Sustainability indicators for bioenergy and the broader bioeconomy

Technical Paper prepared for the Global Bioenergy Partnership (GBEP) Task Force on Sustainability and IEA Bioenergy Task 45

Draft for discussion with GBEP

prepared by

Uwe R. Fritsche, Scientific Director, IINAS

Prepared with funding from the German Ministry for Food and Agriculture (BMEL) via FNR, and IEA Bioenergy Task 45

Darmstadt, November 2022

Table of Content

List of Figures

Acronyms

EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBEP	Global Bioenergy Partnership
GHG	greenhouse gas(es)
GSI	GBEP sustainability indicators
IEA	International Energy Agency
IEA Bio	International Energy Agency Bioenergy Technology Collaboration Program
ISBWG	International Sustainable Bioeconomy Working Group (of FAO)
NGO	Environmental Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
RED	Renewable Energy Directive (of the EU)
SDG	Sustainable Development Goal(s)
UN	United Nations

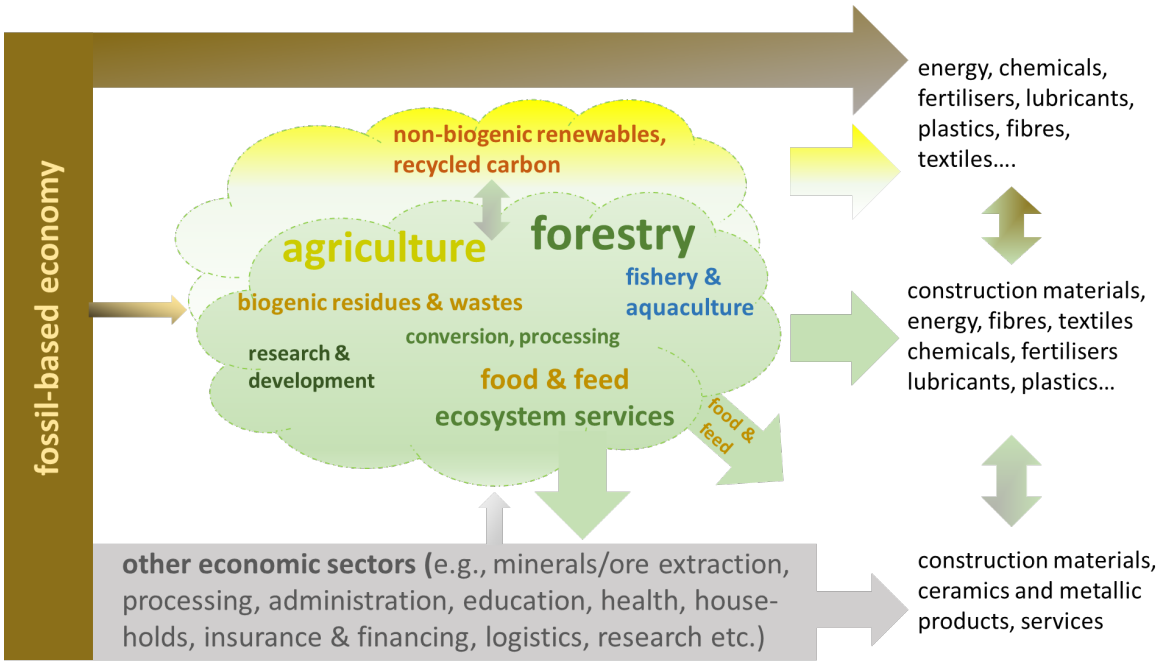
1. Introduction and Overview

The call for a global transformation towards sustainable development and the respective Sustainable Development Goals (SDG) were agreed upon in the UN Agenda 2030 in September 2015 (UN 2015). Bioenergy and the broader bioeconomy are considered **as means** with significant opportunities for a more sustainable use of renewable resources, and for reducing fossil fuel use. The **bioeconomy** – and bioenergy as part of it – provides key opportunities to achieving the SDGs, and to contribute to a "green" recovery after the COVID-19 pandemic. For this, though, it is crucial to assuring the sustainability of the bioeconomy.

This paper[1] provides an overview of the status and recent developments of **indicators** for the sustainability of bioenergy and bioeconomy and derives some recommendations for further work of the Sustainability Task of the Global Bioenergy Partnership[2].

In the following, bioeconomy is understood[3] as the "(…) production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products as well as bio-energy" (EC 2018). A sustainable bioeconomy is part of the renewable segment of the circular economy (Figure 1).

Figure 1 Scope and system boundaries of the bioeconomy



Source: Fritsche et al. (2020); yellow- and green-shaded clouds represent renewable economy, green-shaded cloud represents bioeconomy (as part of renewable economy); right side represents outputs to society (products and services); arrows = outputs; double-arrows = substitution potentials

The bioeconomy - and bioenergy as part of it - is related to several SDG (see Figure 2) and can help to achieve these goals (Blair et al. 2021; Calicioglu & Bogdanski 2021; Heimann 2019).

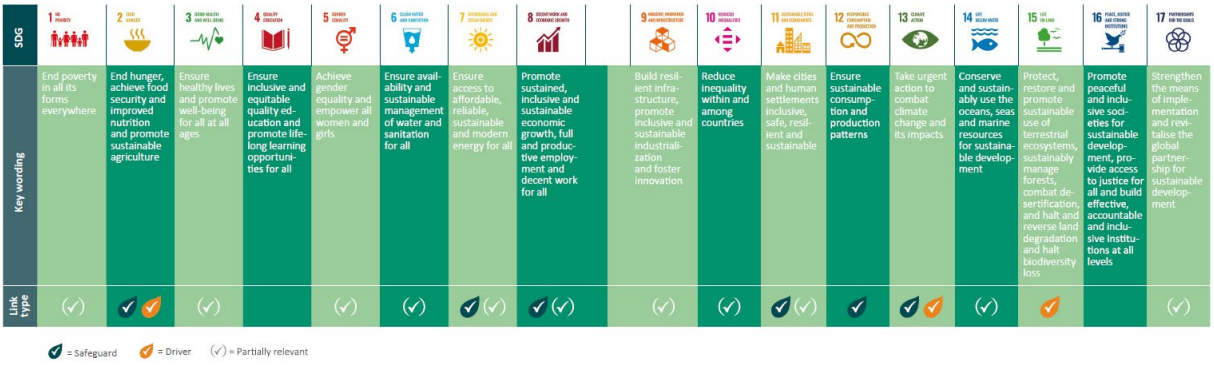
---

1 A previous paper discussed **governance approaches** for the sustainability of the bioeconomy (Fritsche et al. 2021).

2 www.globalbioenergy.org

3 There are many different definitions of what the bioeconomy is – e.g., the OECD and the US refer mostly to "new" economic activities based on biotechnology.

Figure 2 Links between bioenergy and the SDGs



Source: GBEP (2020) based on analysis in Fritsche et al. (2018)

As Iriarte & Fritsche (2019) showed for Latin American countries, the GSI can not only linked to the SDG but also contribute to measuring several of the SDG indicators.

In the following, the issue of "relevant" indicators is discussed.

As sustainability indicators were first developed for bioenergy, the discussion starts with those (Section 2) and is then expanded to sustainability indicators for the broader bioeconomy (Section 3), and the final Section 4 provides some recommendations on the future selection and use of sustainability indicators with a view to practicality.

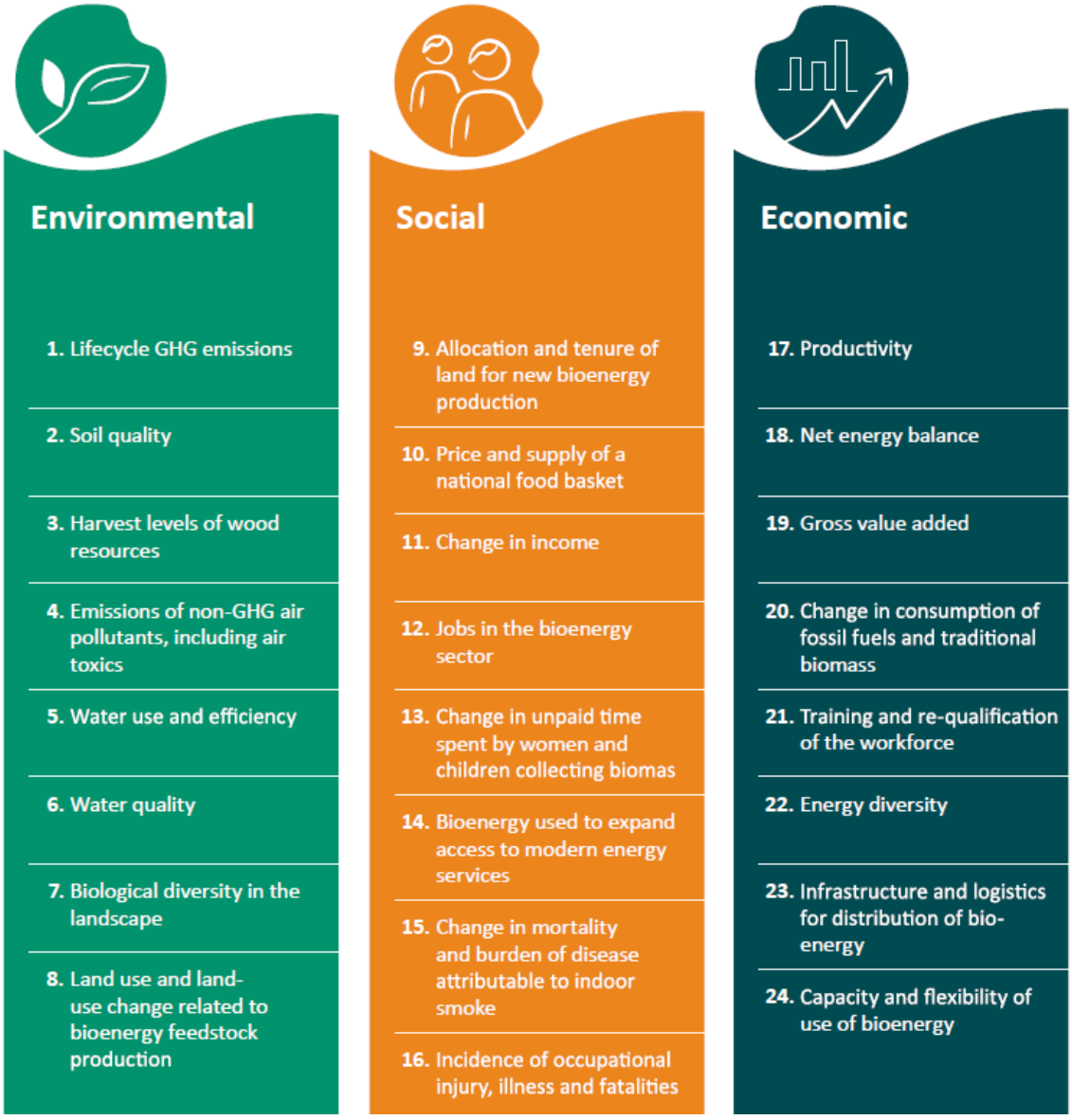
2. Indicators for sustainable bioenergy

Sustainability governance requires to establish **measurements** of sustainability, i.e., to operationalize the concept through evidence-based criteria and respective indicators.

Already in 2011, the Global Bioenergy Partnership (GBEP) established, after more than two years of intense discussions, a set of indicators to measure the sustainability of bioenergy on the national level (GBEP 2011) that has been applied in several countries (GBEP 2020; IINAS 2020).

The result of the work is the set of 24 GBEP sustainability indicators (GSI) for bioenergy (see Figure 3) which provide policy-makers and stakeholders with a tool to guide any analysis of bioenergy undertaken at the domestic level.

Figure 3 The GBEP Sustainability Indicators for Bioenergy



Source: GBEP (2020) based on GBEP (2011)

In 2015, the International Organization for Standardization published "Sustainability criteria for bioenergy" as ISO 13065 (ISO 2015) which was recently reviewed and confirmed[4]. This ISO standard is fully compatible with the GSI.

Various other proposals for sustainability criteria and indicators for bioenergy have been elaborated[5]. As Fritsche (2019) showed, the state of the art is still captured by the GSI.

3. Indicators for a sustainable bioeconomy

Given the close interaction of agriculture, forestry, food and the materials and energy sectors it seems appropriate to consider **all biomass** under the **bioeconomy** concept, i.e., to assess the sustainability not only of bioenergy uses, but of **all uses** of biomass (see Figure 1). The reasoning behind this consideration is that

"*Binding sustainability criteria established for the bioenergy sector but not for other sectors using the same feedstocks may provoke leakages and trade-offs between sectors as well as debates on a meaningful sustainability performance*" (Mai-Moulin et al. 2021: 13).

With growing policy interest in the bioeconomy (see e.g., IACGB 2020), the need to ensure its sustainability is rising in parallel (see e.g., Kircher 2022; OECD 2021a+b). A broad variety of respective criteria and indicators for its sustainability has been developed and proposed, often building on the GBEP indicators for bioenergy[6].

The EU S2Biom project proposed "basic" and "advanced" sets of sustainability indicators for the bioeconomy which reflect "minimal requirements", and then add further indicator options to cover broader sustainability issues of the bioeconomy (Iriarte et al. 2017), as shown in Figure 4.

Figure 4 The S2Biom Sustainability Indicators for the Bioeconomy

Theme	Criterion	Indicator		Level of ambition							
				Basic				Advanced			
		#	Indicator	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive
Environmental	1. Resource use	1.1	Land use efficiency			✓		✓			
		1.2	Secondary resource efficiency			✓		✓			
		1.3	Energy efficiency		✓			✓			
		1.4	Functionality (Output service quality)						✓	✓	

[4] See https://www.iso.org/standard/52528.html

[5] See for recent work e.g., Cucuzzella, Welfle & Röder (2020); FAO (2017); Koper et al. (2021); Mai-Moulin (2020); Mai-Moulin et al. (2021); Szarka et al. (2020).

[6] See e.g., Bracco et al. (2019); Egenolf et al. (2018); Egenolf & Bringezu (2019); Escobar & Britz (2021); FAO (2019a+b, 2021); Fritsche & Rösch (2020); Golaszewski et al. (2020); Hennenberg et al. (2019); Holden et al. (2022); INRO (2013); Iriarte & Fritsche (2014); Iriarte et al. (2017); Kardung et al. (2021); Kooduvalli et al. (2019); Ladu et al. (2018); Möller et al. (2020); Nel et al. (2022); OECD (2013, 2021a+b); Pelkmans et al. (2016); STAR-ProBio (2018); van Schoubroeck et al. (2018); Zeug, Bezema & Thrän (2020); Zhu et al. (2019).

Theme	Criterion	Indicator		Level of ambition							
				Basic				Advanced			
		#	Indicator	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive
	2. Climate change	2.1	Life cycle-based CO_2eq including direct land use change	✓				✓			
		2.2	Other GHG emissions		✓	✓		✓			
	3. Biodiversity	3.1	Protected areas and land with significant biodiversity values	✓				✓			
		3.2	Biodiversity conservation and management			✓		✓			
	4. Soil	4.1	Erosion			✓		✓			
		4.2	Soil Organic Carbon			✓		✓			
		4.3	Soil nutrient balance			✓		✓			
	5. Water	5.1	Water availability and regional water stress		✓			✓		✓	
		5.2	Water use efficiency						✓	✓	
		5.3	Water quality		✓				✓	✓	
	6. Air	6.1	SO_2 equivalents		✓	✓		✓			
		6.2	PM_{10}		✓	✓		✓			
Social	7. Participation and transparency	7.1	Effective participatory processes								✓
		7.2	Information transparency								✓
	8. Land tenure	8.1	Land tenure assurance			✓		✓			
	9. Employment and labour rights	9.1	Full direct jobs equivalents along the full value chain		✓	✓			✓	✓	
		9.2	Full direct jobs equivalent in the biomass		✓	✓			✓	✓	

Theme	Criterion	Indicator		Level of ambition							
				Basic				Advanced			
		#	Indicator	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive	Minimum requirement	Comparative (non-renewable reference)	Comparative (biomass reference)	Descriptive
			consuming region (or country)								
		9.3	Human and Labour Rights	✓				✓			
		9.4	Occupational safety and health for workers	✓				✓			
	10. Health risks	10.1	Risks to public health								✓
	11.Food, fuelwood and other products	11.1	Food, fuelwood and other products supply security			✓		✓			
Economic	**12. Production costs**	12.1	Current levelised life-cycle cost		✓	✓			✓	✓	
		12.2	Future levelised life-cycle costs						✓	✓	

Source: Iriarte et al. (2017), building on Iriarte & Fritsche (2014)

The indicator list in Figure 4 is surely not "complete", as others (see e.g., Footnote 6) have added more specific items: For example, the FAO identified more than 100 indicators for the sustainability of the bioeconomy (Bracco et al. 2019). Yet, this extensive list has a rather broad overlap to the S2Biom list, as analysis in ifeu (2022) has shown, and the FAO list has massive data requirements.

The "minimum requirement" indicators from S2Biom in the basic set are a significant reduction of the overall number compared to other work indicated in Footnote 6, and provide the base for the consideration of the "downsizing" approach discussed in Section 5.1.

It should be noted that in parallel to work on the analysis and assessment of the bioeconomy sustainability, the more general concept for governing the sustainability of the bioeconomy has been elaborated: **monitoring**, i.e., the development of the bioeconomy sustainability over time.

ifeu (2022) provides a synopsis of respective work, and concludes that

"(…) the GSI prove to be still useful baseline to frame all the indicators under study, since

- *they capture most of the indicator proposed by the analysed studies being much more recent and focused on bioeconomy*
- *only few new themes need to be added to complete the picture and*
- *most of these added themes represent further specifications or variations of existing GSI"* (ifeu 2022: 22).

4. Perspective: Sustainability indicators for bioenergy and the bioeconomy

The discussion in the previous sections clearly indicate the need to consider sustainability indicators **for both** bioenergy, and the broader bioeconomy. This need could be addressed through three different options:

- **Downsizing** to radically reduce the number of indicators to the absolute minimum.
- **Improving** to reflect application experiences for improving the applicability and data availability (especially "proxy" indicators).
- **Dashboard** which opens the indicator scope widely and relies on applicant/participant choices of relevant indicators.

4.1. "Downsizing"

This rather **radical** approach reflects experiences from practical applications of the GBEP indicators (see ifeu 2022) and simplifies the metrics to the minimum requirements for the sustainability of bioenergy and the bioeconomy. Building on the S2Biom "minimum requirements" and reflecting available data, the list would be comprised of the following indicators:

- GHG emissions and biodiversity protection
- Employment and secure land tenure
- Gross Domestic Product (GDP)

The GHG emission indicator should include impacts from direct land use changes (if any) and biodiversity protection should be expressed as "no-go" areas for biomass extraction or collection and should include clarification on using genetically modified organisms (GMO)[7]. The multiple other aspects (e.g., air pollution, soil erosion, water stress) are not considered as irrelevant, but hard to quantify and subject to local and regional circumstances.

The employment (number of jobs) and the "secure land tenure" indicator stand for the social pillar and should reflect the number of direct jobs related to the bioeconomy, while the land tenure indicator should be covered by a proxy: the adherence of country (or region) to the VGGT[8].

The GDP indicator should be available in all countries – yet the specific contribution of the bioeconomy might be hard to isolate. In this case, the economic turnover (from investments in and operation of bioeconomy facilities and sales of respective products/services) could be used as a proxy.

For all five "basic" indicators, though, the issue of territorial scope should be clarified, i.e., if the indicators should apply only for the national (or sub-national) territory or should include impacts from imported biomass as well. The latter is relevant especially for the GHG emissions, as climate change is a **global** concern.

4.2. "Improving"

Instead of reducing the number of indicators, the list could be **improved** to reflect experiences from indicator applications, and the additional requirements for covering some of the specific bioeconomy issues.

---

7 GMOs are typically not used in bioenergy value chains (except in some countries for corn and soy) but can play some role in the broader bioeconomy.

8 Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security, endorsed by the Committee on World Food Security on 11 May 2012, see https://www.fao.org/docrep/016/i2801e/i2801e.pdf

As ifeu (2022) has shown, most sustainability indicators discussed or proposed in the literature, or used by various actors such as banks, governments, or within sustainability standards are either directly derived from the GSI, or small variations of those. The most relevant exception is the use of GMOs which should be added either under biodiversity protection (as in the "downsizing" approach) or under indicators covering public or occupational health.

On the other hand, several of the GSI seem to be either impractical due to data restrictions, or not so much relevant for the broader discussion of the bioeconomy:

GSI 13 (unpaid time spent by woman and children collecting biomass), GSI 15 (Change in mortality and burden of disease attributable to indoor smoke) as well as GSI 18 (Net energy balance), GSI 21 (Training and re-qualification of the workforce) and GSI 23 (Infrastructure and logistics for distribution of bioenergy) may be removed from the GSI list. This would allow to add a few more indicators relevant for bioenergy and the broader bioeconomy such as e.g., use of organic waste and food losses, or gender equality.

Any change in the GSI would be subject to approval of the GBEP partners, though.

4.3. "Dashboard"

Following-up on the FAO's broad proposal for bioeconomy sustainability indicators (Bracco et al. 2019) and the work of the EU's Bioeconomy Knowledge Centre on monitoring of the EU bioeconomy[9], a general "dashboard" of indicators is possible with provides the broadest thematic and territorial view on available indicators and respective data.

Under this approach, users would select the indicators of interest, and be provided with respective data – subject to availability.

The ongoing work on the EU level (and its Member States) and related work in the US indicate that this approach seems applicable at least for some of the GBEP member countries – yet, the data requirements and overall work on a **global** "dashboard" appears to be beyond the resources of the GBEP.

Thus, the recommendation to GBEP to consider either the "downsizing" or "improving" approach for its future work in the Task Force on Sustainability.

.

[9] See https://knowledge4policy.ec.europa.eu/bioeconomy/monitoring_en and respective reports, especially Giuntoli et al. (2020); JRC (2020a+b); Kilsedar et al. (2021); Melim-Mcleod et al. (2022); Ronzon et al. (2020)

References

Blair, Jean et al. (2021) Contribution of Biomass Supply Chains for Bioenergy to Sustainable Development Goals. Land 10 (2): 181 https://doi.org/10.3390/land10020181

Bracco, Stefania et al. (2019) Indicators to monitor and evaluate the sustainability of bioeconomy development. Overview and a Proposed Way Forward. Food and Agriculture Organization of the United Nations Working Paper 77. Rome http://www.fao.org/3/ca6048en/ca6048en.pdf

Bringezu, Stefan et al. (2021) Environmental and socioeconomic footprints of the German bioeconomy. Nature Sustainability https://doi.org/10.1038/s41893-021-00725-3

Calicioglu, Özgül & Bogdanski, Anne (2021) Linking the bioeconomy to the 2030 sustainable development agenda: Can SDG indicators be used to monitor progress towards a sustainable bioeconomy? New Biotechnology 61: 40-49 https://doi.org/10.1016/j.nbt.2020.10.010

Cucuzzella, Costanza; Welfle, Andrew & Röder, Mirjam (2020) Harmonising greenhouse gas and sustainability criteria for low-carbon transport fuels, bioenergy and other bio-based sectors. Supergen Bioenergy Hub Report No. 04/2020 https://www.supergen-bioenergy.net/wp-content/uploads/2020/11/Harmonising-sustainability-standards-report.pdf

D'Amato, D. & Korhonen, J. (2021) Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. Ecological Economics 188: 107143 https://doi.org/10.1016/j.ecolecon.2021.107143

DBFZ et al. (2020) Potential links to BE monitoring activities and their support by STAR-ProBio results. STAR-ProBio Deliverable D9.4 http://www.star-probio.eu/wp-content/uploads/2017/04/STAR-ProBio-Report-D9.4_v1.0.pdf

Detzel, Andreas et al. (2019) Implementierung von Nachhaltigkeitskriterien für die stoffliche Nutzung von Biomasse im Rahmen des Blauen Engel (Teil 2) PROSA - Biobasierte Kunststoffe Abschlussbericht. Öko-Institut & ifeu i.A. des Umweltbundesamts. UBA-Texte 88/2019. Dessau https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-08-19_texte_88-2019_be_biomassenutzung_kunststoffe.pdf

EC (2018) Bioeconomy: the European way to use our natural resources - Action plan 2018. European Commission Directorate-General for Research and Innovation Unit F – Bioeconomy. Brussels https://doi.org/10.2777/79401

EC (2021a) Commission Delegated Regulation supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives. C(2021) 2800 final. Brussels https://eur-lex.europa.eu/resource.html?uri=cellar:d84ec73c-c773-11eb-a925-01aa75ed71a1.0021.02/DOC_1&format=PDF

EC (2021b) Amendment to the Renewable Energy Directive to implement the ambition of the new 2030 climate target. Proposal for a regulation of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. European Commission COM(2021) 557 final. Brussels https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf

Egenolf, Vincent et al. (2018) Indikatorensystem zur Bewertung der Nachhaltigkeit der deutschen Bioökonomie. Arbeitspapier von BEPASO und SYMBIO. Center for Environmental Systems Research. Kassel https://symobio.de/wp-content/uploads/2018/03/Indikatorensystem-16.03.2018_final.pdf

Egenolf, Vincent & Bringezu, Stefan (2019) Conceptualization of an Indicator System for Assessing the Sustainability of the Bioeconomy. Sustainability 11: 443 https://doi.org/10.3390/su11020443

FAO (2017) D3.2 Report on the design of the sustainability indicator set. Morese, Maria Michela; Colangeli, Marco & Traverso, Lorenzo. Food and Agriculture Organization of the United Nations. Contribution to the EC project FORBIO https://forbio-project.eu/assets/content/publication/D3.2_Inventory_of_sustainability_indicators.pdf

FAO (2019) Towards sustainable bioeconomy - Lessons learned from case studies. Gomez San Juan, Marta; Bogdanski, Anne & Dubois, Olivier. Food and Agriculture Organization of the United Nations. Rome http://www.fao.org/3/ca4352en/ca4352en.pdf

FAO (2021) How to mainstream sustainability and circularity into the bioeconomy? A compendium of bioeconomy good practices and policies. Gomez San Juan, Marta & Bogdanski, Anne. Food and Agriculture Organization of the United Nations. Rome https://doi.org/10.4060/cb5798en

Fritsche, Uwe (2019) Sustainability of Bioenergy - State of the art. In: Lago, Carmen; Caldes, Natalia & Lechon, Yolanda (eds.) The Role of Bioenergy in the Emerging Bioeconomy - Resources, Technologies, Sustainability and Policy. London etc.: 225-241 https://doi.org/10.1016/B978-0-12-813056-8.00006-6

Fritsche, Uwe et al. (2018) Linkages between the Sustainable Development Goals (SDGs) and the GBEP Sustainability Indictors for Bioenergy (GSI). Technical Paper for the GBEP Task Force on Sustainability. IINAS & IFEU. Darmstadt & Heidelberg http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/IINAS_IFEU_2018_Linkages_SDGs_and_GSIs_-_final.pdf

Fritsche, Uwe & Rösch, Christine (2020) The Conditions of a Sustainable Bioeconomy. In: Pietzsch, Joachim (ed.) Bioeconomy for Beginners. Berlin, Heidelberg: 177-202 https://doi.org/10.1007/978-3-662-60390-1_9

GBEP (2011) The GBEP Sustainability Indicators for Bioenergy. Global Bio-Energy Partnership. Rome http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

GBEP (2020) Global Bioenergy Partnership Sustainability Indicators for Bioenergy: Implementation Guide. Global Bioenergy Partnership. Rome http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Implementation_Guide/Final_Draft_Implementation_Guide_updated_14.04.2020.pdf

Giuntoli, Jacopo et al. (2020) Building a monitoring system for the EU bioeconomy - Progress Report 2019: Description of framework. Joint Research Centre Technical Report EUR 30064 EN. Luxembourg https://doi.org/10.2760/717782

Golaszewski, Janusz et al. (2020) Blueprint of sustainability certification schemes for bio-based products. STAR-ProBio Deliverable D8.2 http://www.star-probio.eu/wp-content/uploads/2017/04/D8.2_SAT-ProBio-blueprint_final-report_3-scalone.pdf

Heimann, Tobias (2019) Bioeconomy and SDGs: Does the bioeconomy support the achievement of the SDGs? Earth's Future 7: 43-57 https://doi.org/10.1029/2018EF001014

Hennenberg, Klaus et al. (2019) Implementierung von Nachhaltigkeitskriterien für die stoffliche Nutzung von Biomasse im Rahmen des Blauen Engel (Teil 1) Machbarkeitsstudie zu übergreifenden Aspekten – Stoffliche Nutzung von Biomasse Abschlussbericht. Öko-Institut & ifeu i.A. des Umweltbundesamts. UBA-Texte 87/2019. Dessau https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-08-19_texte_87-2019_be_biomassenutzung_uebergreifende-aspekte.pdf

Holden, Nicholas et al. (2022) Biocircularity: a Framework to Define Sustainable, Circular Bioeconomy. Circular Economy and Sustainability https://doi.org/10.1007/s43615-022-00180-y

IACGB (2020) Expanding the Sustainable Bioeconomy – Vision and Way Forward. Communiqué of the Global Bioeconomy Summit 2020. International Advisory Council on Global Bioeconomy. Berlin https://gbs2020.net/wp-content/uploads/2020/11/GBS2020_IACGB-Communique.pdf

Ifeu (2022) Linking bioenergy and the bioeconomy: The GBEP Sustainable Bioenergy Indicators and Sustainable Bioeconomy Indicators - Similarities, Differences and Perspectives for Convergence. Köppen, Susanne; Fehrenbach, Horst & Bürck, Silvana. Institut für Energie- und Umweltforschung Heidelberg. Report for the GBEP supported by Fachagentur für Nachwachsende Rohstoff (FNR). Heidelberg

IINAS et al. (2020) The GBEP Sustainability Indicators for Bioenergy - A TOOL FOR POLICY-MAKERS. Prepared for the Global Bioenergy Partnership. Berlin, Darmstadt http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Implementation_Guide/200511_final_WEB_The-GBEP-Sustainability-Indicators-for-Bioenergy-2020.pdf

INRO (2013) Sustainability Criteria for the material use. Initiative Nachhaltige Rohstoffbereitstellung für die stoffliche Biomassenutzung http://www.inro-biomasse.de/documents/Sustainability_Criteria.pdf

Iriarte, Leire et al. (2017) Consistent Cross-Sectoral Sustainability Criteria & indicators. Deliverable D5.4 of the EC project S2Biom. Darmstadt, Madrid https://www.s2biom.eu/images/Publications/D5.4_S2Biom_Cross-Sectoral_Sustainability_Indicators_Final.pdf

Iriarte, Leire & Fritsche, Uwe (2014) Sustainability Criteria and Indicators for the Bio-Based Economy in Europe: State of Discussion and Way Forward. Energies 7 (11): 6825-6836 https://iinas.org/app/uploads/2021/08/energies-07-06825-v2.pdf

Iriarte, Leire & Fritsche, Uwe (2019) SDG implementation in selected Latin America and Caribbean countries and possibilities to link with the GBEP Sustainability Indicators. Technical Paper for the GBEP Task Force on Sustainability by IINAS. Pamplona, Darmstadt http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/SDG_-_GSI_linkages/IINAS__2019__SDG_and_GSI_opportunities.pdf

ISO (2015) Sustainability criteria for bioenergy. International Organization for Standardization. ISO 13065. Geneva

JRC (2020a) Report on the Community of Practice Workshop: Web-based workshop series in preparation of launch of the EU Bioeconomy Monitoring System. Brussels, Ispra https://ec.europa.eu/knowledge4policy/sites/know4pol/files/kcb_report-monitor4be-cop_workshop_june_2020.pdf

JRC (2020b) Report on the Community of Practice Workshop: Joint Research Centre's contributions to Enhancing the knowledge base on the Bioeconomy. Brussels, Ispra https://ec.europa.eu/knowledge4policy/sites/know4pol/files/report_cop_workshop_enhancing_be_knowledge_base_final.pdf

Kilsedar, C. et al. (2021) Implementation of the EU Bioeconomy Monitoring System dashboards - Status and technical description as of December 2021. EC Joint Research Centre report JRC127762. Luxembourg https://doi.org/10.2760/691217

Kircher, Manfred (2022) The bioeconomy needs economic, ecological and social sustainability. AIMS Environmental Science 9 (1): 33-50 https://doi.org/10.3934/environsci.2022003

Kooduvalli, Komal et al. (2019) Sustainability Indicators for Biobased Product Manufacturing: A Systematic Review. Journal of Sustainable Development 12 (1): 55-83 https://doi.org/10.5539/jsd.v12n1p55

Koper, Michèle et al. (2021) Technical Assistance for the preparation of guidance for the implementation of the new bioenergy sustainability criteria set out in the revised Renewable Energy Directive – REDIIBIO. Navigant, EFI, IEEP & OEKO. Final Report for EC DG ENER https://ec.europa.eu/energy/sites/default/files/rediibio_final_report_version_2.pdf

Kardung, Maximilian et al. (2021) Development of the Circular Bioeconomy: Drivers and Indicators. Sustainability 13 (1): 413 https://doi.org/10.3390/su13010413

Ladu, Luana et al. (2018) Recommendations for Standards and criteria for eco-labels for bio-based products. STAR-ProBio Deliverable D9.2 http://www.star-probio.eu/wp-content/uploads/2017/04/STAR-ProBio_D9.2_final.pdf

Lier, Markus et al. (2018) Synthesis on bioeconomy monitoring systems in the EU Member States - indicators for monitoring the progress of bioeconomy. Luke Natural resources and bioeconomy studies 38 /201. Natural Resources Institute Finland. Helsinki https://jukuri.luke.fi/bitstream/handle/10024/542249/luke-luobio_38_2018.pdf

Mai-Moulin, Thuy (2020) Sustainable Bioenergy Pathways - Conditions to move forward. Copernicus Institute of Sustainable Development, Utrecht University https://dspace.library.uu.nl/bitstream/handle/1874/396086/5ea971107e28a.pdf

Mai-Moulin, Thuy et al. (2021) Effective sustainability criteria for bioenergy: Towards the implementation of the european renewable directive II. Renewable and Sustainable Energy Reviews 138: 110645 https://doi.org/10.1016/j.rser.2020.110645

Melim-Mcleod, C.et al. (2022) EU Bioeconomy Monitoring System indicator update - Addressing indicator gaps: social impacts of trade and share of renewable energy in bio-based industry. Mubareka, S. (ed.). EC Joint Research Centre report JRC128054. Luxembourg https://doi.org/10.2760/266060

Möller, Martin et al. (2020) Nachhaltige Ressourcennutzung – Anforderungen an eine nachhaltige Bioökonomie aus der Agenda 2030/SDG-Umsetzung. Öko-Institut et al. i.A. des Umweltbundesamts. UBA Reihe TEXTE 181/2020. Dessau https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020_10_20_texte_181_2020_biooekonomie.pdf

Nel, Jeanne et al. (2022) Managing healthy and resilient ecosystems in the bioeconomy - Guidelines report. Wageningen Environmental Research study for EC DG ENVI. Luxembourg https://doi.org/10.2779/946677

OECD (2013) Recommendation of the OECD Council on Assessing the Sustainability of Bio-based Products. Organisation for Economic Co-operation and Development. Paris

OECD (2020) Developing Sustainable Finance Definitions and Taxonomies. OECD Green Finance and Investment. Paris https://doi.org/10.1787/24090344

OECD (2021a) Recommendation of the Council on Assessing the Sustainability of Bio-Based Products. Organisation for Economic Co-operation and Development. OECD Legal Instruments. OECD/LEGAL/0395. Paris https://legalinstruments.oecd.org/public/doc/283/283.en.pdf

OECD (2021b) Report on the Implementation of the Recommendation of the Council on Sustainability of Bio-Based Products. Organisation for Economic Co-operation and Development C(2021)27. Paris https://one.oecd.org/document/C(2021)27/en/pdf

Pelkmans, Luc et al. (2016) Guidelines and indicators for the evaluation of sustainable resource efficient biomass value chains. Deliverable D2.6 of the EC project "Biomass Policies" https://iinas.org/app/downloads_from_old_page/bio/biomasspolicies/Pelkmans_et_al_2014_Guidelines_and_indicators_for_the_evaluation_of_sustainable_resource_efficient_biomass_value_chains.pdf

Pelkmans, Luc; Berndes, Göran & Fritsche, Uwe (2019) Governing sustainability in biomass supply chains for the bioeconomy - Summary and conclusions from the IEA Bioenergy workshop, Utrecht (Netherlands), 23 May 2019 https://www.ieabioenergy.com/wp-content/uploads/2019/10/ExCo83-Governing-sustainability-in-biomass-supply-chains-for-the-bioeconomy-Summary-and-Conclusions.pdf

Ronzon, Tévécia et al. (2020) Developments of economic growth and employment in bioeconomy sectors across the EU. Sustainability 12: 4507 https://doi.org/10.3390/su12114507

STAR-ProBio (2018) Recommendations for Standards and criteria for eco-labels for bio-based products. STAR-ProBio Deliverable D9.2 www.star-probio.eu

STAR-ProBio (2020) Potential links to BE monitoring activities and their support by STAR-ProBio results. STAR-ProBio Deliverable D9.4 www.star-probio.eu

Stupak, Inge; Mansoor, Maha & Smith, Tattersall (2021) Conceptual framework for increasing legitimacy and trust of sustainability governance. Energy, Sustainability and Society 11: 5 https://doi.org/10.1186/s13705-021-00280-x

Szarka, Nora et al. (2020) All in One: A Comprehensive Goal and Indicator System for Smart Bioenergy. Chem. Eng. Technol. 43 (8): 1554-1563 https://doi.org/10.1002/ceat.202000033

van Schoubroeck, Sophie et al. (2018) A review of sustainability indicators for biobased chemicals. Renewable and Sustainable Energy Reviews 94: 115-126 https://doi.org/10.1016/j.rser.2018.06.007

Zeug, Walther; Bezama, Alberto & Thrän, Daniela (2020) Towards a Holistic and Integrated Life Cycle Sustainability Assessment of the Bioeconomy – Background on Concepts, Visions and Measurements vol 07. Helmholtz-Centre for Environmental Research (UFZ). Leipzig https://doi.org/10.13140/RG.2.2.16912.02564

Zhu, Xinqi et al. (2019) Data and data gaps for bioeconomy drivers and indicators and their implications. Deliverable D2.1 of the EU Project "BioMonitor - Monitoring the Bioeconomy" http://biomonitor.eu/wp-content/uploads/2020/04/Deliverable-2.1.pdf