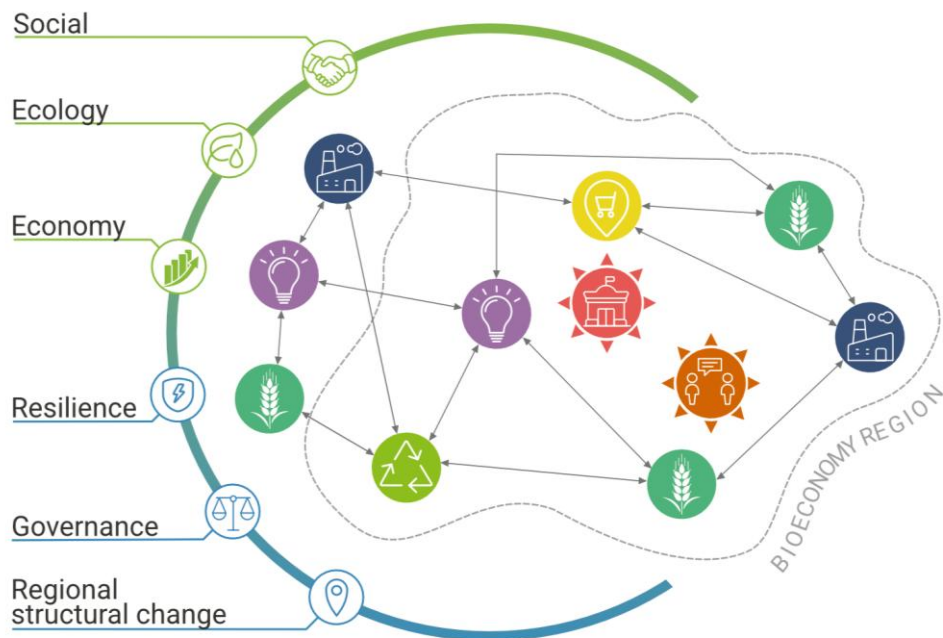


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Sustainability Assessment of Value Creation Systems in Bioeconomy Regions

Implementation Guidance



Imprint

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Introduction & Objectives of this Guide

The term ‘bioeconomy’ refers to the use and processing of renewable biomass with the aim of achieving sustainable development. In practice, the development of bioeconomic value creation systems can lead to conflicts of interest between the social, environmental and economic dimensions of sustainability. Against this backdrop, the following key questions arise: Under what conditions are bioeconomy business models and value creation systems actually more sustainable than conventional solutions? What contribution do they make to sustainable regional structural change? And which bioeconomy approaches should be prioritised in specific local decisions with regard to their impact on sustainability?

As part of the ‘NaGeWe-Bio’ project, a toolkit for assessing the sustainability of bioeconomy business models and value creation systems across economic, environmental and social dimensions was developed and tested within the [WIR! alliance Plant³](#), using existing and planned projects in north-eastern Mecklenburg-Western Pomerania (the Plant³ project region). By taking an integrated view of the individual operational perspectives of bioeconomy enterprises and their associated value creation systems, this approach enables the assessment of business models within the context of regional structural change.

The sustainability assessment for value creation systems in bioeconomy regions evaluates the sustainability of entire networks comprising companies and other organisations in dialogue with regional and supra-regional stakeholders from business, public administration and research. To this end, a modular system for advisory and dialogue processes has been developed. The aim of the sustainability assessment is to identify approaches, courses of action and priority areas through which sustainable regional structural change can be mapped, assessed and expanded via bioeconomic value creation systems.

This guide provides insights into the conceptual and methodological foundations of the NaGeWe-Bio sustainability assessment for value creation systems. The aim is to present the content-related systematics, the theoretical assumptions, and the structure and logic of the tool in a transparent manner and to provide a technical justification for them. To this end, the procedure for carrying out the sustainability assessment is described step by step. The assessment process is divided into four modules, each comprising several steps:

- [Module 1:](#) Defining and mapping the value chain
- [Module 2:](#) Data collection
- [Module 3:](#) Analysis and evaluation
- [Module 4:](#) Processing and transfer of results

Sustainability of Value Creation Systems in the Bioeconomy

Germany's economy is facing multiple crises. Particularly in light of the climate crisis and volatile fossil supply chains, locally available renewable resources are becoming increasingly important as a raw material base for establishing sustainable and crisis-resilient value creation systems.

This is where the bioeconomy comes in as a cross-sectoral economic model. According to the German Federal Government, 'the bioeconomy encompasses the production, development and use of biological resources, processes and systems to provide products, processes and services across all economic sectors within the framework of a sustainable economic system' (BMBF & BMEL, 2020, p. 10) . The national bioeconomy strategy aims to use the bioeconomy to achieve sustainable and climate-neutral development, which is to take the form of a circular economy based on biological resources (BMBF & BMEL, 2020) . The European Commission's bioeconomy strategy (2018, p. 4) focuses on biological resources and processes. All sectors and systems that draw upon these resources are therefore considered part of the bioeconomy. Overall, the bioeconomy is seen as a option of driving forward sustainable development by replacing non-renewable material flows (Beck-O'Brien et al., 2024, p. 12) .

During the NaGeWe-Bio project, the term 'bioeconomy' was examined from the perspective of the definition developed by the Plant³ Alliance:

'Bioeconomy is a cross-sectoral economic concept based on biogenic resources (agricultural, forestry and marine products), biological processes and biological knowledge. It encompasses all actors, relations and processes of production, processing and further valorisation of biogenic resources as well as related services, research and development activities.'

In a narrower sense, bioeconomy aims to increase regional value creation and the sustainability of the economy through the application of knowledge-based, innovative processes. The associated transformation process is realised through at least one of the following pathways:

- *Replacement of fossil raw materials with biogenic, renewable raw materials within the scope of their regenerative capacity.*
- *Cascade and combined use of biogenic raw materials*
- *Increasing biodiversity through diversification of the agricultural, forestry and maritime economy*
- *Ecological compatibility of production by saving resources and minimising emissions*
- *Promotion of regional development in economic, ecological and social terms".*

The focus is therefore on development pathways that strengthen both the sustainable transformation of the economy and regional value creation. The NaGeWe-Bio sustainability assessment examines precisely this combination of regional value creation dynamics and sustainable development. To this end, the processes in bioeconomy regions are analysed at the system level using the concept of bioeconomic value creation systems.

Value-creation systems are networks comprising companies, organisations and other economic entities, within which products and services are created through cooperation and the division of labour. In the context of the bioeconomy, these networks encompass activities relating to the cultivation of bio-based raw materials and the subsequent processing stages, right through to the final product and its disposal or recycling. This explicitly includes supporting services, research and development activities, as well as interactions with government, political and civil society actors.

In order to use value creation systems as the subject of analysis for sustainability assessment, clear system boundaries must be defined. This opens up the possibility of delimiting the value creation system on the basis of one's own objectives and research questions. Therefore, the final definition of the value creation system is not specified here. Instead, [the first module](#) of the sustainability assessment explains how the value creation system to be assessed can be adapted to the respective bioeconomy region through the definition of system boundaries.

The perspective on bioeconomic value creation systems described here was developed through dialogue with stakeholders from the (bioeconomy) region of Vorpommern (Western Pomerania, Germany), in combination with a literature review. A more detailed description of the methodology is provided in the chapter '[Documentation of the development of the sustainability check](#)'.

The sustainability of bioeconomic value creation systems is of interest because this approach facilitates the identification of development options that minimize conflicts with social, environmental and economic interests. As part of the NaGeWe-Bio project, a catalogue of criteria was developed and tested to enable the sustainability assessment of bioeconomic value creation systems. The catalogue is the result of a research phase during which expert interviews were conducted and existing approaches to the sustainability assessment of companies and value creation systems were evaluated. The identified sustainability criteria are assigned to the three sustainability dimensions considered in this guide from the perspective of bioeconomic value creation systems:

- **Social sustainability** describes the contribution of bioeconomic value creation systems to the long-term maintenance and improvement of quality of life in the region, working conditions within companies, and the involvement of regional and societal stakeholders in decision-making processes.
- **Ecological sustainability** describes the contribution of bioeconomic value creation systems to the long-term conservation and restoration of ecosystems, as well as the use of biological resources in accordance with planetary boundaries.
- **Economic sustainability** describes the contribution of bioeconomic value creation systems to the long-term competitiveness and adaptability of the associated business models and economic systems.

The bioeconomy is considered an opportunity to relocate stages of value creation systems to predominantly rural regions where biomass is produced. In this context, agriculturally oriented regions may develop into bioeconomy regions through the establishment of processing companies, suppliers, supporting services and research ecosystems. This process acts as a driver of regional structural change in the affected regions.

Regional structural change is characterized by long-term shifts in economic practices and social conditions within a region. Triggers may include crises, new technologies, demographic change, or political objectives. As a result, the relative importance of individual sectors shifts, leading to new employment structures. To examine regional structural change in the context of sustainable development in bioeconomy regions, three cross-cutting themes have been identified that are closely related to the dimensions of sustainability but cannot be clearly assigned to any single dimension:

- **Regional structural change** refers to the long-term transformation of a region's economic structures and social conditions. It may be driven by factors such as crises, technological innovation, demographic change, or political objectives. These developments alter the significance of individual industries and lead to changes in employment structures. In this guideline, regional structural change encompasses the activities and factors that support the establishment, further development, and scaling of bioeconomy value creation structures within a region. Particular attention is given to the social implications of regional structural change arising from the spatial and organizational distribution of the creation, appropriation, and allocation of economic value generated by the bioeconomy.
- **Resilience** describes the capacity of systems to maintain their current state, adapt to changing conditions, or initiate transformative processes when confronted with disturbances such as crises or long-term trends. In the context of regional structural change, the key question is whether these transformations enhance the resilience of regional value creation structures. However, maintaining resilience may require substantial resource inputs, meaning that more resilient systems are not necessarily more sustainable. Therefore, it is particularly important to examine potential trade-offs between resilience and sustainability objectives.
- **Governance** describes the mechanisms and practices through which decisions are made and coordinated within networks, companies, other organizations, and across different levels of government. Understanding these mechanisms is essential for identifying how the interests of diverse stakeholder groups are represented in decision-making processes. Examining the governance of value creation systems helps to reveal underlying power structures and identify key actors who either drive or hinder regional structural change and the transition towards a bioeconomy.

Documentation of the development of the sustainability assessment

The sustainability assessment was developed using the methods outlined below, primarily in 2024 and 2025. Initially, existing cross-sectoral and sector-specific approaches to sustainability assessment at the level of companies and value creation systems were identified through literature and desk research. In total, over 70 cross-sectoral sustainability assessment systems were identified in this process. Building on this, a catalogue of criteria was developed which maps existing assessment approaches to the respective sustainability dimensions (environmental, economic, social) whilst also determining whether there is a link to value creation systems or business models within the bioeconomy.

In the next stage, a comprehensive review of the previously identified sustainability assessment approaches was carried out. The focus was on documenting the methods, standards, possible certifications, as well as the criteria and indicators of the respective approaches. Alongside this, a discussion on existing assessment systems took place in the form of expert interviews. A total of seven interviews on sustainability assessment in bioeconomy were conducted, along with a further nine interviews with organisations responsible for existing assessment systems.

The results of the previous work steps were then used to further develop and refine the criteria catalogue. The criteria catalogue is structured along ecological, economic, and social dimensions, as well as an overarching sustainability dimension, and comprises (i) links to the SDGs, (ii) specific characteristics of the bioeconomy, (iii) channels of impact on regional structural change, and (iv) technical and organisational aspects of the approaches under consideration. A record of the results, particularly the identified sustainability assessment approaches, was made available for [download](#) in tabular form on the project website to facilitate its use by third parties.

The previously developed and refined criteria catalogue was assessed with regard to the suitability and transferability of the individual assessment criteria to the bioeconomy. In this process, the catalogue was structured along the levels of ‘business models’ and ‘value creation systems’ within the bioeconomy. To identify regional requirements for sustainability assessments, interviews were conducted with stakeholders from Bavaria, the Rhine-Neckar region, and Central Germany as exemplary bioeconomy regions. The discussions highlighted, on the one hand, the need for a clear definition of system boundaries. On the other hand, the neglect of economic and social sustainability dimensions, as well as data gaps, were identified as key challenges for regional indicators. Taking these challenges into account, the regional perspective was incorporated into the catalogue as an assessment criterion. The criteria were further refined to enable an assessment of the impacts of bioeconomy business models and value creation systems on regional structural change. This process was further supported by a literature review.

In order to carry out a final overall assessment of the existing evaluation approaches identified, a strengths and weaknesses analysis of 35 evaluation systems was conducted. The assessments were based on the literature review as well as discussions with the organisations responsible for existing evaluation systems.

As a final step before commencing the development of the sustainability assessment, recommendations for such an assessment were drawn up based on all the activities carried out

previously. In order to validate the findings already obtained and to identify the region's needs at an early stage, a further 19 interviews were conducted with experts from the fields of research, business and intermediary organisations in the north-eastern Mecklenburg-Western Pomerania region. The discussions focused primarily on the benefits of sustainability assessment systems for the region, the requirements for such a system, desired applications, the significance of certification, and the expected future importance of sustainability assessment systems.

Based on the results, an initial draft of a sustainability assessment for regional structural change driven by the bioeconomy was drawn up. This involved defining and selecting suitable indicators and relevant data sources, developing checklists and evaluation tools, assessing data availability and measurability, and establishing weighting approaches. In addition, existing assessment systems were analysed and adapted for the regional context, regional mechanisms of impact were delineated, and alignment with the EU Taxonomy, the European Sustainability Reporting Standards (ESRS) and the Corporate Sustainability Reporting Directive (CSRD) was taken into account.

During an exploratory workshop with regional sustainability experts, this draft was discussed and reviewed, and next steps for its further development were derived from this. The workshop was attended by business and industry partners, business development agencies, regional development practitioners and managers of bioeconomy clusters, who provided feedback on the practical applicability and improvement of the sustainability check.

In the subsequent stages, the sustainability checklist was revised several times and assessed in terms of data collection, measurability, and the relevance of the identified criteria and indicators. Indicators were formulated as questions; data sources, availability, and measurability were defined for each individual indicator; measurability was examined from different perspectives (self-assessment/self-check and external assessment by consultants); and weighting was applied (i.e. weighting indicators against each other to address conflicting objectives and to account for regional aspects and business categories). Through this review process and the consolidation of several indicators, the total number of indicators was reduced from over 300 to 175 and, in a subsequent step, to 110. Some indicators are applicable to both business models and value creation systems, whereas others apply exclusively to one of these two levels. This was followed by a categorisation of the indicators according to sustainability criteria as well as overarching categories and sub-categories.

Subsequently, questions for assessing the indicators were formulated, and methods for data collection and evaluation schemes were defined. Due to differences in data collection and evaluation approaches, the sustainability assessment was divided into a business model assessment and a value creation system assessment.

The business model assessment examines a company's value creation potential in terms of its ability to generate economic returns while simultaneously pursuing environmental and social objectives. The business model module can be accessed and completed via an online questionnaire at <https://biooekonomie.uni-greifswald.de/en/projekte/geschaeftsmodellcheck/>. The module serves as a useful complement to the value creation system assessment, enabling the sustainability of individual business models to be assessed and subsequently recontextualised within the value creation system.

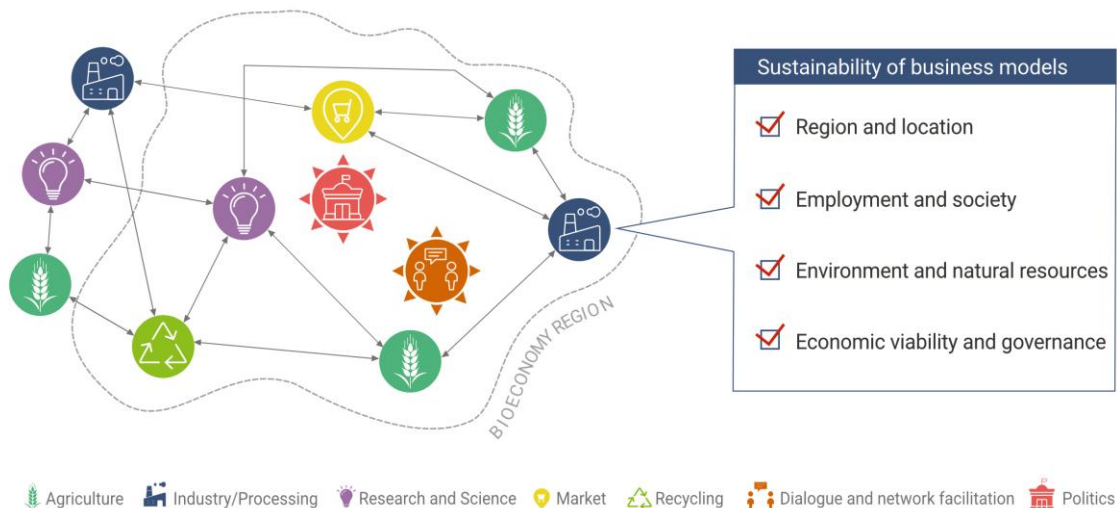


Figure 1: Sustainability check for business models in bioeconomy regions

This guide focuses exclusively on the sustainability assessment for value creation systems. It evaluates the sustainability of entire networks comprising businesses and organisations in dialogue with regional and supra-regional stakeholders from industry, public administration, and research. The aim of this approach is to identify options for action and areas of focus that can support the understanding and advancement of sustainable structural change through regional bioeconomic value creation systems. The prototype for testing the sustainability assessment of value creation systems comprises a selection of indicators from the developed criteria catalogue, which are to be collected through comprehensive data research, surveys, and interviews.

Where necessary, the focus areas identified through the value creation system analysis can be examined from an individual business perspective using the sustainability check for business models. This combination of value creation system and business model perspectives should enable a holistic analysis of the sustainability of processes and structures in bioeconomy regions.

The NaGeWe Bio Sustainability Check for bioeconomy value systems was tested through twelve semi-structured group and individual interviews with bioeconomy experts from industry, public administration, and research between May and August 2025. The interviews aimed to integrate practical knowledge, review indicators across the ecological, economic, social, and governance dimensions, and identify regional transformation pathways for the bioeconomy. During the pilot phase, the prototype of the sustainability assessment for bioeconomic value creation systems was not directly applied; instead, the current state of development was discussed and further refined in dialogue with potential users and stakeholders from the value creation systems. This format was chosen to incorporate as much practical feedback as possible regarding necessary adjustments and opportunities for improving the prototype.

In contrast to business models of individual enterprises, it should also be noted that no single actor or stakeholder can provide a comprehensive overview of a value creation system on their own. A multi-perspective approach based on diverse sources and stakeholders is therefore always required.

The sustainability assessment was tested using the four focus areas of the Plant3Alliance as underlying value creation systems. Consequently, the following value creation systems were examined and discussed during the interviews:

- Building materials
- Food, food supplements and animal feed
- Bioplastics and packaging
- Fine chemicals and phytopharmaceuticals

In this way, the NaGeWe-Bio project fulfils its objective of developing a set of tools with which the alliance's existing and future strategic directions can be assessed and prioritised according to their relevance for structural change and sustainability. At the same time, the diversity of the approaches considered ensures that the toolkit is broadly transferable to other regions and value creation systems.

The results and recommendations for improvement from the interviews were subsequently synthesised into six thematic clusters using thematic content analysis:

1. Strategic Management & Network Governance: Lack of a binding assessment framework for the advisory board and project approval processes (Plant³); need for predictive indicators.
2. Regional Value Creation & Resource Management: Insufficient processing of biogenic residues in Mecklenburg-Western Pomerania; need for a primary biomass processing stage to secure regional value creation.
3. Criteria for indicators & evaluation logic: Regional identity, resource efficiency, job quality, and innovation capacity; weighting of indicators according to company size.
4. One Health / Health Economy: Conceptualisation of the bioeconomy as a contribution to a "health-promoting region"; establishment of linkages between environmental and human health within indicators.
5. SME and investor perspective: Lack of practical tools for self-assessment; proposal of a modular structure for the assessment framework.
6. Framework conditions & policy: Lack of institutional responsibility; need for a coordinated bioeconomy strategy for Mecklenburg-Western Pomerania across ministries.

During the piloting of the value creation system module, it became evident that the required data collection and survey activities are highly resource-intensive. The necessary data must largely be collected independently, as no existing databases could be identified that meet the required level of spatial resolution and differentiation within value creation systems. While it is, in principle, possible to build the required database through extensive in-house surveys and data collection, the target group for the assessment module often lacks the necessary time and financial resources. To ensure the practical applicability of the assessment tool and to address the needs of the target group, the data collection approach therefore had to be fundamentally revised in light of the pilot phase.

Based on the findings from the pilot testing, the following adaptations were made:

- Development of an indicator framework for cross-cutting topics that are closely related to the sustainability dimensions but cannot be clearly assigned to any of the three dimensions (topics: Regional Structural Change, Governance, and Resilience).
- Integration of an analytical focus and study-specific system boundaries to define the scope of the value creation system ([Steps 1](#) and [2](#)).
- Revision of the data collection process through the development of guidance for designing a questionnaire based on the previously defined study-specific system boundaries, as well as by linking each question to appropriate data collection methods and sources ([Step 4](#)).
- Revision of the methodology for analysing and assessing the collected data through the definition of standardized analysis procedures and the development of an assessment scale ([Module 3](#)).

Steps of the Sustainability Check

As a result of this revision, the originally envisaged quantitative scoring approach for assessing the sustainability of bioeconomic value creation systems was transformed into a modular system designed to support advisory and dialogue processes. These processes aim to identify pathways, options for action, and areas of focus in order to capture, assess, and promote sustainable structural change through regional bioeconomic value creation systems. The revised system comprises the following modules:

Module 1: Defining and Characterising the Value Creation System

[Step 1: Defining the Analytical Focus](#)

- ✓ Definition and formulation of an objective variable
- ✓ Definition and formulation of the analytical focus in the form of a research question

[Step 2: Defining the Boundaries of the Value Creation System](#)

- ✓ Delimitation of the bioeconomy region into a core region, immediate surroundings, and external zone
- ✓ Specification of the raw material base of the value creation system (optional)
- ✓ Specification of the value creation stages (optional)
- ✓ Description of the processes within the value creation system (optional)
- ✓ Specification of markets and products within the value creation system (optional)
- ✓ Setting development goals for sustainable regional structural change

[Step 3: Profile Survey](#)

- ✓ Formulation of questions and response options (including open-ended responses) based on the analytical focus and system boundaries for the characteristics listed above
- ✓ Identification of all actors located within the defined system boundaries
- ✓ Conducting the survey
- ✓ Integration of the profiles into a database

Module 2: Data Collection

[Step 4: Preparation of the Questionnaire for Data Collection](#)

- ✓ Specification of the thematic aspects (Steps 4.1 to 4.3) based on the objective variable, analytical focus, and system boundaries defined in Module 1, and formulation as specific questions
- ✓ Assignment of one or more data collection methods to each question
- ✓ Identification and selection of data sources and/or interview partners for each question

[Step 5: Conducting Data Collection](#)

- ✓ Completion of the questionnaire
- ✓ Documentation of data for each question

- ✓ Optional: Further development of the questionnaire and identification of additional data sources and/or interview partners

Module 3: Analysis and Assessment

Step 6: Analysis and Assessment of the Collected Data

- ✓ Synthesis: Integration of collected information from different questions, methods, and data sources using the indicator framework
- ✓ Condensation: Consolidation of information for each indicator
- ✓ Assessment: Evaluation of sustainability for each indicator based on the assessment scale by multiple evaluators
- ✓ Derivation of key findings: Summary of the current sustainability performance of the value creation system and development of recommendations for action towards sustainable regional structural change

Step 7: Workshops for Interpretation of Results

- ✓ Selection and invitation of participants
- ✓ Discussion of the composition and characteristics of the value creation system
- ✓ Discussion of the results of the sustainability assessment
- ✓ Documentation of the workshop through minutes and jointly developed sketches, overviews, or boards

Step 8: Evaluation of the Workshop Phase

- ✓ Allocation of workshop results to the indicator framework
- ✓ Further consolidation and revision of results in the form of key findings, an adapted assessment, and recommendations for action
- ✓ Documentation of the further development of results through the workshop process

Module 4: Preparation and Transfer of Results

Step 9: Compilation and Preparation of Results

- ✓ Summary and presentation of the investigated value creation system
- ✓ Linking the sustainability assessment with the investigated value creation system
- ✓ Derivation of alternative regional transformation pathways
- ✓ Identification of actors and networks for implementing the recommendations for action

Step 10: Transfer of Results and Establishment of Routines

- ✓ Transfer of results into the value creation system
- ✓ Communication of recommendations for action to the identified decision-makers
- ✓ Continuous implementation of the profile survey with additional actors
- ✓ Establishment of a regular exchange format

The procedure for implementing each module is described in detail in the following sections.

Module 1: Defining and mapping the value creation system

Step 1: Defining the analytical focus

In the first step, the focus and direction of the analysis are defined as the basis for the subsequent procedure. Building on this foundation, the sustainability of the value creation system can be assessed through a clearly defined research question and analytical approach. This ensures that the analysis is conducted with a specific objective rather than without a clear focus.

The analytical focus is determined by the objectives of the users. The following section explains how this focus is defined. As the assessment is concerned with the sustainability of bioeconomy value creation systems, the focus should relate to a **target variable** that is relevant to these systems. Examples of suitable target variables include:

- a specific biomass type (e.g. winter wheat) or a group of biomass types (e.g. cereals);
- a specific by-product (e.g. brewers' grains or sawmill wood chips) or a group of by-products (e.g. brewery by-products or sawmill by-products);
- a specific end product (e.g. industrial sugar or blow-in insulation) or a group of end products (e.g. sweeteners or insulation materials);
- a specific stage of the value creation system (e.g. biomass cultivation, pulp production, or biogas generation); and
- a specific process or technology (e.g. biorefining or fermentation).

The range of possible target variables extends far beyond the examples provided above. The list is intended solely as a guide to support the formulation of a target variable appropriate to the specific assessment context.

Based on the selected target variable, the analytical focus is subsequently defined in the form of a research question.

Example:

Target variable: Processing forms of cattail (Typha)

Analytical focus: How do different processing forms of cattail and the associated value creation systems perform in terms of their sustainability impacts in the study region?

The analytical focus should be formulated in a way that allows for different development pathways within the value creation system. The sum of all possible pathways is referred to as the **scope for development**. The aim of the subsequent analysis is to compare these pathways and identify the most sustainable option in relation to the selected target variable. The scope for development therefore constitutes a central and recurring element. It is part of all data collection questions that relate to the gathering of sustainability-related information (Step 4.2).

The target variable and the analytical focus should be formulated as clearly and precisely as possible while still allowing sufficient room for different system configurations. If it is not possible to

limit the analysis to a single target variable and a single research question, the analysis should be conducted in two separate rounds with different target variables and research questions.

Summary of activities for completing Step 1:

- Definition and formulation of a target variable
- Definition and formulation of the analytical focus in the form of a research question

Step 2: Defining the boundaries of the value creation system

Value creation systems are complex networks that are interconnected across regions and sectors. In the second step of the sustainability assessment, the value creation system is delimited using the analytical focus in order to isolate the part of the system in which the defined target variable is effective. In addition to the analytical focus, further user-defined objectives are incorporated into the delimitation process. The procedure is described below.

As a first level of delimitation, the bioeconomy, as a fundamental economic concept, forms the basis of this assessment. All components and relationships within the value creation system under investigation are therefore directly or indirectly linked to the use of bio-based resources and processes. In this context, the value creation system is not limited exclusively to the production and processing of biomass, but also includes related services as well as research and development activities.

2.1 Delineation of the bioeconomy region

Throughout the sustainability assessment, the delineated bio-based value creation system is analysed within a defined **bioeconomy region**, with the aim of deriving recommendations for sustainable regional structural change. For this reason, spatial boundaries of the bioeconomy region must first be defined. The design of these boundaries varies depending on the specific application. Delimitation may, for example, be based on administrative borders, existing network or alliance boundaries, or natural spatial structures. It is essential that the boundaries are clearly defined.

Within the regional delimitation of the value creation system, the following zones are distinguished:

- Core region: the primary focus area of the assessment
- Immediate surroundings: regions that are strongly interconnected with the core region through spatial, cultural, or economic proximity
- External zone: all other regions that are relevant to the value creation system

This zoning approach ensures that effects on other regions are not neglected during the assessment, while maintaining a clear focus on the respective bioeconomy region. The external zone is particularly relevant for analysing whether positive or negative effects of the value creation system are shifted from the core region to external regions or vice versa.

Application example: Bioeconomy alliance region Plant³

- Core region: districts of Vorpommern-Greifswald and Vorpommern-Rügen
- Immediate surroundings: Mecklenburgische Seenplatte district, Województwo Zachodniopomorskie, district and city of Rostock
- External zone: all other regions

2.2 Specification of the raw material base of the value creation system

The raw material base of bioeconomic value creation systems comprises various renewable or naturally regrowing organic resources. Depending on the analytical focus and objectives, it may be useful to further delimit this raw material base. For example, the value creation system may be restricted to areas whose value creation is based on a specific type of biomass (e.g. wood). This delimitation is optional, as it may also be useful to consider the full spectrum of available renewable raw materials, for instance in order to identify the most sustainable combination for a defined end product.

Application example: Delimitation of the raw material base to plants from paludiculture (i.e. from the cultivation of wet or rewetted peatland soils)

2.3 Specification of the value creation stages

From biomass cultivation to final end products, the value creation process passes through various phases that can be structured into value creation stages. There are different approaches to dividing value creation systems into such stages. These classifications always represent simplified descriptions of real-world value creation systems.

In order to structure the analysis of the value creation system, the identification of value creation stages is required. An initial version of this classification can first be developed based on the analyst's prior knowledge and the analytical focus, providing a conceptual framework. During the questionnaire development phase (Step 3), the identified value creation stages are validated and revised in consultation with experts.

The following value creation stages can serve as a **guiding framework** for the exploratory development of the initial version:

- Cultivation and harvesting of biomass
- Primary processing of biomass (e.g. cleaning facilities, mills, or sawmills)
- Secondary processing (further processing) (e.g. refining, bakeries, or production of building components)
- Market stage: marketing and distribution of products (e.g. food retail, beverage wholesale, or building materials trade)
- Intermediate stage (e.g. research, consultancy, and services)
- Recycling and disposal

Depending on the analytical focus and objectives, it may be appropriate to limit the sustainability assessment to individual value creation stages. This restriction is optional, as in most cases a

system-wide perspective across all stages is more suitable for deriving systemic policy and action recommendations.

Application example: “The following value creation stages are considered in the analysis: cultivation and harvesting of biomass; primary and secondary processing of biomass; market stage; intermediate stage; and recycling and disposal.”

2.4 Description of the processes within the value creation system

Various processes can be applied in the cultivation and processing of biomass within bioeconomic value creation systems. The range of processes extends from specialised cultivation techniques to product refinement and packaging. Depending on the analytical focus and objectives, it may be appropriate to consider only selected processes in the analysis. It is also possible to assign a selection of processes to the respective value creation stages that are the focus of the assessment.

Application example: “Delimitation of the value creation system to process streams related to biorefineries.”

2.5 Specification of markets and products within the value creation system

Bioeconomic products and goods are traded across all stages of the value creation process. For the purposes of the subsequent analysis, a fundamental distinction is made between the following market types along the value creation system:

- Factor markets: trade in production factors (inputs)
- Intermediate product markets: trade in intermediate goods for further processing by other companies (B2B), e.g. industrial sugar
- Final product markets: trade in consumer goods or capital goods

Depending on the analytical focus and objectives, it may be appropriate to concentrate the analysis on specific markets. In addition, a shortlist of relevant products may be defined for each market.

Application example: Exclusion of factor markets and restriction of final product markets to bio-based insulation materials and their by-products.

2.6 Setting development goals for sustainable regional structural change

As the final step in defining the system boundaries, development goals for sustainable regional structural change should be established. These goals play a central role throughout the subsequent stages of the assessment, as they provide the benchmark for the later sustainability evaluation. In [Step 6](#), the extent to which the investigated value creation system contributes to achieving these development goals is assessed.

The development goals should be formulated as concretely as possible and supported by a sound conceptual and scientific basis. It is recommended to use existing regional strategies, political decisions, guiding principles, or scientific findings as a foundation. The legitimacy of the goals can be strengthened by developing them jointly with relevant regional stakeholders or by aligning them with already agreed objectives, for example from regional steering committees or transformation processes. Throughout the assessment process, the development goals should be critically

reviewed and adjusted if necessary. Preliminary discussions with overarching experts in Step 4 are particularly suitable for this purpose.

For each of the following sustainability dimensions and cross-cutting topics, three to five development goals should be formulated:

- Social sustainability
- Ecological sustainability
- Economic sustainability
- Regional structural change
- Governance
- Resilience

The goals should describe the desired future state of the regional value creation system and should clearly indicate the criteria by which the success of sustainable structural change can be assessed.

Application example: Social sustainability – Goal 1: By 2035, the regional bioeconomy should create at least 500 additional jobs subject to social security contributions. Particular emphasis should be placed on creating employment opportunities in rural areas, while aiming for a high proportion of permanent and collectively agreed employment relationships.

Summary of activities for completing Step 2:

- Delimitation of the bioeconomy region into a core region, immediate surroundings, and an external zone
- Optional delimitation of the raw material base of the value creation system
- Optional delimitation of value creation stages
- Optional delimitation of processes within the value creation system
- Optional delimitation of markets and products within the value creation system
- Setting Development Goals for Sustainable Regional Structural Change

Step 3: Profile survey

The value creation system is now defined and can be analysed. A survey is used to first capture the basic composition of the value creation system. The aim of the survey is to locate all companies and actors within the defined system boundaries based on selected characteristics. This enables the identification of interview partners in later stages of the analysis and allows findings to be directly linked to system actors and their activities.

The survey is designed in the form of a compact profile. The effort required from participants is deliberately kept low in order to reduce response barriers and enable as complete a representation of the value creation system as possible. For all companies and actors within the defined system, the following characteristics are collected:

- Classification according to SME status (EU definition)
- Number of employees in full-time equivalents (four predefined categories)
- Assignment to one or more value creation stages (selection from Step 2.3)

- Biomass flows in which the organisation participates within the value chain
- Geographical sourcing area of biomass flows (estimated percentage shares for core region, immediate surroundings, and external zone from Step 2.1)
- Products or value added (in the case of services) resulting from the organisation's value creation activities
- Distribution area of products or services (estimated percentage shares for core region, immediate surroundings, and external zone from Step 2.1)
- Optional: list of cooperation partners within the value creation system

By linking these characteristics with the analytical focus and system boundaries, the questionnaire can be developed. For each characteristic, the questionnaire should include a clearly formulated question and either predefined response options or a free-text field. Specifications based on system boundaries are particularly required for value creation stages, biomass flows, and final products.

To implement the profile survey, the questionnaire should be completed by all companies and actors within the defined system boundaries. If not all actors are known at the time of implementation, it is useful to ask the optional question (see list above) to selected well-connected key actors. This allows the already known network to be expanded within the scope of the study. The profile survey can be conducted continuously as new actors within the value creation system are identified.

To make use of the completed questionnaires, they should be stored in a database. This enables future queries within the value creation system. A key requirement for this is terminology harmonisation within the database; similar terms from the individual responses should therefore be standardised and aligned.

Summary of activities for completing Step 3

- Formulation of questions and response options (including free-text fields where appropriate) based on the analytical focus and system boundaries for the characteristics listed above
- Identification of all actors within the defined system boundaries
- Implementation of the survey
- Storage of the completed profiles in a database

Module 2: Data collection

Step 4: Preparation of the questionnaire for data collection

The sustainability assessment of value creation systems is based on empirical data. Suitable sources include both primary data collected through interviews, surveys, and case studies, as well as secondary data derived from existing studies, life cycle assessments, or databases. This guide does not prescribe specific data collection methods; rather, it defines the thematic focus of the data collection and the subsequent evaluation of data for sustainability assessment purposes. Depending on available resources and thematic suitability, different data collection methods may be combined.

The data collection is based on a structured questionnaire. All items included in the questionnaire should be answerable through expert interviews. If resources allow, it is advisable to use multiple quantitative and qualitative data sources for each question. This is particularly relevant for the “Questions along the sustainability dimensions” ([Step 4.2](#)).

Before data collection can be carried out in [Step 5](#), the questionnaire must be adapted and formulated in accordance with the analytical focus and system boundaries defined in [Module 1](#). The content requirements for the questionnaire are structured into three thematic blocks in Steps [4.1](#) to [4.3](#). For each item listed therein, the following preparatory steps are required:

1. Specification of the content items (Steps [4.1](#) to [4.3](#)) using the target variable, analytical focus, scope for development, and system boundaries from [Module 1](#), followed by formulation as research questions
2. Assignment of one or more data collection methods to each research question
3. Identification and selection of data sources and/or interview partners for each research question

The preparation of the questionnaire may be supported by preliminary discussions with actors from the value creation system or with overarching experts. Participants from the profile survey in [Step 3](#), for example, are well suited for this purpose. As part of the preliminary discussions, the system boundaries established in [Step 2](#) can also be reviewed and discussed. In particular, the development goals for sustainable regional structural change should be considered.

4.1 Introduction and description of the value creation system

Up to this point, the value creation system under investigation has been considered primarily in theoretical terms and has been delimited accordingly. The data collection therefore begins with capturing the actual structure of the value creation system. This makes the real-world composition of the system within the defined boundaries visible.

The following content should be included in the questionnaire in order to capture the structure of the value creation system:

- Characteristics of the study region as a location for the value creation system (location factors)
- Key actors and sites
- Classification of the system into value creation stages (complemented by and cross-checked with the classification from [Step 2.3](#))
- Currently established bioeconomic value creation processes in the study region
- Relevance of bioeconomic value creation processes compared to conventional approaches
- Dynamics and developments over the past ten years

4.2 Questions along the sustainability dimensions

For the sustainability assessment of bioeconomic value creation systems, the collection of sustainability-related information is a necessary first step. The content requirements are structured along the ecological, social, and economic sustainability dimensions. When designing the questionnaire, each content item should be linked to the **scope for development** defined in [Step 1](#). This enables the comparison of different pathways and value creation strands within the system and supports the identification of the potentially most sustainable option in relation to the selected target variable.

The following content should be included in the questionnaire in order to capture sustainability-related information on the value creation system:

Ecological impacts of the value creation system

- Environmental pressures and ecological compatibility
- Resource efficiency across value creation stages
- Options for cascade use and coupling of material flows
- Contribution to the substitution of fossil-based resources
- Contribution to biodiversity enhancement and ecological regenerative capacity

Social impacts of the value creation system

- Effects on employment (quantitative and qualitative)
- Contribution to workforce qualification and skill development
- Contribution to inter-organisational cooperation and collaboration
- Social innovation capacity and participation of society and employees

- Health and safety standards along supply chains (with a focus on external regions from [Step 2.1](#))

Economic impacts of the value creation system

- Demand and market performance of (by-)products (status quo and dynamics)
- Investment attractiveness and scalability of business models
- Innovation performance through knowledge transfer and R&D cooperation
- Competitiveness

Cross-dimensional sustainability

- Conflicts between ecological, social, and economic impacts of the value creation system and approaches to resolving these conflicts
- Potential of value creation strands to contribute to regionally embedded and effective sustainable structural change

4.3 Structural change and regional development prospects

Using the sustainability-related information collected in [Step 4.2](#), the different value creation strands within the scope for development can be compared in terms of their sustainability impacts. This raises the question of which forces drive the transition towards greater sustainability and which factors, in contrast, hinder this development. The aim is to derive options for action that enable the steering and support of sustainable development pathways.

The following content should be included in the questionnaire in order to capture the contribution to structural change and regional development perspectives of the value creation system:

- Disclosure of power structures with the aim of identifying actors who have the capacity to drive and steer change within the value creation system
- Identification of measures that promote sustainable structural change within the regional value creation system
- Future visions for a sustainable bioeconomic value creation system

Summary of activities for completing Step 4:

- Specification of content items (Steps [4.1](#) to [4.3](#)) using the target variable, analytical focus, scope for development, and system boundaries from [Module 1](#), followed by formulation as research questions
- Assignment of one or more data collection methods to each research question
- Identification and selection of data sources and/or interview partners for each research question

Step 5: Implementation of data collection

When carrying out the data collection, the prepared questionnaire is systematically processed and the respective data collection methods are applied. It is essential that all collected data are carefully

documented and that the linkage to the corresponding research questions is maintained. After completing the data collection process, a dataset should be available for each formulated question.

During data collection, it may be useful to adjust research questions and to include additional data sources or interview partners. This step is optional but is particularly recommended when only a limited number of methods and data sources are available.

Summary of activities for completing Step 5:

- Systematic completion of the questionnaire
- Documentation of data per research question
- Optional: refinement of the questionnaire and identification of additional data sources and/or interview partners

Module 3: Analysis and assessment

Step 6: Analysis and assessment of the collected data

The sustainability assessment is based on an indicator system developed over the course of the project. The development of this indicator system is described in the chapter “[Documentation of the development of the sustainability assessment](#)”. Definitions of the individual sustainability dimensions can be found in the chapter “[Sustainability of Value Creation Systems in the Bioeconomy](#)”.

The data collected in [Module 2](#) are assigned to the indicator set during the analysis phase. Each indicator is linked to information derived from different research questions, methods, and data sources from the data collection phase. Once this allocation has been completed, the information is synthesised in order to summarise the key findings regarding the state of sustainability for each indicator.

For the actual assessment of the sustainability of the regional bioeconomy value creation system, the level of sustainability for each indicator is evaluated using a predefined assessment scale. The assessment examines the extent to which sustainability characteristics are reflected in relation to the development goals for sustainable regional structural change established in [Step 2.6](#). The assessment is based on the consolidated sustainability information for each indicator.

The assessment should preferably be conducted by at least three overarching experts from the fields of science, regional development, and public administration. By integrating diverse and, where possible, independent perspectives on the value creation system, the objectivity and validity of the assessment can be enhanced. The experts should independently review the consolidated sustainability information for each indicator and subsequently classify its level of achievement in relation to the development goals from [Step 2.6](#) according to the following assessment scale:

Value	Achievement of Development Goals	Description
10	Fully achieved	Sustainability is fully achieved in all respects. There are no significant deficits; any potential for improvement is marginal at most.
9	Nearly fully achieved	Sustainability is very high across all aspects. Only minor improvement potential exists, with no fundamental need for action.
8	Very good	Sustainability is very high in most aspects. Individual improvements may further enhance overall performance.
7	Good	Sustainability is predominantly high; however, some relevant areas for improvement remain.
6	Advanced	Sustainability is already well developed; however, improvements are required in several areas.
5	Moderate	Positive and negative sustainability aspects are roughly balanced. Action is required to ensure long-term sustainable development.
4	Limited	Sustainability is only partially achieved. There is considerable need for improvement.
3	Lagging	Significant sustainability deficits exist. Extensive measures are required to initiate a positive development trajectory.
2	Severely lagging	Sustainability is present only to a very limited extent. Deficits are severe and difficult to address.
1	Critically lagging behind	Severe structural deficits and substantial backlogs exist. Sustainable development is currently barely discernible, and improvements would require an exceptionally high level of effort.

The identification and selection of reviewers should be based on the insights already gained regarding the structure of the regional bioeconomy value creation system. Existing committees, steering groups, or comparable regional structures may serve as suitable sources for selecting reviewers. These can be complemented by overarching experts from the fields of regional development and science. To incorporate external perspectives, experts from other regions should be specifically selected to provide an independent external perspective on the value creation system under investigation. Overall, attention should be paid to achieving a balanced composition that considers both regional embeddedness and supra-regional perspectives while minimizing potential conflicts of interest.

Alternatively, the assessment can also be conducted as a self-assessment by the person carrying out the analysis or by the applying organization. In this case, the assessment is likewise based on the consolidated sustainability information and follows the same assessment scale. Compared to an external expert assessment, however, self-assessments may be more strongly influenced by subjective perceptions and may provide less diversity of perspectives. They are therefore particularly suitable for initial assessments, internal analyses, or regular progress monitoring. An assessment

conducted by multiple independent reviewers can significantly increase the legitimacy and validity of the results.

Following the assessment, the individual evaluation results can be aggregated. For this purpose, the arithmetic mean of the individual ratings (see assessment scale) is calculated for each indicator. In cases where there is a deviation of more than two rating points between individual assessments, the evaluation should be discussed and revised jointly with all assessors.

As a result, each indicator is assigned a value on a scale from one to ten. These results can then be aggregated at the level of sustainability dimensions and cross-cutting themes by calculating the mean value of all indicators within each respective category. In a final step, an overall sustainability score for the entire value creation system can be calculated as the mean of the dimension-level averages.

This results in a score between one and ten for each of the following levels:

- Level of sustainability indicators (average of all individual ratings per indicator)
- Level of sustainability dimensions and cross-cutting themes (average of all indicators within each dimension)
- Cross-dimensional overall sustainability score of the value creation system (average of all six dimensions)

Based on the aggregated results and the synthesised sustainability information, key findings are derived along the sustainability dimensions and cross-cutting themes. These findings critically interpret the current state of the value creation system and, based on the analytical focus, identify options for action to enhance sustainability within the defined scope for development.

Summary of analysis steps

- **Synthesis:** Integration of information from different research questions, methods, and data sources using the indicator set
- **Condensation:** Aggregation of information at indicator level
- **Assessment:** Evaluation of sustainability for each indicator on the rating scale by multiple assessors
- **Derivation of key findings:** Summary of the current sustainability state of the value creation system and identification of recommendations for sustainable regional structural change

The indicator set used consists of the sustainability dimensions and cross-cutting themes and is described below.

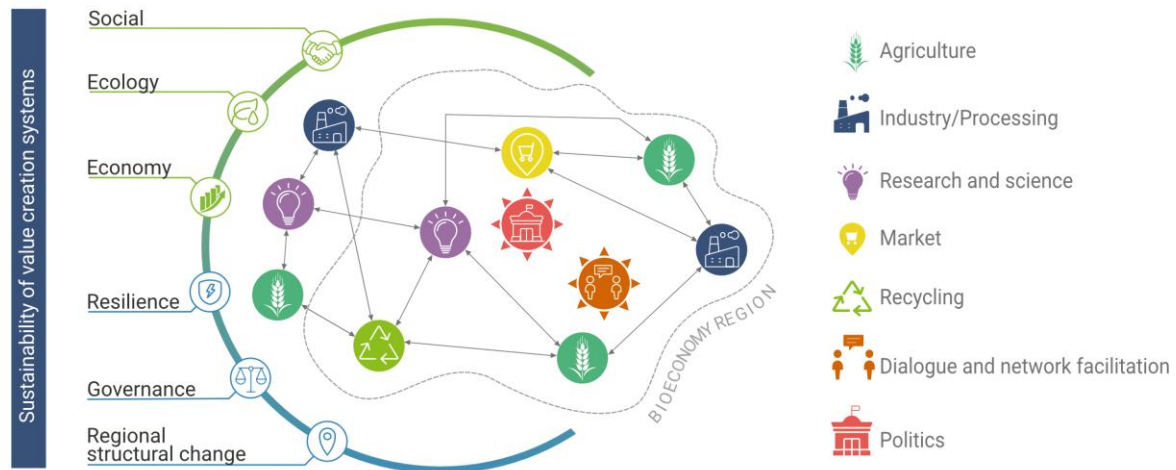


Figure 2: Dimensions of the Sustainability Assessment for Value Creation Systems

6.1 Social sustainability

The indicators for social sustainability examine how different value creation strands contribute to the long-term safeguarding and improvement of quality of life. In addition, they assess the extent to which regional and societal actors are integrated into decision-making processes. Structurally, the indicators for social sustainability closely correspond to the questions on the social impacts of the value creation system defined in [Step 4.2](#). These questions are therefore of particular relevance for the assessment.

Indicator 1.1: Effects on employment

Employment, in the form of jobs, is a fundamental prerequisite for the long-term safeguarding of quality of life for employees. Regional employment within bioeconomic value creation systems also enables the local population to participate in the biobased transformation process. For these reasons, the analysis examines how different value creation strands differ in terms of the quantity and dynamics of employment.

The assessment of this indicator should take the following information into account:

- Number of jobs created/secured: What differences exist between value creation strands regarding the number and type of jobs created and secured? At which value creation stages do these differences occur?
- Employment dynamics: How does employment develop within different value creation strands under conditions of growth or contraction/recession?

Indicator 1.2: Skills and collaboration

The transition towards bioeconomic value creation systems is accompanied by fundamental structural changes in both the economy and the labour market. The knowledge-intensive nature of many bioeconomic processes and the continuously evolving requirements placed on employees may reinforce existing social inequalities. Skills development and continuous training are therefore

essential to ensure broad access to emerging labour market opportunities and to enable equitable participation in the benefits generated by the value creation system.

The assessment of this indicator should take the following information into account:

- Competencies and knowledge requirements within the value creation system: What differences exist between value creation strands regarding the competencies and knowledge bases required? What qualification requirements arise for employees as a result?
- Education and training opportunities: To what extent do value creation strands differ in the availability of education, training, and professional development opportunities? Does the existing provision meet the respective demand?
- Collaboration in skills development: What differences exist in the cooperation between actors involved in providing education and training opportunities? Where are synergies utilised or shared structures established?

Indicator 1.3: Social innovation capacity and participation

The involvement of civil society and regional actors in decision-making processes can not only foster synergies but also strengthen the acceptance of and trust in emerging value creation systems among different societal groups. The following questions help assess the extent to which societal and regional actors are involved in the decision-making processes of the respective value creation strands.

The assessment of this indicator should take the following information into account:

- Engagement opportunities for civil society: Do value creation strands differ in the opportunities they offer for engagement with civil society? To what extent are these opportunities utilised by the local population?
- Representation of regional actors in governance structures: Do value creation strands differ with regard to the representation and influence of regional actors within relevant governance structures?
- Involvement of regional stakeholders in decision-making: At which stages and with what level of influence are actors from the core region involved in decision-making processes within the value creation strand? What differences exist between the various value creation strands in this regard?

Indicator 1.4: Health and safety standards along supply chains

Within the core region of the value creation system, health and safety standards are generally safeguarded through a common and binding regulatory framework. However, significant differences in health and safety standards may occur in upstream and downstream stages of the value creation system that are located in external regions. Inadequate health and safety standards pose substantial risks to affected individuals and should therefore be explicitly considered when assessing the social sustainability of value creation strands.

The assessment of this indicator should take the following information into account:

- Health and safety standards in external regions: Are there upstream or downstream stages of the value creation system where the level of health and safety standards established within the core region cannot be guaranteed? What differences exist between the various value creation strands in this regard?

6.2 Environmental sustainability

The indicators for ecological sustainability assess the extent to which individual value creation strands contribute to the long-term preservation and restoration of ecosystems and to the use of resources within planetary boundaries. The questions can generally be answered through desk-based research using relevant life cycle assessments (LCAs) and comparable studies, which can be identified through major scientific literature databases such as Web of Science, Google Scholar, or PubMed. Where necessary, particularly in the case of highly specific issues, consultations with experts from industry and academia may provide valuable additional insights.

Structurally, the indicators for ecological sustainability closely correspond to the questions on the ecological impacts of the value creation system defined in [Step 4.2](#). These questions are therefore of particular relevance for the assessment.

Indicator 2.1: Environmental impacts and ecological compatibility

Throughout the value creation process, environmental and climate-related pressures arise from the use of resources, as well as from emissions and pollutant releases. The ecological sustainability of value creation systems can be enhanced through efficient and resource-conserving processes, the use of renewable energy sources, and environmentally compatible agricultural practices.

The assessment of this indicator should take the following information into account:

- Energy demand and energy supply: What differences exist between value creation strands with regard to their energy demand? To what extent are there constraints on the use of renewable energy sources?
- Emissions: How do value creation strands differ in terms of their emissions, and which types of emissions are involved?
- Pollutant releases: What differences exist regarding the release of pollutants into ecosystems? Which pollutants are involved and into which ecosystems are they discharged?
- Water consumption: To what extent does water demand vary across different value creation strands?

Indicator 2.2: Resource efficiency

The land use requirements of value creation systems can be reduced through efficient use of raw materials and resources. At the same time, environmental pressures arising from the cultivation and processing of biomass can be mitigated. Resource-efficient value creation systems therefore have the potential to enhance ecological sustainability. In addition, efficient resource use reduces costs, thereby generating economic benefits.

The assessment of this indicator should take the following information into account:

- Cascade and coupled use: What differences exist between value creation strands in terms of the potential for and practical feasibility of cascade and coupled use of biomass streams?
- Circular material flows: Do value creation strands differ with regard to their potential to close material loops and maintain circular flows of resources?
- Integration of recycled resources: What potential exists for integrating recycled inputs into value creation, and how do value creation strands differ in terms of feasibility?
- Waste and wastewater: What differences exist in the type and volume of waste and wastewater generated? How are these material streams further treated or recovered?

Indicator 2.3: Substitution of fossil resources

Throughout bioeconomic value creation processes, carbon stored in biomass is either sequestered over the long term (e.g. in buildings) or re-emitted into the atmosphere at the end of the life cycle (e.g. combustion of biogas). As a result, bio-based products can be carbon neutral or even act as carbon sinks. In the context of the defossilisation of the economy, fossil-based value creation systems are increasingly being substituted by renewable, carbon-neutral alternatives. The bioeconomy is expected to play a key role in this transition. The climate impact of bioeconomic value creation systems is particularly significant when they replace fossil-based systems. The assessment of this indicator should take the following information into account:

- Substitution of fossil resources: Do the value creation strands provide alternatives to fossil-based systems? Which fossil resources are being replaced?

Indicator 2.4: Promotion of biodiversity and ecological resilience

The cultivation of biomass for bioeconomic value creation systems directly influences the state of surrounding ecosystems. Even small adjustments within bioeconomic value creation systems can have significant impacts on affected ecosystems. The following questions primarily refer to agricultural ecosystems.

The assessment of this indicator should take the following information into account:

- Land use requirements: How do value creation strands differ in terms of land use intensity? Which types of land are used?
- Soil health: How do value creation strands affect soil health, and what differences can be observed? To what extent can negative impacts be mitigated through appropriate management practices?
- Diversity of the raw material base: How does the diversity of inputs vary between value creation strands?
- Biodiversity enhancement: What differences exist in the contribution of value creation strands to biodiversity? Through which mechanisms or measures is biodiversity promoted?

6.3 Economic sustainability

The indicators for economic sustainability assess the extent to which individual value creation strands contribute to the long-term competitiveness and adaptive capacity of bioeconomic business models. For a more detailed analysis of individual business models, the [sustainability assessment for business models in bioeconomy regions](#), also developed within the NaGeWe-Bio project, may be applied as a complementary tool.

Structurally, the indicators for economic sustainability closely correspond to the questions on the economic impacts of the value creation system defined in [Step 4.2](#). These questions are therefore of particular relevance for the assessment.

Indicator 3.1: Demand and market performance

The long-term economic success of bioeconomic value creation systems depends on stable demand and reliable market opportunities. Differences in market structures and demand dynamics can fundamentally influence the economic prospects of individual value creation strands. The analysis of demand and market performance therefore enables an assessment of market opportunities and development potential across different strands.

The assessment of this indicator should take the following information into account:

- Market position: What differences exist in terms of market share and positioning compared to competing products and processes? Are structural changes expected in the future?
- Sales markets: To what extent do value creation strands differ in their dependence on regional, national, or international markets?
- Sales risks: What differences exist between value creation strands regarding risks to market performance, such as price volatility, competing products, or fluctuations in demand?
- Customer structure: How do value creation strands differ in terms of the diversity of their target groups and customer bases?

Indicator 3.2: Investment attractiveness

The establishment and further development of bioeconomic value creation systems depend on the availability of investment capital. Differences in investment requirements, return expectations, and risk profiles can significantly influence the development prospects of individual value creation strands. Investment attractiveness therefore provides important insights into the long-term growth potential of different strands.

The assessment of this indicator should take the following information into account:

- Investment requirements: To what extent do value creation strands differ in their capital requirements?
- Volume of public and private investment: What differences exist between value creation strands in terms of the volume of public and private investment to date? Which strands particularly benefit from public support or policy-driven risk mitigation instruments?

- Attractiveness and risk for investors and funding bodies: What differences exist in the attractiveness of value creation strands for private investors and public funding agencies?

Indicator 3.3: Innovativeness

Innovation plays a key role in ensuring the long-term competitiveness and adaptive capacity of bioeconomic value creation systems. Differences in innovation capacity may determine whether individual value creation strands are able to exploit new market opportunities more quickly or develop more efficient production processes.

The assessment of this indicator should take the following information into account:

- Knowledge transfer: What differences exist between value creation strands and their networks regarding the exchange of knowledge between science, industry, and other actors? To what extent do strands differ in the identification and application of new technologies and research outcomes?
- R&D cooperation: What differences exist in the number and intensity of research and development collaborations? Which value creation strands exhibit particularly high innovation dynamics, and what factors drive this?

6.4 Regional structural change

The indicators for the cross-cutting theme of regional structural change assess the extent to which individual value creation strands utilise regional potentials to support the long-term development, expansion, and scaling of bioeconomic value creation structures, or whether they depend on resources and competencies located in other regions. The analysis particularly focuses on the social implications of regional structural change.

Indicator 4.1: Location factors of the bioeconomy region

The development of bioeconomic value creation systems is influenced by location-specific framework conditions and regional characteristics. Regional potentials can either enable or constrain the availability of resources, cooperation between actors, and the economic development of individual value creation strands. This perspective on regional location factors therefore allows an assessment of the extent to which individual strands benefit from regional conditions.

The assessment of this indicator should take the following information into account:

- Societal potentials: To what extent do value creation strands utilise existing regional education, research, and training institutions, or contribute to their development? Are there differences regarding the societal acceptance of the respective value creation strands?
- Ecological potentials: To what extent do value creation strands utilise the ecological conditions of the region for biomass sourcing?
- Economic-structural potentials: To what extent do value creation strands differ in their integration into existing regional economic structures? Which strands benefit particularly from existing regional clusters and networks?

Indicator 4.2: Decentralisation of value creation system stages

The spatial organisation of value creation stages influences regional value creation, transport requirements, and the participation of local actors. Decentralised structures can contribute to relocating economic activity to structurally weaker and agriculturally characterised regions. The central question is whether the processing and further transformation of biomass takes place directly in the region of production.

The assessment of this indicator should take the following information into account:

- Degree of decentralisation: What differences exist between value creation strands regarding the spatial distribution of their value creation stages? Is value creation predominantly located within the region or outside the study region?
- Primary processing of biomass: What differences exist between value creation strands regarding the location of primary biomass processing? Does the first processing step or pre-treatment take place within the study region?

Indicator 4.3: Sustainable structural change

The expansion of bioeconomic value creation systems is driven by the objective of fostering a sustainable transformation of regional economic structures through structural change. This process can influence regional employment opportunities, societal participation, and the overall quality of life. The following analysis therefore focuses on the potential of structural change and its social implications.

The assessment of this indicator should take the following information into account:

- Potential for sustainable structural change: What differences exist between value creation strands regarding the creation of new economic perspectives in the region? Which strands exhibit the greatest potential to support a sustainable transformation of the regional economy?
- Social implications of structural change: Which value creation strands show the greatest potential to mitigate social challenges associated with structural change and to enable broader societal participation in regional development opportunities?

6.5 Governance

The indicators for the cross-cutting theme of governance examine the mechanisms and practices through which decisions are made along the individual value creation pathways. The focus is on power relations within value creation systems and on the participation of different societal groups in decision-making processes.

Indicator 5.1: Power and dependency structures

The configuration of bioeconomic value creation systems is strongly shaped by existing power and dependency relations between the involved actors. These structures influence who makes key decisions, which actors drive innovation processes, and which groups tend to facilitate or hinder change. The spatial distribution of power structures also significantly affects the organisation of

value creation systems and, consequently, their contribution to sustainable regional structural change. Analysing power and dependency structures therefore enables the identification of key actors for steering transformation processes.

The assessment of this indicator should take the following information into account:

- Power relations: To what extent do value creation pathways differ in terms of the dependence of smaller actors on large companies or central processing stages? Is decision-making power concentrated among a few actors or more widely distributed?
- Drivers and barriers to transformation: What differences exist between value creation pathways in terms of the actors and framework conditions that promote or hinder transformation processes?

Indicator 5.2: Participation in decision-making processes

Participation in decision-making processes influences the legitimacy, acceptance, and further development of bioeconomic value creation systems. It determines the extent to which different stakeholder groups are involved in decision-making structures and the extent to which relevant information is accessible and transparent. Broad and inclusive participation can help align value creation processes more closely with societal needs and thereby contribute to addressing societal challenges.

The assessment of this indicator should take the following information into account:

- Transparency of decision-making processes: To what extent do value creation pathways differ in terms of the accessibility of information related to decision-making processes?
- Participation in decision-making processes: What differences exist between value creation pathways in terms of formal and informal regional and supra-regional participation opportunities in decision-making processes? Which stakeholder groups are involved?

6.6 Resilience

The indicators for the cross-cutting theme of resilience examine the extent to which individual value creation pathways are able to either maintain their core functions under changing conditions, adapt to new circumstances, or initiate transformative processes. In some cases, maintaining resilience requires substantial resource inputs, meaning that resilient systems are not necessarily more sustainable in ecological or economic terms. Therefore, it is particularly relevant to assess potential trade-offs between resilience and sustainability objectives. In particular, a strong persistence of actors and structures may lead to long-term path dependencies that constrain system flexibility and transformability.

Indicator 6.1: Persistence of value creation

Persistence of value creation describes the ability of bioeconomic value creation systems to maintain their core functions and value-generating processes despite internal or external disruptions. It includes both resistance to short-term shocks and long-term stability under changing framework conditions. Differences in persistence provide insights into how robust individual value

creation pathways are in the face of uncertainty and crises. High persistence can ensure stability, but may also limit adaptation and transformation due to path dependencies.

The assessment of this indicator should take the following information into account:

- Short-term persistence: What differences exist between value creation pathways in their ability to cope with short-term disruptions and crises? In the event of supply chain or production failures, are there reserves or alternative sourcing options available?
- Long-term persistence: To what extent do value creation pathways differ in their robustness against long-term changes in markets, resource availability, or policy frameworks? Do these dynamics lead to structural constraints or path dependencies?

Indicator 6.2: Adaptive capacity

Adaptive capacity describes the ability of bioeconomic value creation systems to respond to changing conditions and adjust existing structures accordingly. It includes both short-term reactions to acute disruptions and gradual adjustments to long-term developments. Differences in adaptive capacity indicate how flexibly individual value creation pathways can respond to change.

The assessment of this indicator should take the following information into account:

- Short-term adaptive capacity: What differences exist between value creation pathways in their ability to respond quickly to disruptions or changing framework conditions? To what extent can existing processes, products, or business models be adjusted in the short term?
- Long-term adaptive capacity: What differences exist between value creation pathways in their ability to adapt to long-term technological, ecological, or societal changes? To what extent do existing structures enable continuous development and adaptation?

Indicator 6.3: Transformative capacity

Transformative capacity describes the ability of bioeconomic value creation systems to implement fundamental changes in their structures, processes, and value creation logics. Unlike adaptation, it does not refer to the optimisation of existing structures, but to the emergence of new development pathways. Differences in transformative capacity indicate the extent to which individual value creation pathways can contribute to the long-term renewal and evolution of the bioeconomy.

The assessment of this indicator should take the following information into account:

- Short-term transformative capacity: What differences exist regarding the availability of resources and room for manoeuvre for transformative experiments and pilot projects?
- Long-term transformative capacity: What differences exist between value creation pathways in their ability to establish new value creation structures and development trajectories over time?

Summary of activities for completing Step 6:

- Synthesis: Integration of information from different research questions, methods, and data sources using the indicator set
- Condensation: Aggregation of information at indicator level
- Assessment: Evaluation of sustainability for each indicator on the rating scale by multiple assessors
- Derivation of key findings: Summary of the current sustainability state of the value creation system and identification of recommendations for sustainable regional structural change

Step 7: Workshop for validation and refinement of results

After completing the data collection and evaluation of the value creation assessment, each sustainability indicator is associated with a corresponding assessment, key findings, and initial recommendations for action. These results should be discussed, validated, and, if necessary, complemented in a workshop together with actors from the value creation system and relevant experts. The objective is to contextualise and further develop the results through additional perspectives and practical knowledge.

The selection of participants is based on the stakeholder mapping from the initial survey ([step 3](#)) and the data collection phase. It should include actors from different value creation pathways and stages, as well as relevant experts from academia and public administration. The aim is to ensure a diverse group representing a wide range of perspectives and interests.

At the beginning of the workshop, the analysed value creation system should be presented based on the results of the stakeholder survey and the system delineation defined in [Module 1](#). The composition and characteristics of the value creation system should then be discussed with participants and, if necessary, refined or expanded. Particular attention should be given to the development goals for sustainable regional structural change established in [Step 2.6](#).

The main part of the workshop focuses on the results of the sustainability assessment. First, the indicator-based evaluation results, key findings, and recommendations for action should be presented. These results should then be discussed in terms of their plausibility, completeness, and relevance. Any additions, corrections, or new recommendations should be documented and incorporated into the final assessment.

All discussions and outcomes of the workshop should be continuously documented. It is recommended to prepare a structured protocol capturing key comments, additions, critiques, and recommendations. In addition, jointly developed sketches, diagrams, or boards can be used to visualise interdependencies, challenges, and development pathways within the value creation system and to ensure they are retained for further analysis.

Summary of activities for completing Step 7:

- Selection and invitation of participants
- Discussion of the composition and characteristics of the value creation system
- Discussion of the sustainability assessment results
- Documentation of the workshop (minutes, sketches, visualisations, boards)

Step 8: Evaluation of the workshop phase

The contributions collected during the workshop should be systematically assigned to the respective indicators of the sustainability framework. Both new substantive aspects and confirming or diverging assessments from the discussion need to be taken into account. The objective is to structure the workshop input clearly along the existing indicator system.

The workshop contributions assigned to the indicators should then be re-condensed together with the results from the previous data collection. Repeated information should be reduced, and key statements for each indicator should be derived in order to produce a concise description of sustainability performance. Based on these condensed findings, the existing evaluation results, key messages, and recommendations for action should be reviewed and, where necessary, adjusted, supplemented, or reformulated. In particular, practice-oriented insights and additional perspectives from the workshop should be integrated.

In general, all changes resulting from the workshop phase should be documented in a transparent and traceable manner. This includes, in particular, content additions, modifications of assessments, and newly developed or refined recommendations for action. The aim is to ensure a clear representation of how the results evolved through the workshop process, which should subsequently be communicated back to the workshop participants.

Summary of activities for completing Step 8:

- Assignment of workshop inputs to the indicator system
- Re-condensation and revision of results in the form of key findings, adjusted assessments, and recommendations for action
- Documentation of the development of results through the workshop process

Module 4: Synthesis and transfer of results

Step 9: Consolidation and presentation of results

A comprehensive description of the analysed value creation system should first be developed. This requires integrating insights from the stakeholder surveys, data collection, and workshops. The sketches and visualisations developed during the workshop should be further refined with the aim of producing a complete and coherent representation of actors, value creation pathways and stages, as well as relevant relationships within the system.

Subsequently, the results of the sustainability assessment should be consolidated again and structured along the considered sustainability dimensions. They should be presented in the form of recommendations for action and impact relationships. Key findings from individual indicators should be synthesised and assigned to the respective value creation pathways and stages. In this way, driving forces, constraints, trade-offs, and synergies within the value creation system can be made visible. In addition to the results of the data collection, the perspectives and assessments added during the workshop should also be taken into account.

The identified recommendations for action should be combined into overarching regional transformation pathways or alternative scenarios for regional transformation. These pathways integrate a holistic view of sustainability with the further development of selected value creation pathways. It should be identified which measures can contribute to improvements in ecological, economic, and social sustainability, without neglecting the cross-cutting themes. At the same time, it should be analysed which actors have the necessary influence to implement the respective recommendations. This makes it possible to identify responsibilities, cooperation needs, and entry points for sustainable regional structural change and to link them with decision-makers.

The alternative regional transformation pathways thus provide a basis for linking sustainability objectives, recommendations for action, and relevant actor groups. They create orientation for future development processes and support the strategic design of sustainable structural change within the value creation system and the region.

Summary of activities for completing Step 9:

- Consolidated description and representation of the analysed value creation system
- Linking the sustainability assessment with the value creation system
- Derivation of alternative regional transformation pathways
- Identification of actors and networks for implementing recommendations for action

Step 10: Transfer of results and establishment of routines

The results of the sustainability assessment should be made available to all participants of the stakeholder survey, data collection, and workshops. In addition, targeted communication of key findings, core messages, and recommendations for action within relevant networks and alliances of the value creation system is recommended. This increases transparency, supports the uptake of results, and strengthens exchange among actors. Recommendations should be specifically

communicated to those actors who are essential for their implementation. The aim is to translate identified transformation potentials into concrete measures and decision-making processes.

The stakeholder survey should be continuously updated and expanded in order to reflect changes within the value creation system and to integrate new actors into the network. This ensures the long-term maintenance of the database and enhances its usability for future analyses and assessments.

The workshops conducted as part of the sustainability assessment should be established as a recurring exchange format within the network. They can be used to reflect on progress in implementing recommendations, identify new challenges, and jointly develop solutions. Regular implementation supports continuous development of the value creation system and fosters cooperation between involved actors.

Summary of activities for completing Step 10:

- Transfer of results into the value creation system
- Communication of recommendations to relevant decision-makers
- Continuous updating of the stakeholder survey for new actors
- Establishment of a recurring exchange format

Concluding remarks

The sustainable development of regional bioeconomic value creation systems requires a comprehensive understanding of their ecological, economic, and social impacts in relation to the identified cross-cutting themes, particularly the actual impacts of the locally embedded or realistically localisable parts of the value creation system.

This guideline provides a structured approach to identifying the composition of value creation systems and their actors, systematically collecting information, assessing sustainability aspects, and deriving recommendations for sustainable regional structural change. It serves as a conceptual framework that can be flexibly combined with a wide range of methods.

The guideline is intended as an orientation and can be adapted to the specific requirements, conditions, and objectives of different regions and value creation systems. It is therefore not necessary to follow the procedure in every region in a rigid or fully standardised way. In particular, exchange with experts and local stakeholders during preparatory consultations can help tailor the approach to regional needs.

Sustainability assessment should not be understood as a one-off exercise, but as a long-term process characterised by continuous exchange and iterative development of bioeconomic regions. The integration of diverse perspectives and regular reflection on developments and challenges can help design transformation processes in an integrated and inclusive way and strengthen the long-term sustainability of bioeconomic value creation systems.

This guideline focuses on assessing regional sustainability impacts of the bioeconomy and the resulting regional structural change. However, this does not imply that global implications of the bioeconomic transformation should be neglected—for example in relation to climate change, biodiversity loss, or ecosystem degradation (particularly soils and hydrological systems). A sustainable bioeconomic transformation can only be achieved through sustainable development across all spatial scales.

Glossary

Analytical focus refers to a research question defined by the objectives of the users and determines the direction of the sustainability assessment. Since this is a sustainability check for bioeconomic value creation systems, the focus must relate to a target variable that is part of these value creation systems.

Bioeconomy describes a cross-sector economic concept based on biogenic resources (agricultural, forestry and marine products), biological processes, and biological knowledge. It includes all actors, relations, and processes involved in the production, processing, and further valorisation of biogenic resources as well as related services and research and development activities. In a narrower sense, the bioeconomy aims to increase regional value creation and the sustainability of the economy through the application of knowledge-based and innovative processes (definition of the Plant3 cluster).

Scope of Development consists of development pathways that are delineated by the analytical focus.

Governance describes the mechanisms and practices through which decisions are made and coordinated within networks, companies, other organizations, and across different levels of government. Understanding these mechanisms is essential for identifying how the interests of diverse stakeholder groups are represented in decision-making processes. Examining the governance of value creation systems helps to reveal underlying power structures and identify key actors who either drive or hinder regional structural change and the transition towards a bioeconomy.

Ecological sustainability describes the contribution of bioeconomic value creation systems to the long-term conservation and restoration of ecosystems, as well as the use of biological resources in accordance with planetary boundaries.

Economic sustainability describes the contribution of bioeconomic value creation systems to the long-term competitiveness and adaptability of the associated business models and economic systems.

Regional structural change refers to the long-term transformation of a region's economic structures and social conditions. It may be driven by factors such as crises, technological innovation, demographic change, or political objectives. These developments alter the significance of individual industries and lead to changes in employment structures. In this guideline, regional structural change encompasses the activities and factors that support the establishment, further development, and scaling of bioeconomy value creation structures within a region. Particular attention is given to the social implications of regional structural change arising from the spatial and organizational distribution of the creation, appropriation, and allocation of economic value generated by the bioeconomy.

Resilience describes the capacity of systems to maintain their current state, adapt to changing conditions, or initiate transformative processes when confronted with disturbances such as crises or long-term trends. In the context of regional structural change, the key question is

whether these transformations enhance the resilience of regional value creation structures. However, maintaining resilience may require substantial resource inputs, meaning that more resilient systems are not necessarily more sustainable. Therefore, it is particularly important to examine potential trade-offs between resilience and sustainability objectives.

Raw material base of the value creation system consists of various renewable or naturally replenishing organic raw materials and forms the material foundation of the value creation process.

Social sustainability describes the contribution of bioeconomic value creation systems to the long-term preservation and improvement of quality of life, as well as the inclusion of regional and societal actors in decision-making processes.

Value creation stages describe the different phases of the value creation process, from biomass cultivation to final products.

Value creation systems are networks consisting of companies, organisations, and other economic actors in which products and services are created through cooperation and division of labour. In the context of the bioeconomy, these networks include activities related to the cultivation of biobased raw materials and subsequent processing steps through to final products and their disposal or recycling. This explicitly includes supporting services, research and development activities, as well as interactions with governmental, political, and civil society actors.

Target variable is a component of the value creation system under study, such as a specific type of biomass (e.g. winter wheat), a group of biomass types (e.g. cereals), a specific by-product (e.g. brewer's spent grain, wood chips from sawmills), a group of by-products (e.g. brewery by-products, sawmill residues), a specific end product (e.g. industrial sugar, blown-in insulation), a group of end products (e.g. sweeteners, insulation materials), a specific value creation step (e.g. pulp mills, biogas plants, cultivation of a specific biomass), or a specific process or technology (e.g. biorefinery, fermentation). The target variable is necessary for defining the analytical focus.

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