Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

D5.4
Consistent Cross-Sectoral Sustainability Criteria & Indicators

Draft Report

March 2015




About S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a "resource-efficient" Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a "computerized and easy to use" toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

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About this document

This report corresponds to deliverable 5.4 – Consistent Cross-Sectoral Sustainability Criteria & Indicators - of S2Biom.

Due date of deliverable:	December 2014
Actual submission date:	March 2015
Start date of project:	2013-01-09
Duration:	36 months

Work package	5
Task	5.4
Lead contractor for this deliverable	IINAS
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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services):	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Version	Date	Author(s)	Reason for modification	Status
0.1	13/02/2015	Leire Iriarte, Uwe R. Fritsche	First version defining request for input from partners	Draft
0.2	10/03/2015	Leire Iriarte, Uwe R. Fritsche	Draft version including input from partners	Revised Draft
0.3	30/03/2015	Leire Iriarte, Uwe R. Fritsche	Final draft version including input from partners	Final Draft

This project is co-funded by the European Union within the 7th Frame Programme. Grant Agreement n°608622. The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

Executive Summary

The general objective of S2Biom Work Package 5 (WP5) is to provide a better understanding regarding sustainability requirements in biomass value chains. The compilation of consistent sustainability criteria & indicators (C&I) for the short- and medium-term bioeconomy is one of the specific objectives of this WP and the focus of this draft paper.

Based on the compilation of sustainability requirements and provisions made in task 5.2 of this project and literature review, this paper provides:

a) an overview of different points of view to be acknowledged when delineating the approach to sustainability (i.e. scope, sustainability sets or type of indicators) , and

b) a specific proposal of sustainability C&I for non-food biomass.

The approach to sustainability has taken into account the scope of the assessment (biomass value chains and calculation of biomass potentials), the sustainability ambition (a “basic” and a more “advanced” set of C&I), and the types of indicators to be considered (minimum requirements, comparative with non-renewable or biomass references, and descriptive indicators).

The sustainability C&I draft proposal has considered the three “pillars” (dimensions) of sustainability, i.e. environment, social and economic. In total, 12 criteria and 27 indicators are included. This set aims to serve as an **umbrella** to the bioeconomy (bioenergy and bioproducts) that can be the basis for more specific indicators in certain applications.

In the environment dimension, the following C&I are proposed:

- Resource use: Land use efficiency, secondary resource efficiency, energy efficiency, and functionality (Output service quality),
- Climate Change: Life cycle-based CO_2eq including direct land use change, and other GHG emissions,
- Biodiversity: Protected areas and land with significant biodiversity values, and biodiversity conservation and management,
- Soil: Erosion, Soil Organic Carbon, and soil nutrient balance,
- Water: Water availability and regional water stress, water use efficiency, and water quality,
- Air: emissions of SO_2 equivalents, and PM_{10}.

In the social dimension:

- Participation and transparency: Effective participatory processes, information transparency,
- Land Tenure: Land tenure assurance

- Employment and labor rights: Full direct jobs equivalents along the full value chain, full direct jobs equivalent in the biomass consuming region (or country), Human and Labor Rights, and occupational safety and health for workers,
- Health risks: Risks to public health,
- Food, fuelwood and other products: Food, fuelwood and other products supply security

The criterion related to the economic dimension is:

- Production costs: Current levelized life-cycle cost, and future levelized life-cycle costs

Most of these indicators are “mid-point” indicators that need further elaboration to be implementable for specific feedstocks, locations or value chains. Further work will refine these indicators and develop respective thresholds, if applicable.

Other tasks of the project will analyze how these indicators can be applied for the calculation of biomass potentials and value chains.

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List of Acronyms and Abbreviations

BEE	Biomass Energy Europe
BOD	Biological Oxygen Demand
C	Completeness (in data quality evaluation)
CF	Characterisation Factor
C&I	Criteria and Indicators
CFCs	Chlorofluorocarbons
CPA	Statistical Classification of Products by Activity
CTU	Comparative Toxic Unit
DG ENV	Directorate General for Environment
DQR	Data Quality Rating
EC	European Commission
EF	Environmental Footprint
EMAS	Eco-Management and Audit Schemes
EoL	End-of-Life
GR	Geographical Representativeness
GHG	Greenhouse Gas
GIS	Geographic Information Systems
iLUC	Indirect Land Use Change
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCT	Life Cycle Thinking
LHV	Low Heating Value

LU	Land Use
LUC	Land Use Change
M	Methodological appropriateness and consistency (in data quality evaluation)
MS	Member State
NMVOC	Non-Methane Volatile Organic Compounds
OEF	Organisation Environmental Footprint
P	Precision/Uncertainty (in data quality evaluation)
PM	Particulate Matter
PEF	Product Environmental Footprint
SOM	Soil Organic Matter
TeR	Technological Representativeness (in data quality evaluation)
TiR	Time-related representativeness (in data quality evaluation)
VGGT	Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security

1. Introduction and Objectives

The general objective of S2Biom Work Package 5 (WP5) is to provide a better understanding among decision-makers in policy and industry as well as in the scientific community and civil society regarding **sustainability requirements** in biomass value chains addressed in Theme 1.

This goes beyond the previous discussions around sustainability of liquid biofuels[1], and the ongoing discussions on solid/gaseous bioenergy[2] and biomaterials[3] in aiming to develop comprehensive sustainability requirements for **all non-food biomass** in the broader **bioeconomy**[4].

To achieve this, the specific objectives of WP5 are:

1. Adaptation of the life cycle-based EC Environmental Footprint methods in order to develop a complementary methodology specific to non-food biomass value chains[5].
2. Identification of sustainability criteria and indicators (C&I) for non-food biomass value chains, gap analysis of respective legislation, regulation and voluntary schemes at international, European and Member States level[6].
3. Compilation of consistent sustainability C&I for the short- and medium-term bioeconomy, and an outlook for long-term developments (i.e. this paper).
4. Development of guidelines for evaluating the environmental performance with the toolset developed in WP4 of all lignocellulosic feedstocks for the various industrial routes, building on existing tools, and extending to bio-based products (chemicals; materials, etc.), and their interrelations[7].

[1] See EU (2009) for the respective requirements in the EU, and Franke et al. (2013) for global requirements.

[2] See EC (2014) for the view of the European Commission on that, and Fritsche et al. (2014) for other views.

[3] See e.g. BISO (http://sa.jrc.ec.europa.eu/), the Bioeconomy observatory (http://www.biobasedeconomy.eu/) and INRO (http://www.inro-biomasse.de/en.htm)

[4] "Bioeconomy" (EC 2012) encompasses 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 and bioenergy. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge. For a discussion of the status of activities to derive sustainability requirements for the broader bioeconomy, see Fritsche, Iriarte (2014).

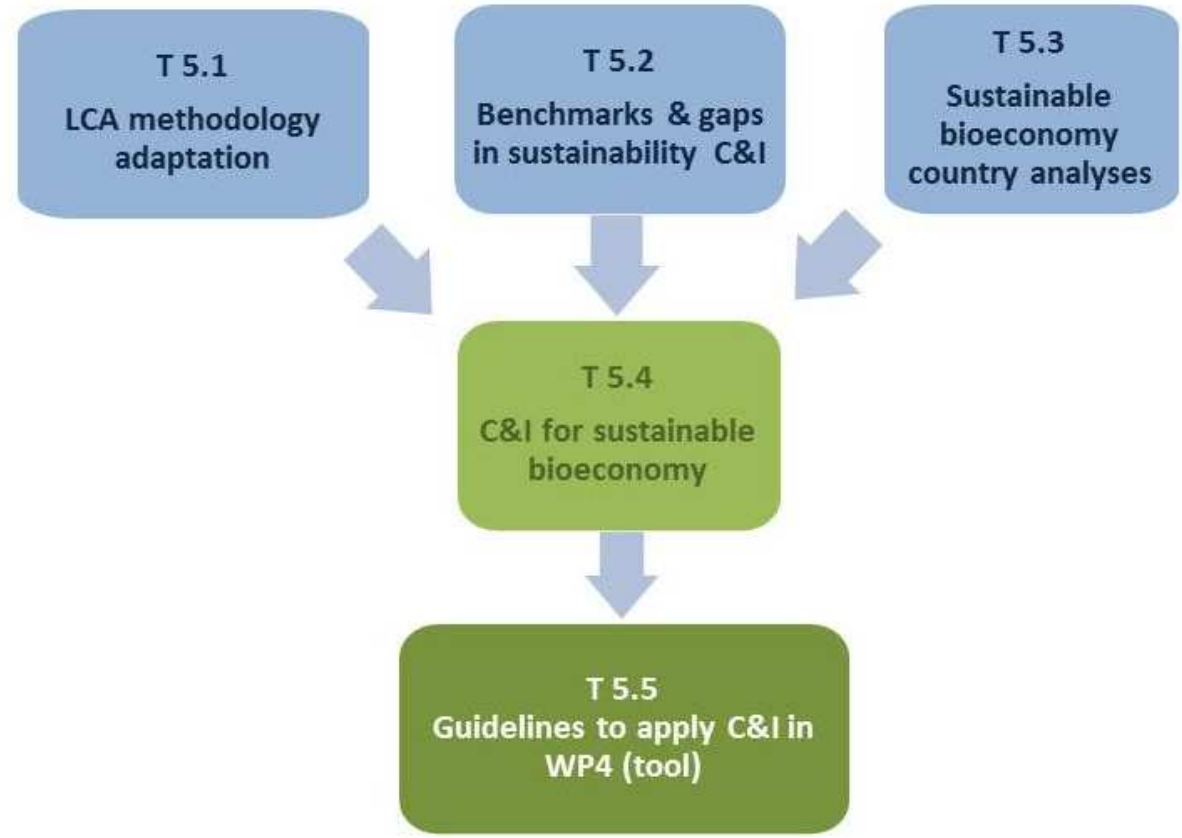
[5] See WP5 Task 5.1 (carried out by the JRC) with its deliverable D 5.1

[6] See WP5 Task 5.2 (carried out by IINAS) with its deliverable D 5.2

[7] See Task 5.5 (carried out by EFI).

To this end, five tasks have been identified in WP5, as shown in Figure 1. The outcomes of the first three tasks serve in addition to their own value to the purposes of this work. Later, task 5.5 provides the link to the other project WPs of the project.

Figure 1 Structure of Sustainability Activities in S2Biom



Source: own elaboration

This draft paper presents preliminary findings from Task 5.4, focusing on consistent sustainability C&I for the short- and medium-term bioeconomy. The specific objectives of Task 5.4 are twofold:

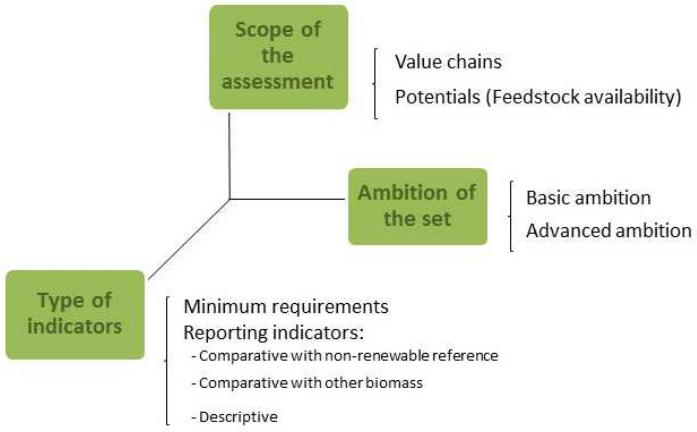
- Develop a sustainability **framework** according to which biomass chains can be evaluated in the S2BIOM project (and beyond), particularly in the tools developed as part of the project, as illustrated in Figure 2. This includes the distinction among:
    - **Scope** of the assessment: different considerations have to be in place when biomass value chains are assessed or when biomass potentials calculated.

- **Ambition** of the sustainability assessment: "sustainability" might refer to many different indicators, and respective thresholds. Taking this into account, once a comprehensive set of indicators were identified, a "basic" and a more "advanced" set of sustainability C&I were proposed.

In both cases, it is necessary to differentiate between **types** of indicators (different categories): minimum requirements, and reporting indicators (comparative with non-renewable reference, comparative with biomass reference, and descriptive indicators).

- Propose a draft (scientific) sustainability **C&I set** and from this set elaborate basic and advanced sustainability sets that capture different ambitions.

Figure 2 The various dimensions of sustainability in S2Biom – The umbrella approach



Source: own elaboration

The main added value of this report over previous efforts is that it addresses sustainability within the several aspects encompassed by the bioeconomy in a sound way, providing a comprehensive and coherent framework. Within the scope of the assessment "policy" considerations have not been included since this is indirectly addressed when analyzing value chains and potentials. It is **not** the objective of Task 5.4 to develop a sustainability scheme for certification.

The paper is structured as follows:

- **Section 2** describes the various approaches considered in carrying out a sustainability assessment in bioeconomy value chains.
- In **Section 3**, the preliminary list of sustainability criteria and indicators and a proposal for a basic and advanced sustainability set are presented.

- **Section 4** drafts the next steps to elaborate the final report.

The **references** used are given in the last section.

In the **annex**, detailed requirements proposed in other projects relevant for the scope of this work are provided.

2. Sustainability Assessment

Assessing biomass sustainability is a complex exercise. The proposal presented here did not only focus on drafting a list of sustainability C&I (Section 3) but also on depicting different approaches to facilitate sound understanding. This refers, for example to describing various types of indicators (see Section 2.2), defining the scope of analysis and assessment (see Section 2.3) or defining the ambition of the assessment (see Section 2.4).

This report builds on previous relevant efforts to address a sound approach to biomass sustainability such as Biomass Policies (Pelkmans et al. 2014), Biomass Energy Europe - BEE- (Vis et al. 2010; Koch et al. 2011), Biomass Futures (Fritsche et al. 2012), Biocore (Piotrowski et al. 2013; Rettenmaier et al. 2014), and Global BioPact (Diaz-Chavez et al. 2012).

Definition of Principles, Criteria and Indicators, based on FAO (2002):

- **Principles (or themes)** are commonly formulated around a core concept based on societal ethics, values, and tradition as well as on scientific knowledge. Principles are used as the primary framework for the general scope and provide the justification for criteria, indicators and verifiers.
- **Criteria** are 'second order' principles that add meaning and operationability to standards/principles without being a direct measure of performance. Criteria are intermediate points to which information provided by indicators can be integrated, facilitating an interpretable assessment.
- **Indicators** are quantitative or qualitative factors or variables providing means to measure achievement, to reflect changes, or to help assess performance or compliance, and - when observed periodically - demonstrate trends. Indicators should convey a single meaningful message (information). Indicators have to be judged on the scale of acceptable standards of performance.

2.1 Overall approach

As explained in Section 1, the S2Biom project is focused on the delivery of **non-food** biomass for the bioeconomy. This has implications in terms of sustainability since it has to consider a broad variety of products with alternative end-uses (bioenergy or bio-based products). Given this complexity, this C&I sustainability proposal (see section 3.2) opted for an **umbrella approach** from which more specific indicators could be derived.

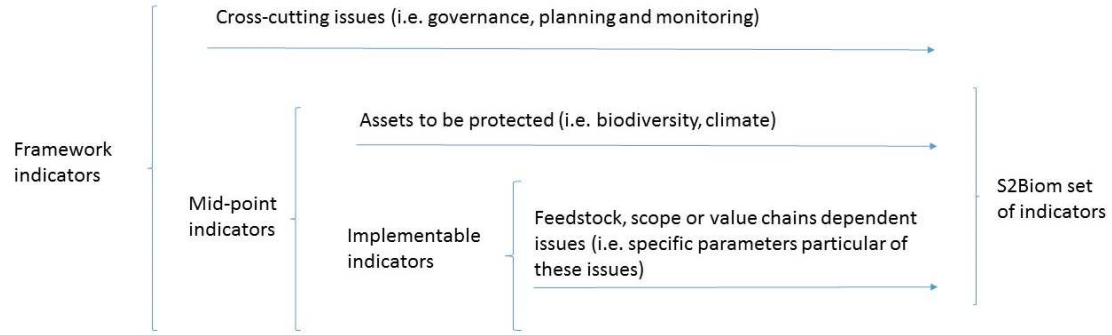
A working hypothesis of the S2Biom project is that all non-food biomass in the bioeconomy should be subject to the **same** sustainability requirements, regardless of feedstocks and end-uses (bioenergy or bio-based products).

This is the main reason why this proposal for sustainability C&I is mainly focused on midpoint indicators from which implementable indicators (with respective

thresholds – see Section 4) applicable for specific feedstocks and end-uses can be derived when needed. Nonetheless, the approach to sustainability indicators presented here has been conceptualized around 3 categories of information, as shown in Figure 3. Thus, this proposal has distinguished between:

- **Framework indicators**: This type of indicator refers to general cross-cutting requirements that might apply to several criteria and indicators included in this proposal (e.g. compliance with laws or planning and monitoring) and that are beyond the scope of the indicators elaborated here.
- **Mid-point indicators**: Are those requirements that aim to address assets or commons to be maintained or protected. This proposal focuses on this type of indicators since this is the conceptual level that can cover all types of feedstocks and value chains. From this "umbrella" set of indicators, specific implementable indicators can be elaborated.
- **Implementable indicators**: based on the mid-point indicators, this level aims to delineate concrete indicators adapted to various feedstocks, value chains or scopes. In this category, cross-cutting requirements that could affect to several mid-point indicators are also included.

Figure 3 Conceptualization of the types of indicators



Source: own elaboration

Some of the mid-point indicators can be directly applied to achieve the respective scope (e.g. assess biomass potentials or sustainability in a value-chain) while other indicators have to be further elaborated to capture (and assure) the sustainability risks posed by any activity (implementable indicators). For instance, when harvesting forest residues for bioenergy, it is necessary to leave a certain amount of residues to protect biodiversity and soils. On the other hand, the amount of residues to be left on the ground is a very particular sustainability consideration for primary residues, not being relevant for other types of feedstocks. The draft set of C&I considers biodiversity and soils but does not specify this particular requirement (the amount of residues to be left on the ground), as illustrated in Table 1. Then, for this specific feedstock more detailed indicators, aimed to meet sustainability requirements formulated as midpoint

indicators might be proposed. The question here would be whether these specific indicators are enough to show the compliance with the mid-point indicators or additional considerations are needed.

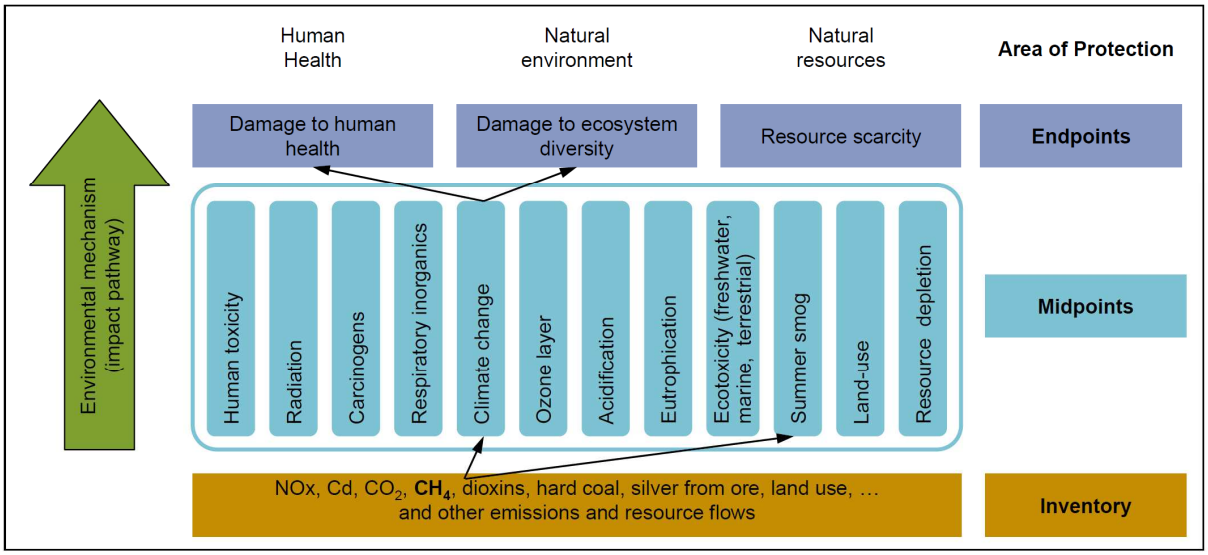
Table 1 Overview of the relation between "mid-point" indicators and "implementable" indicators.

S2Biom Criteria	S2Biom Mid-point Indicators		S2Biom Implementable Indicators
3. Biodiversity	3.1	Protected areas and land with significant biodiversity values	Amount of residues to be left on the ground in every location
	3.2	Biodiversity conservation and management	
4. Soil	4.1	Erosion	
	4.2	Soil Organic Carbon	
	4.3	Soil nutrient balance	

Source: own elaboration

This conceptualization is in line with the hierarchy used in life-cycle assessment, as represented in Figure 4, which distinguishes between "inventory", "mid-points" and "endpoints". In the approach presented here, the LCA point of view is acknowledged but also non-environmental indicators are proposed to address all sustainability dimensions (see Section 0).

Figure 4 Life cycle impact assessment: Schematic steps from inventory to category endpoints



Source: JRC (2010)

The main difference between the midpoint indicators proposed in life-cycle impact assessment and those proposed here (see Section 3) is structure and scope:

Here we have used themes (sustainability dimensions) instead of LCA "endpoints", and criteria and indicators instead of LCA "impact categories". Scope-wise, social and economic aspects are also addressed here. Yet, the environmental criteria proposed here are comparable to the midpoint indicators used in LCA.

Table 2 describes the impact categories considered in the "Methodology for life-cycle based environmental sustainability assessment of non-food biomass value chains" developed within the S2Biom project (JRC 2014). These impact categories were taken as a base for the environmental theme in the S2Biom proposal (see Section 3.2).

Table 2 Default list of impact categories and indicators for inclusion in the environmental sustainability assessment

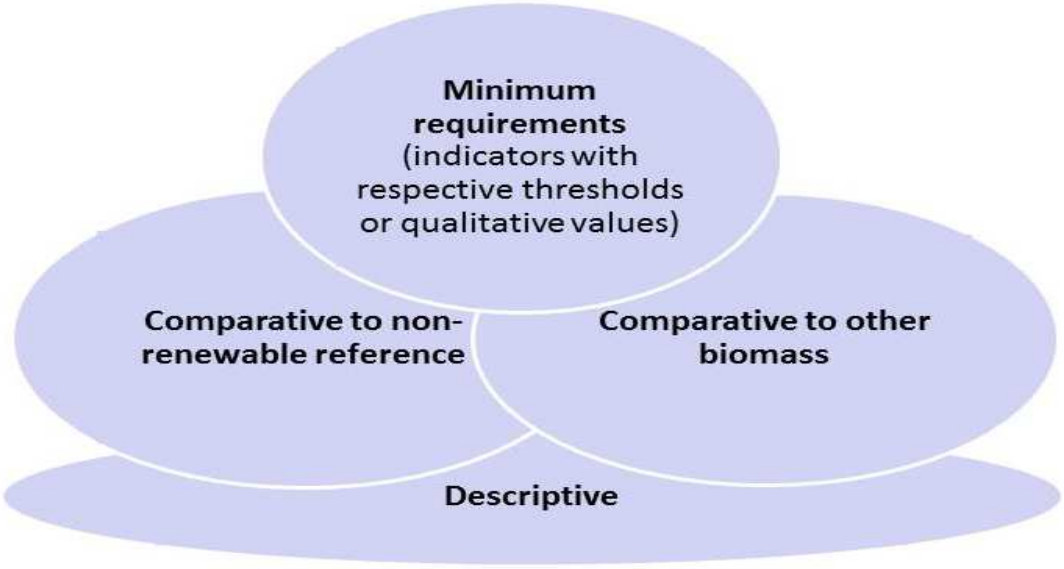
Impact Category	Impact Category indicators
Climate change	kg CO_2 equivalent
Ozone depletion	kg CFC-11 equivalent
Ecotoxicity for aquatic fresh water	CTUe (Comparative Toxic Unit for ecosystems)
Human toxicity - cancer and non-cancer effects	CTUh (Comparative Toxic Unit for humans)
Particulate matter/respiratory inorganics	kg $PM_{2.5}$ equivalent (particulate matter with a diameter of 2.5 µm or less)
Ionising radiation – human health effects	kg U^{235} equivalent (to air)
Photochemical ozone formation	kg NMVOC equivalent
Acidification	mol H+ eq
Eutrophication – terrestrial	mol N eq
Eutrophication – aquatic	fresh water: kg P equivalent; marine: kg N equivalent
Resource depletion – water	m^3 water use related to local scarcity of water
Resource depletion – mineral, fossil	kg antimony (Sb) equivalent
Land use	Soil Organic Matter kg (deficit)

Source: JRC (2014)

2.2 Type of Indicators

As shown in Figure 5, this work distinguishes between different types of indicators that play different roles in sustainability assessments. In general words, we distinguish between two main categories: "minimum requirements" and "reporting indicators" (those that provide complementary information to assess sustainability performance).

Figure 5 Type of Indicators



Source: own elaboration

Four categories are identified:

- **Minimum requirements**: present the minimum list of indicators, which sustainable biomass is subject to, and associated thresholds (or qualitative attributes) that should be met, resulting in an acceptable compliance only if indicator meets a certain value (e.g. minimum GHG emissions reduction level).
- **Comparative to non-renewable reference**: these indicators can be compared with e.g. fossil fuel or non-renewable material references (e.g. PM_{10} and SO_2eq).
- **Comparative to other biomass value chains**: indicators that are to be compared to other biomass systems only, as they are not relevant for non-renewable value chains (e.g. Soil Organic Carbon).
- **Descriptive**: these indicators provide information about key complementary characteristics relevant for assessment (e.g. participation and transparency).

These indicators are helpful to assess both biomass potentials (i.e. availability of feedstocks) and the sustainability performance of biomass value chains.

The differentiation into minimum requirements and “reporting indicators” (i.e. comparative and descriptive indicators) is also considered in other schemes such as the draft NTA8080-1 (NEN 2014), currently under development.

The concepts included within each of these indicators is quite flexible and might be overlapped. This means that depending on the ambition of the sustainability

assessment (see Section 2.4), the same indicator might be descriptive, comparative or a minimum requirement. For example, CO_2 emissions from indirect Land Use Change and carbon stock changes might be classified as descriptive, comparative to other biomass value chains, or a minimum requirement depending on the sustainability ambitions.

2.3 Scope of Analysis and Assessment

Applying sustainability considerations might serve different purposes such as the evaluation of the sustainability of value chains in the bioeconomy or the calculation of sustainable biomass potentials.

Assessing sustainability in a **value chain** should consider the full range of indicators to obtain the full and complete picture[8]. Comparative and descriptive indicators could provide additional information to be expressed by means of a spider chart (or a traffic light system in tools and applications for which this classification might be of interest).

When assessing sustainable biomass **potentials**, the minimum requirements should be used to derive the sustainable potential from the technical potential.

The indicators are also different with regard to their geographical scope, as they can be:

- **spatially explicit** (e.g. for biodiversity, soil, etc.) when they depend on the location.
- **partially** attributable to spatial distribution (e.g. GHG, land use efficiency) when a part of the indicator is associated to the location (i.e. production) and another part depends on the value chain.
- **non-spatial** but circumstantial (e.g. labor conditions, employment) when their performance depend on the context and not specifically on the location.

Then, the methodology both for the assessment of biomass potentials and value chains needs to combine:

- Definition of typical (default) data of value chains to perform LCA.
- Geographic Information Systems (GIS) application (especially for potentials).
- Setting approach (for circumstances).

[8] When the **end use** of the value chain is unknown, the delivered biomass can be compared to a fossil or biomass reference system. Complete combustion for all end-energy carriers might be assumed to take into account the C in the fuels (and S etc. for the air emissions) so that the emissions per unit of energy is known without factoring in efficiencies, location etc.

2.4 Ambition of the Sustainability Sets

First a science-based set of sustainability C&I was elaborated (see Section 3.1). **Policy** issues and other practical aspects that might restrict the application of these indicators have not been considered.

Based on this set, a set with minimum ambition (**basic set**) towards sustainability, and a more "advanced" one (**advanced set**) with higher ambition can be elaborated which explicitly takes into account the "willingness" to apply a narrower or a broader concept of sustainability requirements to the bioeconomy. A proposal in this respect is provided in Section 3.2.

There are several ways to **move** from the basic set to the advanced one:

(1) **Type of indicators**: an issue classified as comparative or descriptive indicator might become minimum requirements, e.g. the proposal in the basic and advanced set (see Table 3) with respect to "food, fuelwood and land tenure security".

(2) **Threshold** level: thresholds of the minimum requirements might become more "demanding", e.g. regarding GHG savings.

(3) **Issues** to consider: the list of indicators might be expanded, e.g. with respect to air emissions, soil or water criteria.

3. Proposal for Sustainable Biomass C&I

This proposal goes beyond sustainability requirements for biomass for bioenergy, including also provisions for bio-based products, thus targeting non-food biomass for the bioeconomy in general. Given the differences in various feedstocks and end-uses that the bioeconomy includes, this work focused on the "**mid-point indicators**" (see Section 2.2).

This approach aims to go beyond current sectoral policies in the agriculture, forestry or waste sectors to provide an integrated point of view towards sustainability. Further work (see section 4) will consider current policies and respective sustainability requirements in the various sectors involved in the bioeconomy.

3.1 Data Background for the C&I Proposal

To develop this set of sustainability C&I, particular attention has been paid to:

- The methodology for life-cycle based environmental sustainability assessment of non-food biomass value chains, elaborated by the JRC (2014)
- Current criteria and indicators developed for bioenergy at the international, EU and country level, including voluntary private sector schemes[9].
- Other sectoral policies with sustainability requirements (i.e. EU Forest Strategy).
- Proposals from other research projects focused (mainly) on biomass for bioenergy such as Biomass Energy Europe (Vis et al. 2010), Biomass Futures (Fritsche et al. 2012), Biomass Policies (Pelkmans et al. 2014), Global Bio-Pact (Díaz Chavez et al. 2012) and BioTrade2020plus[10].
- Efforts from other projects that focuses on biorefineries such as BIOCORE (Piotrowski et al. 2013; Rettenmaier et al. 2014), EuroBioRef[11], and SUPRA-BIO[12].

Also, the information compiled in the deliverable 5.2 of S2Biom (benchmark and gap analysis) has been taken into account. This benchmark and gap analysis covered more than 50 sustainability schemes in the agriculture, bioenergy, forest and other sectors (e.g. waste, biodiversity, etc.) and selected schemes were

[9] See the schemes identified in S2Biom Deliverable 5.2

[10] The main aim of BioTrade2020plus project is to provide guidelines for the development of a European Bioenergy trade strategy for 2020 and beyond, see project website: http://www.biotrade2020plus.eu/

[11] http://eurobioref.org/

[12] http://www.suprabio.eu/

benchmarked against the draft set of indicators developed in this proposal. This report concluded that biodiversity, soil and land tenure criteria were extensively addressed in the schemes subject to the analysis. Indicators related to climate change, water, participation and transparency as well as employment and labor conditions were partially considered while indicators for resource efficiency and risks to public health were addressed only occasionally. Food security and production costs were not meaningfully covered in any sector.

The benchmark and gap analysis made a wide range of suggestions, including some with respect to the draft set indicators. These recommendations have been incorporated in this proposal.

3.2 Sustainability C&I

The proposal on sustainability C&I for bioeconomy is presented in Table 3. This proposal has considered the three common sustainability dimensions, i.e. environment, social and economic. Each indicator is formulated in a general way and accompanied by its respective definition. In total, 12 criteria and 27 indicators are included in this proposal.

Table 3 Draft Sustainability Criteria and Indicators for the Bioeconomy

Theme	Criterion	Indicator Description		
		#	Indicator	Definition
Environment	1. Resource use	1.1	Land use efficiency	Biomass (including by- and co-products along life cycles) per hectare of cultivated area
		1.2	Secondary resource efficiency	Heating value of biomass output divided by heating value of secondary resource; applies to conversion of residues and wastes
		1.3	Energy efficiency	Cumulative energy requirements (all inputs based on LHV primary energy) compared to outputs
		1.4	Functionality (Output service quality)	Economic value of outputs (€/GJ and €/ton), compared to economic value of heat which could be produced from burning (dried) primary inputs (reference = heat from NG ~ 10€/GJ); economic values excluding taxes, for industrial customers
	2. Climate Change	2.1	Life cycle-based CO_2eq including direct land use change	GHG emissions during the whole value chain (i.e. crop growth & harvesting, logistics, pretreatment and conversion, distribution and end-use phase) in relation to the final output (combination of electricity, useful heat, biofuels & biomaterials)
		2.2	Other GHG emissions	GHG from indirect land use changes (iLUC) and carbon stock changes in forests

Theme	Criterion	Indicator Description		
		#	Indicator	Definition
	3. Biodiversity	3.1	Protected areas and land with significant biodiversity values	Categories established by the RED: - Protection of land with high biodiversity value (Art. 17.3). Primary forests, areas designated by laws, and other highly biodiverse areas (recognized by international agreements or International Union for Conservation of Nature (IUCN)) and natural and non-natural highly biodiverse grasslands should be excluded. - Protection of land with high carbon stocks (Art. 17.4). Wetlands, continuously forested areas and lightly forested areas with this status in January 2008 but no longer have it should be avoided (not applicable if the status in January 2008 is maintained). - Protection of peatlands (Art. 17.5).
		3.2	Biodiversity conservation and management	"Agrobiodiverse cultivation" (crop rotation; diversity in the landscape; avoidance of alien species), amount of chemicals (pesticides/herbicides), and release/ monitoring of Genetically Modified Organisms
	4. Soil	4.1	Erosion	Probability of erosion where mitigation measures are not feasible
		4.2	Soil Organic Carbon	Probability of soil organic carbon loss where mitigation measures are not feasible (it depends on the type of crops - perennials and annual crops- and respective land management)
		4.3	Soil nutrient balance	Probability of nutrient balance loss where mitigation measures are not feasible
	5. Water	5.1	Water availability and regional water stress	Water use in relation to TARWR (total actual renewable water resources), or average replenishment from natural flow in a watershed
		5.2	Water use efficiency	Water use for biomass production (cropping), irrigation, and processing/kg biomass
		5.3	Water quality	Presence of water pollutants (e.g. nitrate, phosphorous, pesticides, biochemical oxygen demand)
	6. Air	6.1	SO_2 equivalents	Life cycle emissions of SO_2, NO_x, NH_3 and HCl/HF from bioenergy provision, expressed in SO_2 equivalents and calculated in accordance to GHG emissions
		6.2	PM_{10}	Life cycle emissions of PM_{10}, calculated in accordance to GHG emissions
Social	7. Participation and	7.1	Effective participatory processes	Enable effective participation of all directly affected stakeholders by means of a due diligence consultation process, incl. Free Prior & Informed Consent when relevant

Theme	Criterion	Indicator Description		
		#	Indicator	Definition
		7.2	Information transparency	Freely availability of documentation necessary to inform stakeholder positions in a timely, open, transparent and accessible manner
	8. Land Tenure	8.1	Land Tenure assurance	Compliance with the Voluntary Guidelines on the Responsible Governance of Tenure of Land to secure land tenure and ownership (CFS 2012)
	9. Employment and labor rights	9.1	Full direct jobs equivalents along the full value chain	Number of jobs (gross figure) from biomass along the full value chain
		9.2	Full direct jobs equivalent in the biomass consuming region (or country)	Number of jobs (gross figure) from biomass in the biomass consuming region (or country)
		9.3	Human and Labor Rights	Adherence to ILO (1998) principles and voluntary standards
		9.4	Occupational safety and health for workers	Measures taken to guarantee occupational and health safety for workers
	10. Health risks	10.1	Risks to public health	Measures taken to safeguard public health, i.e. regulation of noise level and prevention of accidents
	11.Food, fuelwood and other products	11.1	Food, fuelwood and other products supply security	Measures to avoid risks for negative impacts on price and supply of national food basket, fuelwood and other products.
Economic	12. Production costs	12.1	Current levelized life-cycle cost	Current levelized life-cycle cost, excluding subsidies (excl. subsidies, incl. CAPEX and OPEX)
		12.2	Future levelized life-cycle costs	Future levelized life-cycle cost, excluding subsidies (excl. subsidies, incl. CAPEX and OPEX)

Source: own elaboration

To have a better understanding of the sustainability requirements in other research projects, and apply their outcomes in S2Biom, a benchmark of the indicators proposed in these works against this proposal has been carried out, as shown in Table 4. The projects considered in this benchmark are:

- Biomass Policies (Panoutsou et al. 2013): This ongoing project "Strategic Initiative for Resource Efficient Biomass Policies" aims to develop integrated policies for the mobilisation of "resource efficient" indigenous bioenergy 'value chains' in order to contribute towards the 2020 bioenergy targets set within NREAPs & 2030, and other EU27/ national policy measures. Within the project principles of resource efficiency for biomass uses have been developed (Pelkmans et al. 2014). These principles and guidelines have been aligned with the efforts within S2Biom.
- BEE: Biomass Energy Europe (Vis et al. 2010). This project proposed a list of sustainability requirements to assess different types of biomass potentials.
- Biomass Futures (Fritsche et al. 2012). This project developed a set of criteria and indicators for bioenergy.
- BIOCORE: BIOCOmmodity Refinery (Piotrowski et al. 2013; Rettenmaier et al. 2014). This project focused on developing a sustainability approach for biorefinerires. Sustainability requirements of this project were harmonized with those of other research projects investigating biorefineries (e.g. EuroBioRef and Suprabio). The Star Colibri project[13], which also targeted biorefineries, provided an overview of fundamental considerations regarding environmental, economic and social aspects of biorefineries from a life cycle perspective. Given that the approach is based on LCA, the indicators have not been specifically included in this benchmark.
- Global BioPact (Diaz-Chavez et al. 2012). This project developed and harmonised a global sustainability certification systems for biomass production, conversion systems and trade in order to prevent negative socio-economic impacts.

Main differences between this proposal and the proposals of the projects stated above refer to:

At the **theme** level:

- The BIOCORE project took into account indicators related to technology that did not seem relevant in this umbrella proposal.

[13] http://www.star-colibri.net/wiki/index.php?title=Main_Page

- At the **criterion level**:
  - In the environmental theme, BEE, Biocore and Global Bio-Pact have included “Land Use, Land Use Change and indirect Land Use Change” (LU, LUC and iLUC) as a criterion. This proposal based on mid-point indicators does not take this criterion into account since it is a cross-cutting issue. Thus, issues related to “LU, LUC and iLUC” might have impacts on climate change, biodiversity soil or water mid point criteria and indicators. Because of this, provisions with respect to “LU, LUC and iLUC” will be considered when developing “implementable indicators”.
  - Rural development and infrastructure: this criterion, proposed in Biocore and addressed by Global Bio-Pact, is indirectly considered in the indicators proposed here with respect to jobs creation (see indicators 9.1 and 9.2). On the other hand, potential indicators under this criterion, should be “reporting indicators”. Same is the case with respect to “Production of feedstock”, “Identification of stakeholders along the supply chain” and “Policies and regulations”.
  - Gender equality: given the difficulty on proposing a sound definition of this criterion and the lack of sound data for its quantification, it has not been included in this proposal.
  - The Biomass Policies project also considers “Markets” and “System versatility” as criteria under the economic theme. Those criteria and corresponding indicators, even if relevant are related to the various systems and are not focused on the sustainability assessments of biomass potentials or values chains so have not been included in this proposal.
  - “Other economic considerations” refer to different issues as considered in Biocore and Global Bio-Pact. Most of this issues are related somehow to the production-costs and to avoid an extensive list of indicators they have not introduced here.
- At the **indicator level**:
  - The requirement stated in BEE, “Increase of resource efficiency” refers to recycle before waste is used for energy production, and ensure a sustainable use of renewable resources”. This is partially included in indicators 1.4 (Functionality) and 11.1 (Measures to avoid risks for negative impacts on price and supply of national food basket and fuelwood) of this proposal.
  - “Fauna” and “Landscape”, as proposed in Biocore, are covered by the criterion for biodiversity.
  - “Photochemical ozone formation (POPC)” and “(Stratospheric) Ozone depletion”. These indicators are partially covered though the “Life Cycle-based CO_2eq including direct land use change” and the “SO_2eq emissions”. POPC might be relevant due to CO release, when biomass is combusted incompletely. This might happen only in fireplaces and stoves. Then, given this limited potential impacts, these indicators have not taken into account in the S2Biom proposal.

It is worth noting that in the scientific discussion around “relevant” environmental impact categories, the UNEP-SETAC Life-Cycle Initiative tries to achieve a broad consensus[14]. Following lines aim to explain why some of the impact categories included in the “LCA indicators” (see JRC 2014) are not directly covered here.

One outcome of the UNEP-SETAC Life-Cycle Initiative is a prioritization of impact categories which identified global warming (i.e. climate change), particulate matter (e.g. PM_{10}), land and water use as well as acidification, among others, as key issues (Jolliet et al. 2014), and argues:

"The success of the Montreal protocol makes stratospheric ozone depletion less relevant as the magnitude of impacts has been largely mitigated." (Jolliet et al. 2014:964)

Furthermore, biomass systems typically contribute only very small emissions relevant for this impact category (similar for tropospheric ozone formation).

Acidification is most commonly expressed in SO_2eq (instead of mol H+ eq) and data for particulate matter emissions are available typically for PM_{10} (instead of $PM_{2.5}$).

As regards mineral and fossil resource depletion, the use of Antimon equivalents (Sbeq) is surely one option to quantify impacts, but it may be more informative to differentiate overall resource and to focus on e.g. non-renewable primary energy factors (PEF).

Last but not least, the environmental impacts are just on part of sustainability assessment (see e.g. Singh et al. 2012). Indeed, social and economic issues are also relevant.

[14] See http://www.lifecycleinitiative.org/

Table 4 Benchmark of the indicators included in previous relevant research projects

Theme	Criterion	Indicator	S2Biom	Biomass Policies	BEE	Biomass Futures	Biocore	Global Bio-Pact
Environmental	Resource use	Land Use Efficiency	✓	✓		✓		
		Secondary Resource Efficiency	✓	✓		✓		
		Energy Efficiency	✓	✓			~	
		Functionality (Output service quality)	✓	✓				
		Increase of resource efficiency		~	✓			
	Climate Change	Life cycle-based CO_2eq including direct land use change	✓	✓		✓	✓	
		Other GHG emissions	✓	✓		✓		
	Biodiversity	Protected areas and land with significant biodiversity values	✓	✓	✓	✓		~
		Biodiversity conservation and management	✓	✓	✓	✓		✓
		Fauna					✓	✓
		Landscape					✓	
		Access to ecosystem services						✓
	Soil	Erosion	✓	✓	✓	✓	✓	✓
		Soil Organic Carbon	✓	✓	~	✓	✓	✓
		Soil nutrient balance	✓	✓	~	✓	~	✓
	Water	Water availability and regional water stress	✓	✓	✓	✓	✓	✓
		Water use efficiency	✓	✓				
		Water quality	✓	✓	✓	✓	✓	✓
	Air	SO_2 equivalents	✓	✓	✓	✓	✓	~
		PM_{10}	✓	✓	✓	✓	✓	~
		Photochemical ozone formation					✓	~
		(Stratospheric) ozone depletion					✓	
	Land use, LUC and iLUC	Land use, Land Use Change and indirect Land Use Change			✓		✓	✓
Social	Participation and transparency	Effective participatory processes	✓				✓	~
		Information transparency	✓					
	Land Tenure	Compliance with the Voluntary Guidelines on the Responsible Governance of Tenure of Land to secure land tenure and ownership (CFS 2012)	✓			✓	✓	✓
	Employment and labor rights	Full direct jobs equivalents along the full value chain	✓	✓			✓	~

Theme	Criterion	Indicator	S2Biom	Biomass Policies	BEE	Biomass Futures	Biocore	Global Bio-Pact
		Full direct jobs equivalent in the biomass consuming region (or country)	✓	✓				
		Human and Labor Rights	✓		✓	✓	✓	✓
		Occupational safety and health for workers	✓				✓	✓
	Health risks	Risks to public health	✓					
	Food, fuelwood and other products	Measures to avoid risks for negative impacts on price and supply of national food basket, fuelwood and other products	✓		~	✓	~	✓
	Rural development and infrastructure	Rural development and infrastructure		✓			✓	✓
		Local embedding-proximity to markets		✓				
	Production of feedstock	Production of feedstock					✓	
	Identification/involvement of stakeholders along the supply chain	Identification of stakeholders along the supply chain					✓	~
	Policies and regulations	Policies and regulations					✓	
	Gender equality	Gender equality					✓	✓
Economic	Production costs	Current levelized life-cycle cost (excl. subsidies, incl. CAPEX and OPEX)	✓	✓			✓	✓
		Future life cycle costs		✓				
	Markets	Business case for biomass mobilization		✓				
		Market size		✓				
		Technological maturity		✓				
		Other non-fossil alternatives		✓				
		Competing pathways/market distortion		✓				
		Access to markets					✓	
	System versatility	Flexibility and controllability		✓				
		(energy) security		✓				
	Other economic considerations	Internal Rate of Return					✓	
		Price support					✓	
		CO_2 avoidance costs					✓	
		Energy resource savings costs					✓	
		Value added						✓
		Taxes/royalties paid to the government						✓
		Contributions made by the operation to allied industries in the local economy						✓

Theme	Criterion	Indicator	S2Biom	Biomass Policies	BEE	Biomass Futures	Biocore	Global Bio-Pact
Technology		Maturity					✓	
		Availability of infrastructure for logistics and storage					✓	
		Use of GMOs					✓	
		Risk of explosions and fires					✓	
		Development of legislative framework and bureaucratic hurdles					✓	
		Feedstock flexibility of conversion technologies					✓	

Source: own elaboration

3.3 Basic and Advanced Set of Sustainability C&I

Based on the list of indicators proposed in Table 3, and considering the various ways to elaborate a basic and an advanced set of sustainability C&I as described in Section 2.3 (i.e. indicators to be considered and changes in the type of indicator), Table 5 presents a proposal of basic and advanced sustainability sets.

The basic set depicts a minimum sustainability ambition level (especially with respect to the indicators that might be “minimum requirements”). This proposal is in line with the Renewable Energy Directive requirements for biofuel and bioliquids (EU 2009). The advanced set is more ambitious in considering more indicators that are minimum requirements in contrast to be “reporting indicators”. These two sets aim to reflect „stronger“ or „looser“ sustainability concerns.

Table 5 S2Biom Proposal for Basic and Advanced Sustainability C&I Sets

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)						✓	✓	
	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}		✓	✓		✓			

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
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 labor rights	9.1	Full direct jobs equivalents along the full value chain		✓	✓			✓	✓	
		9.2	Full direct jobs equivalent in the biomass consuming region (or country)		✓	✓			✓	✓	
		9.3	Human and Labor 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 levelized life-cycle cost		✓	✓			✓	✓	
		12.2	Future levelized life-cycle costs						✓	✓	

Source: own elaboration

4. Way Forward

This umbrella proposal is the basis to carry out further work:

- Integrate further the **findings** from the ongoing work on analyses of sustainable bioeconomy in selected countries (Task 5.3), and from other ongoing projects, especially BioTrade2020plus and on cascading use of wood[15].
- **Further discussing** this approach to sustainability (i.e. list of indicators, type of indicators, scope, etc.) and proposed sets within S2Biom and with external stakeholders.
- Agree upon the **implementability** of the mid-point indicators and develop implementable indicators for specific feedstocks, value chains in different activities and for implementation in different tools in the project and for an overall sustainability evaluation framework to be used by end-users of the project.
- Develop **thresholds** for the indicators for all lignocellulose resources and value chains.
- Agree on how to **test** the indicators as part of activities in the S2Biom project.

[15] i.e. the on-going research project on "Resource efficiency by cascading use of biomass" by Nova Institute (http://www.biomassekaskaden.de/) and the EC funded „Study on Optimised Cascading Use of Wood (http://ted.europa.eu/udl?uri=TED:NOTICE:166917-2014:TEXT:en:HTML&src=0)

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