

## **METHODOLOGY FOR ENVIRONMENTAL SUSTAINABILITY ASSESSMENT IN THE FRAMEWORK OF BIOECONOMY OBSERVATORY \***

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### **1. Background and Context**

The methodology presented hereafter is meant to provide a user friendly tool to assess the environmental sustainability of bio-based products<sup>1</sup> and their supply chains, largely using a life-cycle perspective. It should be regarded as a comprehensive science-based method, able to provide quantitative understanding of a wide range of environmental aspects. In practice, its applicability may be constrained by the actual extent of availability and/or accessibility of data and information. In turn, applying the methodology can help identifying existing gaps in data and/or information availability and/or accessibility, thus bringing useful insights to the understanding of the product-system being assessed. In the context of this project, such a methodology will be used e.g. to conduct comparative environmental assessments of bio-based products along their supply chains, i.e. from primary production of biological resources to end-of-life (EoL) processes.

This methodology is largely based on the Product Environmental Footprint (PEF) method developed by the Joint Research Centre (JRC) of European Commission (EC) in close cooperation with the Directorate General for the Environment (DG ENV). The EC PEF method has undergone extensive testing and consultation phases and, ultimately, the 2013 Recommendation of the European Commission “on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations” supports its use when undertaking environmental footprint studies of products and organisations (EC, 2013a and 2013b).

The EC PEF method supports multi-criteria assessment of the environmental performance of products (i.e. goods or services, as from ISO14040:2006) throughout their life cycle (ISO, 2006). It can be used for in-house applications (e.g., support to environmental management, identification of environmental hotspots, environmental performance improvement and tracking) and external applications such as Business-to-Business (B2B) and Business-to-Consumers (B2C) e.g., marketing, benchmarking, environmental labelling, supporting eco-design throughout supply chains, green procurement, or responding to the requirements of environmental policies at European or Member State level. It aims at providing for a greater degree of methodological consistency and establishes unambiguous requirements, hence facilitating increased comparability and reproducibility of results.

Five key principles were considered for advancing the EC PEF method:

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<sup>1</sup> Bio-based products are products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilized (CEN – Report on Mandate M/429).

1. Relevance: all accounting models used and data collected should be as relevant to the study as possible;
2. Completeness: PEF studies should include all environmentally relevant material / energy flows, all relevant impact categories and other environmental interventions as required for adherence to the defined system boundaries, the data requirements and the impact assessment models employed;
3. Consistency: PEF studies should adhere to “strict” guidelines allowing for limited flexibility in order to make it possible to develop consistent assessment studies;
4. Accuracy: all reasonable efforts should be taken to reduce uncertainties in product system modelling and reporting of results;
5. Transparency: PEF information should be disclosed in such a way as to provide intended users with the necessary basis for decision-making, and for stakeholders to assess its robustness and reliability.

The next section presents the methodology for environmental sustainability assessment elaborated for the Bioeconomy Observatory (BISO). This is intended as an adaptation of the general (i.e. applicable to virtually any products) EC PEF method to the specific context of bio-based products and their supply chains.

## 2. Methodology for Environmental Sustainability Assessment of Bio-Based Products

### 2.1 Overview

The methodology for environmental assessment of bio-based products is structured into six phases: (1) definition of the goals of the assessment, (2) definition of the scope of the assessment, (3) development of the assessment inventory, (4) development of the impact assessment, (5) interpretation and reporting of the results of the assessment, (6) critical review of the assessment (Figure 1).

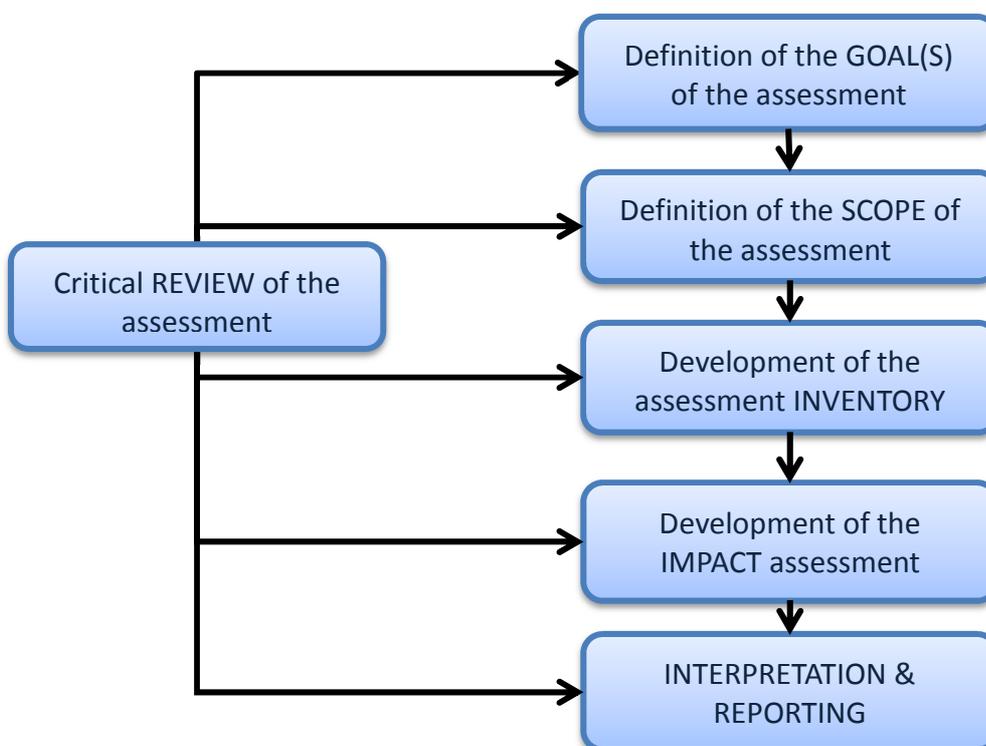


Figure 1: Phases of the methodology for environmental assessment of bio-based products.

## 2.2 Phase 1: Definition of the goals of the environmental assessment

The definition of the goals of the assessment is the first methodological phase, aiming at unambiguously identifying the general context of the evaluation. In practice, the goal definition should specify all of the aspects listed in the table hereafter:

**Table 1: Definition of the goal(s) of the environmental sustainability assessment**

Aspect of goal definition	Definition / Specifications / Examples
Intended applications	<p>Specification of the way(s) the results of the assessment are intended to be used.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Identify opportunities for improvements of the overall environmental performance of e.g. a wooden table;</li> <li>• Respond to a request from a consumer on a certain bio-based product;</li> <li>• Provide environmental information to be used for eco-labelling of a certain bio-based product;</li> </ul>
Reasons for carrying out the study	<p>Specification of the reason(s) for carrying out the assessment that will allow using the results of the assessment for its intended applications.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Identify the life cycle stages of e.g. a given wooden table that influence the most the environmental performance;</li> <li>• Quantify the impact on certain impact categories (e.g. Climate Change and Ozone Depletion) arising along the life cycle of e.g. one tonne of oranges.</li> </ul>
Whether comparisons and/or comparative assertions are to be disclosed to the public	<p>A comparative assertion is an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function. This should be clarified in the goal definition phase.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• The assessment will be made publicly available but it will not contain comparisons or comparative assertions;</li> <li>• The assessment will contain comparative assertions intended to be made publicly available.</li> </ul>
Target audience	<p>Specification of the person(s) / group(s) that are intended to use the assessment, its results and conclusions in order to fulfil its intended applications.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• The assessment is meant for any potential consumer of a given bio-based product;</li> <li>• The assessment is intended to be used by company “X” and company “Y”;</li> <li>• The assessment is intended to be used by a regulatory body that can use results of the assessment to define relevant product parameters used as objectives in product policies (e.g. Ecodesign, Ecolabel, etc.).</li> </ul>
Review procedure, if any	<p>Whether or not the study will undergo a critical review, and who will perform it.</p> <p>Example:</p> <ul style="list-style-type: none"> <li>• The study will undergo a third party critical review conducted by reviewers</li> </ul>

	"A", "B", and "C".
Commissioner or the study	<p>Specification of the person / entity / group that has mandated the assessment.</p> <p>Example:</p> <ul style="list-style-type: none"> <li>• Directorate General for the Environment (DG ENV) of the European Commission (EC);</li> <li>• Company "X";</li> <li>• University "Y".</li> </ul>

### 2.3 Phase 2: Definition of the scope of the environmental assessment

The definition of the scope of the assessment is the second methodological phase, aiming at unambiguously describing the system being assessed. Based on the indicators evaluated in this phase of the methodology, and based on the outcome of the review of relevant reports/studies from internal and external to the JRC source, e.g. various FP7 projects, studies of other DGs (which is being conducted by the JRC Institute for Environment and Sustainability in the framework of the Bioeconomy Observatory), it is foreseen that minimum sets of sustainability criteria will be elaborated.

In practice, the scope definition should address all of the aspects listed in the table hereafter:

**Table 2: Definition of the scope of the environmental sustainability assessment**

Aspect of scope definition	Definition / Specifications / Examples
Unit of analysis and reference flow	<p>The <b>unit of analysis</b> should be defined according to the following aspects<sup>2</sup>: the functions(s) / service(s) provided ("what"), the extent of each function/service ("how well"), the expected level of quality ("how well"), the duration / life-time of the bio-product ("how long").</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Assessment of one table made of red-pine wood and used for 30 years before it is incinerated in a municipal solid waste incinerator with high-efficiency energy recovery;</li> <li>• Assessment of compost produced from municipal biodegradable waste by in-vessel composting technique, and used for soil as replacement of chemical fertilizers.</li> </ul> <p>The <b>reference flow</b> is the amount of bio-based product that is needed to provide the defined unit of analysis. The reference flow is used as a reference for the subsequent phases of "inventory" and "impact assessment", in that any input/output flow and any estimated impact will be expressed "per reference flow". For instance, with respect to the two above examples of unit of analysis, potential reference flows could be:</p> <ul style="list-style-type: none"> <li>• 75 kg of red-pine wood;</li> <li>• 1 tonne of compost.</li> </ul>
Boundary of the system assessed	<p>The system boundary defines which parts of the life-cycle of the bio-based product and which associated processes belong to the product-system being assessed, i.e. are needed for carrying out the function(s) defined by the unit of analysis. It is recommended to include a system boundary diagram to help visualize and structure the system being assessed.</p> <p>The system boundary should be defined following the general cradle-to-grave supply-chain</p>

<sup>2</sup> Depending on the specific bio-based product system, not all of these aspects may always be specified.

	<p>logic, thus including all stages from primary production of biological resources through processing, production, distribution, storage, use stage and End of Life (EoL) treatment.</p> <p>It is recommended to divide the processes included in the system boundaries into <b>foreground processes</b> (i.e. core processes in the product life cycle for which direct access to information/data is available<sup>3</sup>) and <b>background processes</b> (i.e. those processes in the product life cycle for which no direct access to information/data is possible<sup>4</sup>).</p>
Impact categories	<p><b>Impact categories</b> refer to specific categories of impacts considered in an environmental assessment study. These are generally related to resource use, emissions of environmentally damaging substances (e.g., greenhouse gases and toxic chemicals), which may as well affect human health. These categories refer to specific <b>impact assessment methods</b> used for quantifying the causal relationships between the material/energy inputs and the emissions associated with the product life cycle (assessment inventory) and each impact category considered. Each category, hence, refers to a certain stand-alone <b>impact assessment model</b>.</p> <p>The list of recommended environmental impact categories and related impact assessment models for inclusion in the assessment is provided by Table 5 in Annex 1.</p>
Additional environmental information	<p>Relevant potential environmental impacts of a product (including of bio-products) may go beyond the life-cycle based impact categories listed in Table 5 (Annex 1). It is important to consider these environmental impacts whenever feasible. For example, biodiversity impacts due to land use changes may occur in association with a specific site or activity.</p> <p>This may involve the application of additional impact categories or other quantitative indicators that are not included in the default list provided here, or even additional qualitative criteria/descriptions where impacts cannot be linked to the product supply-chain in a quantitative manner. Such additional information should be viewed as <b>optional, complementary</b> to the default list of impact categories and it is intended to help interpreting the results of the assessment and deriving conclusions. Additional environmental information should be:</p> <ul style="list-style-type: none"> <li>• Based on information that is substantiated and has been reviewed or verified;</li> <li>• Specific, accurate and not misleading;</li> <li>• Relevant to the particular type of bio-based product.</li> </ul> <p>For the purpose of environmental assessment of bio-based products, the following relevant aspects may be considered for inclusion as “additional environmental information”:</p> <ul style="list-style-type: none"> <li>• Indicators on the content of bio-based materials in typical product groups;</li> <li>• Recoverability rates indicators (i.e. recyclability rate and energy recoverability rates) for typical bio-based products groups (wholly or partly derived from materials of biological origin);</li> <li>• Content of recycled materials (including recycled fibres) in the product;</li> <li>• Environmentally based life cycle indicators associated to the content of bio-based materials in the product (including the content of recycled fibres), compared to the non bio-based materials;</li> <li>• Environmentally based life cycle indicators associated to the recoverability rates, compared to the option when the materials are landfilled;</li> <li>• Presence of hazardous substances in the product (type, quantity);</li> <li>• Indicators for biomass resources availability<sup>5</sup></li> <li>• Indicators for biomass provision and costs<sup>6</sup></li> </ul>

<sup>3</sup> For example, the producer’s site and other processes operated by the producer or its contractors such as goods transport, head-office services, etc.

<sup>4</sup> For example, e.g. most of the upstream life cycle processes – such as infrastructures, buildings - and generally all processes further downstream

<sup>5</sup> This should presumably and partially come as input from the economic and socio-economic assessment conducted within the framework of Bioeconomy Observatory (BISO)

<sup>6</sup> This should presumably come as input from the economic and socio-economic assessment conducted within the BISO framework

	<ul style="list-style-type: none"> <li>• Indicators for biomass demand<sup>7</sup></li> <li>• Indicators for the proportion of biomass issue from organic agriculture and / or processed via certified organic processors.</li> </ul> <p>These aspects are presented and elaborated in Annex 1</p>
Assumptions and limitations	<p>Several limitations to carrying out the analysis may arise and therefore assumptions need to be made. All assumptions should be justified and transparently documented. For instance, accessible site-specific data typically do not cover in full the need of data to conduct the assessment, thus generic, site-unspecific data (not representing the reality of the product analysed) may need to be identified and adapted for better representation before they can be used in the assessment.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• In a bio-based product system such as “production of wooden table”, several types of chemicals are used, but for some of these chemicals not all the necessary information is known/accessible (e.g. amount used, concentrations). Other comparable bio-based product systems are thus looked at to extrapolate the missing information.</li> <li>• In a bio-based product system such as “production of compost from biodegradable waste”, no information is available / accessible on the type of chemical fertilizer that the compost will replace. This may be approached in a conservative way by neglecting the benefits arising from the replacement of the chemical fertilizer, or by accounting for these benefits making an assumption on the type of chemical compost that would likely be replaced.</li> </ul>

## 2.4 Phase 3: Development of the assessment inventory

### 2.4.1 Overview

An inventory of all material / energy resource inputs / outputs and emissions into air, water and soil for the product supply chain has to be compiled as a basis for evaluating the environmental performance. Ideally, the model of the product supply chain should be constructed using product-specific data (i.e. modelling the exact life cycle depicting the supply chain, use, and end-of-life stages as appropriate). In practice and as a general rule, directly collected and facility-specific inventory data should be used wherever possible. For processes where the company does not have direct access to specific data (i.e. background processes), generic data<sup>8</sup> will typically be used.

All resource use and emissions associated with the life-cycle stages included in the defined system boundaries should be considered in the assessment inventory. In particular, the elements described in the next subchapter should be taken into account to populate the assessment inventory (Table 3).

### 2.4.2 Compiling the assessment inventory

<sup>7</sup> This should presumably come as input from the economic and socio-economic assessment conducted within the BISO framework

<sup>8</sup> Generic data refers to data that is not directly collected, measured, or estimated, but rather sourced from a third-party life cycle inventory database or other source.

**Table 3: Key aspects for consideration in the compilation of the assessment inventory**

Aspect of scope definition	Definition / Specifications / Examples
Raw material acquisition and pre-processing	<p>The raw material acquisition and pre-processing stage starts when resources are extracted from nature and ends when the product components enter (through the gate of) the product's production facility. Processes that may occur in this stage include e.g.:</p> <ul style="list-style-type: none"> <li>• Mining and extraction of resources;</li> <li>• Pre-processing of all material inputs to the studied product system;</li> <li>• Conversion of recycled material;</li> <li>• Photosynthesis for the biogenic fraction of the bio-based product;</li> <li>• Cultivation and harvesting of trees or crops;</li> <li>• Transportation within and between extraction and pre-processing facilities, and to the production facility.</li> </ul>
Capital goods	<p>Examples of capital goods that should be included (if applicable) are:</p> <ul style="list-style-type: none"> <li>• Machinery used in production processes;</li> <li>• Buildings;</li> <li>• Office equipment;</li> <li>• Transport vehicles;</li> <li>• Transportation infrastructure.</li> </ul> <p>Linear depreciation should be used for capital goods. The expected service life of the capital goods should be taken into account (and not the time to evolve to an economic book value of "0").</p>
Production, distribution and storage	<p>Products are distributed to users and may be stored at various points along the supply chain. Examples of processes related to distribution and storage that should be included (if applicable) are:</p> <ul style="list-style-type: none"> <li>• Energy inputs for warehouse lighting and heating;</li> <li>• Use of refrigerants in warehouses and transport vehicles;</li> <li>• Fuel use by vehicles.</li> </ul>
Use stage	<p>The use stage begins when the consumer or end user takes possession of the product and ends when the used product is discarded for transport to a recycling or waste treatment facility. Examples of use-stage processes that should be included (if applicable) are:</p> <ul style="list-style-type: none"> <li>• Use/consumption patterns, location, time (day/night, summer/winter, week/weekend), and assumed use stage lifespan of products;</li> <li>• Transportation to the location of use;</li> <li>• Refrigeration at the location of use;</li> <li>• Preparation for use (e.g. microwaving);</li> <li>• Resource consumption during use (e.g. energy consumption for microwaving, water use, etc.);</li> <li>• Repair and maintenance of the product during the use stage.</li> </ul>
Logistics	<p>Transport parameters that should be taken into account are:</p> <ul style="list-style-type: none"> <li>• <b>Transport type:</b> The type of transport, e.g. by land (truck, rail, pipe), by water (boat, ferry, barge), or air (airplane), should be taken into account;</li> <li>• <b>Vehicle type and fuel consumption:</b> The type of vehicle should be taken into account by transport type, as well as the fuel consumption when fully loaded and empty. An adjustment should be applied to the consumption of a fully-loaded vehicle according</li> </ul>

	<p>to loading rate<sup>9</sup>;</p> <ul style="list-style-type: none"> <li>• <b>Number of empty returns</b> (when applicable), i.e. the ratio of the distance travelled to collect the next load after unloading the product to the distance travelled to transport the product;</li> <li>• <b>Transport distance</b>;</li> <li>• <b>Fuel production</b>.</li> </ul> <p>Additional transport parameters that should be taken into account (if relevant) are: transport infrastructure, additional resources and tools such as cranes and transporters, allocation for personal transport based on time or distance, allocation for staff business travel based on time, distance or economic value.</p>
End of Life (EoL)	<p>The EoL stage begins when the used product is discarded by the user and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). Examples of EoL processes that (if applicable) should be included in the assessment are:</p> <ul style="list-style-type: none"> <li>• Collection and transport of end-of-life products and packages;</li> <li>• Dismantling of components;</li> <li>• Shredding and sorting;</li> <li>• Conversion into recycled material;</li> <li>• Biological treatment, e.g. composting and anaerobic digestion;</li> <li>• Littering;</li> <li>• Incineration and disposal of bottom ash;</li> <li>• Landfilling and landfill operation and maintenance;</li> <li>• Transport required to all EoL treatment facilities.</li> </ul> <p>A comprehensive source of technical information about management of biodegradable waste and methodological specification on life-cycle modelling is provided by the JRC technical report "Supporting environmentally sound decisions for bio-waste management – A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA)" (EC, 2010).</p> <p>Life cycle inventories for these EoL processes have to be typical of the bio-product groups and of the materials contained in them.</p>
Accounting for electricity use	<p>For electricity from the grid consumed upstream or within the defined assessment boundary, supplier-specific data should be used if available. If these are not available, country-specific consumption-mix data should be used of the country in which the life cycle stages occur. For electricity consumed during the use stage of products, the energy mix should reflect ratios of sales between countries or regions. Where such data are not available, the average EU consumption mix, or otherwise the most representative mix, should be used.</p>
Accounting for renewable energy generation	<p>Within the assessed system boundary, energy may be produced from renewable sources. If <b>renewable energy</b> is produced in excess of the amount consumed within the defined system boundary and it is provided to, for example, the electricity grid, this should be credited to the product assessed provided that the credit has not already been taken into account in other schemes. Credits associated with renewable energy generated by the system boundary should be calculated with respect to the corrected (i.e. by subtracting the externally provided amount of renewable energy) average, country-level consumption mix of the country to which the energy is provided. Where such data is not available, the corrected average EU consumption mix, or otherwise the most representative mix should be used.</p>
Accounting for removals and emissions of	<p>Carbon can be removed from the atmosphere due to the growth of trees (characterisation factor<sup>10</sup> of -1 CO<sub>2</sub> eq. for the category Climate Change), while it is released during the burning of wood (characterisation factor of +1 CO<sub>2</sub> eq. for the category Climate Change).</p>

<sup>9</sup> The loading rate is the ratio of actual load to the full load or capacity (e.g. mass or volume) that a vehicle carries per trip.

biogenic carbon	Removals and emissions of biogenic carbon sources should be kept separated when compiling the assessment inventory <sup>11</sup> .
Accounting for temporary carbon storage and delayed emissions	Credits associated with temporary (carbon) storage or delayed emissions should not be considered in the calculation of the default impact categories. However, if relevant, these should be included as “additional environmental information”.

### 2.4.3 Data quality evaluation

In order to obtain reliable results from the environmental assessment it is essential to use high quality data. For this purpose, it is important to evaluate the quality of the data collected in order to verify whether these provide for a robust assessment or whether better data should be identified. In order to evaluate data quality, the following criteria should be considered:

- **Technological representativeness (TeR):** i.e. the degree to which the dataset reflects the true population of interest regarding technology, including the background datasets, if any;
- **Geographical representativeness (GR):** i.e. the degree to which the dataset reflects the true population of interest regarding geography, including the background datasets, if any;
- **Time-related representativeness (TiR):** i.e. the degree to which the dataset reflects the true population of interest regarding technology, including the background datasets, if any;
- **Completeness (C):** to be judged with respect to the coverage for each impact category and in comparison to a hypothetical ideal data quality;
- **Parameter uncertainty (P):** qualitative expert judgement or relative standard deviation as percentage if a Monte Carlo simulation is used;
- **Methodological Appropriateness and Consistency (M):** the applied inventory methods and methodological choices (e.g. allocation, substitution, etc.) are in line with the goal and scope of the dataset, especially its intended applications as support to decisions. The methods have also been consistently applied across all data.

### 2.4.4 Data collection

Specific data are those data (directly measured or collected) that are representative of activities at a specific facility or set of facilities. Specific data can be collected, measured or calculated using activity data<sup>12</sup> and related emission factors.

Generic data refer to data that are not based on direct measurements or calculation of the respective processes in the system. Generic data can be either sector-specific, i.e. specific to the sector being considered for the environmental assessment, or multi-sector. Examples of generic data include: data from

<sup>10</sup> A characterisation factor is a factor derived from a characterisation model which is applied to convert each inventory flow to the common unit of the impact category indicator (based on ISO 14040:2006).

<sup>11</sup> A separate inventory of emissions/removals of biogenic carbon sources implies that the following characterisation factors should be assigned for the environmental footprint impact category Climate Change: “-1” for removals of biogenic carbon dioxide; “+1” for emissions of biogenic carbon dioxide; “+25” for methane emissions.

<sup>12</sup> Activity data are data that are specific to the process being considered, as opposed to generic data.

literature or scientific papers; industry-average life-cycle data from life-cycle-inventory databases, industry association reports, government statistics, etc.

The data should include all known inputs and outputs for the processes. Inputs are (for example) use of energy, water, materials, etc. Outputs are the products, co-products<sup>13</sup> and emissions. Emissions can be subsequently divided into four categories: emissions to air, to water, to soil, and emissions as solid waste.

Specific data should be obtained for all foreground processes and for background processes, where appropriate. However, if generic data are more representative or appropriate than specific data for foreground processes (to be justified and reported), generic data should also be used for the foreground processes. Generic data should be used only for processes in the background system (unless they are more representative or appropriate than specific data for foreground processes). When available, sector-specific generic data should be used instead of multi-sector generic data.

## **2.5 Phase 4: Development of the impact assessment**

### **2.5.1 Overview**

Once the assessment inventory has been compiled, the impact assessment should be undertaken to calculate the environmental performance of the bio-based product, using the selected impact categories and models (Table 5, Annex 1). The impact assessment phase does not have the objective to predict whether at any specific location and at any specific time thresholds are exceeded and actual impacts occur. In contrast, it describes the existing pressures on the environment, resource consumption and human health. The impact assessment phase includes two mandatory steps – classification and characterisation, and two optional steps – normalisation and weighting.

#### **2.5.1 Mandatory steps: classification and characterisation**

**Classification** requires assigning the material/energy inputs and outputs included in the assessment inventory to the relevant impact categories. For example, during the classification phase, all inputs/outputs that result in greenhouse gas emissions are assigned to the Climate Change category. Similarly, those that result in emissions of ozone-depleting substances are classified accordingly to the Ozone Depletion category. In some cases, an input/output may contribute to more than one impact category. For example, chlorofluorocarbons (CFCs) contribute to both Climate Change and Ozone Depletion.

**Characterisation** refers to the calculation of the magnitude of the contribution of each classified input/output to their respective impact categories, and aggregation of the contributions within each category. This is carried out by multiplying the values in the assessment inventory by the relevant characterisation factor for each impact category. The characterisation factors (CFs) are substance- or resource- specific. They represent the impact intensity of a substance relative to a common reference substance for a given impact category. For example, in the case of calculating climate change impacts, all greenhouse gas emissions inventoried are weighted in terms of their impact intensity relative to carbon dioxide, which is the reference substance for this category. This allows for the aggregation of impact

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<sup>13</sup> Co-product – any of two or more products coming from the same unit process or product system (ISO 14040:2006)

potentials and expression in terms of a single equivalent substance (in this case – CO<sub>2</sub> equivalents) for each impact category. For example, the CF expressed as global warming potential for methane equals 25 CO<sub>2</sub> – equivalents and its impact on global warming is thus 25 times higher than that of CO<sub>2</sub> (i.e. CF of 1 CO<sub>2</sub>-equivalent).

### **2.5.2 Optional steps: normalisation and weighting**

Following the two mandatory steps of classification and characterisation, the impact assessment phase may be complemented with normalisation and weighting.

**Normalisation** is a recommended step, where the impact assessment results are multiplied by normalisation factors (NFs). This is done in order to calculate and compare the magnitude of their contributions to the impact categories relative to a reference unit (typically the pressure related to that category caused by the emissions over one year of a whole country or an average citizen). As a result, dimensionless normalised results are obtained. They reflect the burdens attributable to a product relative to the reference unit, such as per capita for a given year and region. This allows the relevance of the contributions, made by individual processes, to be compared to the reference unit of the considered impact categories. For example, impact assessment results may be compared to the same impact assessment results for a given region such as the EU-28 and on a per person basis. In that case they would reflect person-equivalents relative to the emissions associated with the EU-27. Normalised impact assessment results do not, however, indicate the severity or relevance of the respective impacts.

**Weighting** is not an optional step that may support the interpretation and communication of the results of the analysis. At this step, impact assessment results (normalised results, for example) are multiplied by a set of weighting factors that reflect the perceived relative importance of the considered impact categories. Weighted impact assessment results can then be compared to judge their relative importance. They can also be aggregated across impact categories to obtain several cumulative values or a single overall impact indicator. Weighting requires making value judgements as to the respective importance of the considered impact categories. These judgements may be based on expert opinion, cultural / political viewpoints or economic considerations.<sup>14</sup>

## **2.6 Phase 5: Interpretation and reporting the results of the assessment**

### **2.6.1 Interpretation of environmental assessment results**

Interpretation of the results of an environmental assessment study serves two purposes:

- The first is to ensure that the performance of the assessment exercise corresponds to the goals and scope of the study. In this sense, the interpretation phase may inform iterative improvements of the assessment until all goals and scopes are met or covered respectively;

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<sup>14</sup> For more information on existing weighting approaches in Life Cycle Impact Assessment, please refer to the reports developed by the JRC and CML entitled “Background review of existing weighting approaches in LCIA” and “Evaluation of weighting methods for measuring the EU-27 overall environmental impact”. These are available online at <http://lct.jrc.ec.europa.eu/assessment/publications>

- The second purpose is to derive robust conclusions and recommendations from the analysis, for example in support of environmental improvements.

To meet these objectives, the interpretation phase should include four key steps: (1) evaluation of robustness, (2) identification of hotspots, (3) estimation of uncertainty, and (4) formulation of conclusions and recommendations (Table 4).

**Table 4: Key steps of the interpretation phase**

Step	Definition / Specifications / Examples
Evaluation of robustness	<p>The robustness of the environmental assessment can be evaluated by assessing the extent to which methodological choices made for e.g. system boundaries, data sources, and coverage of the impact categories, influence the analytical outcomes. Tools that can be used for this purpose include:</p> <ul style="list-style-type: none"> <li>• <b>Completeness check:</b> evaluates the extent to which the assessment inventory is complete relative to the defined goals, scope and system boundaries. This includes completeness of process coverage (i.e. all processes at each supply-chain stage considered have been included) and input/output coverage (i.e. all material or energy inputs and emissions associated with each process have been included).</li> <li>• <b>Sensitivity checks:</b> assesses the extent to which the results are determined by specific methodological choices and the impact of implementing alternative choices where these are identifiable.</li> <li>• <b>Consistency check:</b> assesses the extent to which assumptions, methods, and data quality considerations have been applied consistently throughout the environmental assessment.</li> </ul>
Identification of hotspots	<p>Once it has been ensured that the environmental assessment is robust and conforms to all aspects defined in the goal and scope definition phases, the next step is to identify the main contributing elements to the calculated results. This step may also be referred to as “hotspot” or “weak point” analysis. Contributing elements may be specific life-cycle stages, processes or individual material/energy inputs/outputs associated with a given stage or process of the bio-based product supply chain. These are identified by systematically reviewing the calculated results. Such analyses provide the necessary basis to identify improvement potentials associated with specific management interventions.</p>
Estimation of uncertainty	<p>Estimating the uncertainties of the final assessment results supports iterative improvement of the studies. It also helps the target audience to assess the robustness and applicability of the assessment results. There are two key sources of uncertainty in environmental assessment studies:</p> <ul style="list-style-type: none"> <li>• <b>Stochastic uncertainties</b> for assessment inventory. Stochastic uncertainties (both parameter and model) refer to statistical descriptions of variance around a mean/average. For normally distributed data, this variance is typically described in terms of an average and standard deviation. Assessment results that are calculated using average data (i.e. the mean of multiple data points for a given process) do not reflect the uncertainty associated with such variance. However, uncertainty may be estimated and communicated using appropriate statistical tools.</li> <li>• <b>Choice-related uncertainties.</b> Choice-related uncertainties arise from the methodological choices including modelling principles, system boundaries, choice of impact assessment methods and other assumptions related to time, technology, geography, etc. These are not readily amenable to statistical</li> </ul>

	description, but rather can only be characterised via scenario model assessments (e.g. modelling worst- and best-case scenarios for significant processes) and sensitivity analyses.
Formulation of conclusions and recommendations	<p>The final aspect of the interpretation phase is to draw conclusions based on the analytical results, answer the questions posed at the outset of the assessment study and advance recommendations that are appropriate to the intended audience and context whilst explicitly taking into account any limitations to the robustness and applicability of the results.</p> <p>Potential improvements should be identified such as cleaner technology techniques, changes in product design, environmental management systems [e.g. Eco-Management and Audit Scheme (EMAS)] or other systematic approaches.</p>

### **2.6.2 Summary of results from the environmental assessment**

A summary of the environmental assessment should be developed in order to provide a relevant, comprehensive, consistent, accurate and transparent account of the study and of the calculated environmental impacts associated with the bio-based product. It reflects the best possible information in such a way as to maximise its usefulness for the intended current and future users, whilst honestly and transparently communicating limitations. The environmental assessment summary should consist of the following elements:

- Key elements of the goal and scope of the study with relevant limitations and assumptions;
- A description of the system boundary;
- The main results from the assessment inventory;
- Relevant statements about data quality, assumptions and value judgements;
- The main results from the impact assessment;
- A description of what has been achieved by the study, any recommendations made and conclusions drawn;
- Overall appreciation of the uncertainties of the results.

### **2.7 Phase 6: Critical review of the assessment**

Critical review is essential to ensure the reliability of the results from the environmental assessment and to improve the quality of its conclusions and recommendations. In particular, the critical review should ensure that:

- The methods used to carry out the assessment are scientifically and technically valid;
- The data used are appropriate, reasonable and of sufficient quality;
- The interpretation of results reflects the limitations identified;
- The study report is transparent, accurate and consistent.

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## ANNEX 1: METHODOLOGY FOR ENVIRONMENTAL SUSTAINABILITY ASSESSMENT OF BIO-BASED PRODUCTS – COMPLEMENTS

This annex complements the methodology for environmental sustainability assessment and should be considered as an essential part of such methodology.

### A – Recommended List of Impact Categories, Impact Assessment Models and Indicators

**Table 5: Default list of impact categories, models and indicators for inclusion in the environmental sustainability assessment**

Impact Category	Impact Assessment Model	Impact Category indicators	Source
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100 year time horizon.	kg CO <sub>2</sub> equivalent	Intergovernmental Panel on Climate Change, 2007
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon.	kg CFC-11 equivalent	WMO, 1999
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008
Human Toxicity - cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Human Toxicity – non-cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg PM2.5 equivalent	Humbert, 2007
Ionising Radiation – human health effects	Human Health effect model	kg U <sup>235</sup> equivalent (to air)	Dreicer et al., 1995
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC equivalent	Van Zelm et al., 2008 as applied in ReCiPe
Acidification	Accumulated Exceedance model	mol H+ eq	Seppälä et al., 2006;
Eutrophication – terrestrial	Accumulated Exceedance model	mol N eq	Seppälä et al., 2006;
Eutrophication – aquatic	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe
Resource Depletion – water	Swiss Ecoscarcity model	m <sup>3</sup> water use related to local scarcity of water	Frischknecht et al., 2008
Resource Depletion – mineral, fossil	CML2002 model	kg antimony (Sb) equivalent	van Oers et al., 2002
Land Transformation	Soil Organic Matter (SOM) model	Kg (deficit)	Milà i Canals et al., 2007
<p>* CFC-11 = Trichlorofluoromethane, also called freon-11 or R-11, is a chlorofluorocarbon.  ** PM2.5 = Particulate Matter with a diameter of 2.5 µm or less.  *** NMVOC = Non-Methane Volatile Organic Compounds  **** Sb = Antimony</p>			

## **B – Recommended Additional Environmental Information for Inclusion in the Environmental Impact Assessment**

### ***B.1 Additional indicators on resource efficiency of products***

Resource efficiency is currently high in the industrial and in the policy agenda<sup>15</sup>, and it has some strong links with other policies such as sustainable production and consumption, product and waste policies. Although LCA is in principle a powerful tool that could address resource efficiency of products, it still falls short of addressing many important aspects of resource efficiency. The JRC Institute for Environment and Sustainability has recently developed the method called Resource Efficiency Assessment of Product (REAPro) aiming at addressing some of these aspects, using a life cycle perspective<sup>16,17,18,19</sup>. The method assesses the performances of products against various criteria including recycled content, environmentally-weighted recycled content, recyclability / recoverability rates, environmentally-weighted recyclability / recoverability rates, presence of hazardous substances and durability. It has been already identified that other parameters concerning bio-based materials contained in products (e.g. % content of bio-based materials, environmentally-weighted content of bio-based materials, etc.) should also be addressed<sup>14</sup>. For the Bio-economy Observatory, the following indicators have been identified as potentially relevant:

- Indicators for the content of bio-based materials in typical product groups;
- Recoverability rates indicators (i.e. recyclability rate and energy recoverability rates) for typical bio-based product groups (wholly or partly derived from materials of biological origin);
- Content of recycled materials (including recycled fibres) in the product;
- Environmentally based life cycle indicators associated with the content of bio-based materials in the product (including the content of recycled fibres), compared to the non-bio-based materials;
- Environmentally based life cycle indicators associated with the recoverability rates, compared to the option when the materials are landfilled;
- Presence of hazardous substances in the product (type, quantity).

Based on the multi-criteria assessment, the REAPro methodology leads to the identification of product's hot spots (i.e. product's parts that are relevant to some resource efficiency criteria). Successively, the method identifies potential product's measures for the improvement of the resource efficiency and assesses the measures at the case-study level and at the product group level. Product's measures can be suitable for different policies, including requirements of regulatory policies (e.g. enforced via the EU Ecodesign Directive) or voluntary policies (e.g. environmental labelling schemes or environmental claims).

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<sup>15</sup> European Commission (EC), 2011. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Roadmap to a Resource Efficient Europe. Brussels, 20.9.2011. COM(2011) 571 final.

<sup>16</sup> Ardente, F., Mathieux, F., 2013. Identification and assessment of product's measures to improve resource efficiency of products: the case-study of an Energy Using Product. (Submitted to the Journal of Cleaner Production – 8th January 2013).

<sup>17</sup> Ardente, F., Mathieux, F. Recchioni, M. 2013. Combining five criteria to identify relevant products measures for resource efficiency of an energy using product. 20th CIRP International Conference on Life Cycle Engineering, Singapore, 17-19 April 2013, pp. 111-116.

<sup>18</sup> Allacker K, Mathieux F, Manfredi S, Pelletier N, De Camillis C, Ardente F, Pant R. Allocation solutions for secondary material production and end of life recovery: proposals for policy initiatives. Resources Conservation and Recycling. Submitted in April 2013; 2013.

<sup>19</sup> F. Ardente, F. Mathieux. Refined methods and Guidance documents for the calculation of indices concerning Reusability / Recyclability / Recoverability, Recycled content, Use of Priority Resources, Use of Hazardous substances, Durability. JRC Technical Report. September 2012

## **B.2 Additional indicators on availability, costs and demand of biomass resources**

The Land Use Modelling Platform<sup>20</sup> (LUMP) is a GIS-based platform that enables dynamic simulation of competing land uses based on pre-defined allocation rules (for example, land demand, neighbourhood characteristics, suitability factors and scenario/policy-specific decision rules). LUMP is interoperable with numerous existing models/data sources (CBM, CAPRI, EUROP2008, LEITAP/IMAGE, TRANSTOOLS, GEM-E3, RHOMOLO, POLES, etc.) and impact assessment models (LISFLOOD, SOC-TOP, GUIDOS, GREEN/SWAT, EFD, EDGAR, etc.) and can be used for the purpose of constructing spatially and temporally-specific models that combine environmental, social and economic indicator data<sup>21 22</sup>.

The added value of such land-use modelling approach is chiefly related to the possibility of dynamically simulating the competition between different land uses. In fact, sectorial macro-economic models provide projections for economic activities and land requirements at national or regional scale under specific scenarios. These requirements, together with the building pressure generated by the population dynamics, are responsible for a tight competition for land at local level. Therefore, the resulting land use changes might not fully satisfy all these land requirements. Besides that, the local land use/cover changes and the resulting patterns (landscapes) affect the performance of several environmental indicators, e.g. related to biodiversity, soil quality<sup>23 24</sup> and water consumption<sup>25 26</sup>.

Within the context of the Bioeconomy Observatory, the LUMP platform could possibly contribute to the estimation of indicators related to the availability, costs and demand of biomass resources. The environmental impacts of production and consumption systems on the resource 'land' can be identified with a spatially-explicit approach. Indicators of interest are:

### Biomass resources availability

1. Dedicated energy crops (i.e. New Energy Crops - NECR)
  - a. Total availability of NECR, regional level (Nomenclature of Territorial Units for Statistics, level 2 - NUTS2)<sup>27</sup>:

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<sup>20</sup> Lavalley, C., Baranzelli, C., Batista e Silva, F., Mubareka, S., Rocha Gomes, C., Koomen E., Hilferink, M., 2011. A high resolution land use/cover modelling framework for Europe. ICCSA 2011, Part I, LNCS 6782, 60–75.

<sup>21</sup> Lavalley, C., Baranzelli, C., Mubareka, S., Rocha Gomes, C., Hiederer, R., Batista e Silva, F., Estreguil, C., 2011. Implementation of the CAP Policy Options with the Land Use Modelling Platform: A first indicator-based analysis. JRC Scientific and Technical Reports EUR 24909 EN doi: 10.2788/45131.

<sup>22</sup> Batista e Silva, F., Lavalley, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Baranzelli, C., Perpiña, C., Vandecasteele, I., Ustaoglu, E., Barbosa, A., 2013. Direct and Indirect Land Use Impacts of the EU Cohesion Policy - Assessment with the Land Use Modelling Platform. JRC Scientific and Policy Reports EUR 26460 EN doi: 10.2788/60631.

<sup>23</sup> Hiederer, R., Barbosa, A., Baranzelli, C., Grassi, G., Lavalley, C., 2013. IPCC Tier 1 Method for Estimating C-Stocks of Mineral Soils Applied to Modeled Land Use Change 2010-2050 - Contribution to JRC AA Nr 070307/2010/585065/A4: Analysis and modeling of energy, transport and climate change scenarios: future GHG emission from agriculture and forestry. JRC Technical Reports. *In publication*.

<sup>24</sup> Hiederer, R., Barbosa, A., Baranzelli, C., Lavalley, C., 2013. Land Use Related Changes in C-Stocks of Mineral Soils Indicator for Resource Efficiency - Contribution to JRC discussion paper: An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. JRC Technical Reports. *In publication*.

<sup>25</sup> Burek, P. A., Mubareka, S., Rojas Mujica, R. F., De Roo, A., Bianchi, A., Baranzelli, C., Lavalley, C., Vandecasteele, I., 2012. Evaluation of the effectiveness of Natural Water Retention Measures -Support to the EU Blueprint to Safeguard Europe's Waters - EUR 25551 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2012. JRC75938.

<sup>26</sup> De Roo, A., Burek, P. A., Gentile, A., Udias, A., Bouraoui, F., Aloe, A., Bianchi, A., La Notte, A., Kuik, O., Elorza Tenreiro, J., Vandecasteele, I., Mubareka, S., Baranzelli, C., Van Der Perk, M., Lavalley, C., Bidoglio, G., 2012. A multi-criteria optimisation of scenarios for the protection of water resources in Europe: Support to the EU Blueprint to Safeguard Europe's Waters - EUR 25552 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2012. JRC75919.

<sup>27</sup> For info: [http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts\\_nomenclature/introduction](http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction)

Allocated NECR per NUTS2 on available land, expressed in hectares and correspondent biofuel production, taking into account current constraints (e.g. protected areas and certain land use/cover classes must be excluded from the available land).

b. Availability of NECR, classified by suitability categories:

Allocated NECR, classified according to the local suitability of the land to grow NECR. The suitability map for NECR is based on climate conditions, topography, soil properties and current land uses. In short, the higher the suitability, the higher the potential productivity level without the need of additional inputs that are potentially harmful to the environment.

c. Availability of NECR on policy-relevant soil categories (unfavourable agriculture soil conditions):

Allocated NECR, classified according to the presence of some location-specific soil categories, e.g. associated with land degradation and contamination issues. The conversion of this land to NECR might have additional positive benefits due to the reclamation and utilization of degraded, marginal and abandoned lands.

2. Provision of primary agricultural residues:

a. Availability of agricultural land suitable for the provision of primary agricultural residues, based on the CAPRI model projections:

Allocated land per NUTS2, expressed in hectares and corresponding quantity of raw residues/produced biofuels.

b. Availability of agricultural land suitable for the provision of primary agricultural residues, based on additional environmental and bio-physical criteria:

Allocated land per NUTS2, expressed in hectares and corresponding quantity of raw residues/produced biofuels.

3. Biomass for energy purposes from forest:

a. Availability of forest land suitable for the provision of biomass for energy purposes:

Allocated forest land per NUTS2, expressed in hectares, taking into account environmental and basic technical constraints associated with biomass extraction activities.

b. Availability of biomass for energy purposes from forest land, taking into account environmental, bio-physical and forest management criteria:

Biomass from forest land, per NUTS2.

4. Local availability of raw materials:

c. Distribution of Collection Centres:

Allocation of local collection facilities for biomass raw material.

### Biomass provision and costs

5. Costs associated with some stages of the supply chain (e.g. transport and pre-processing from field to collection point / biorefinery, etc.)

### Biomass demand

6. Demand from potential users (e.g. urban settlements, existing power plants, etc.)

### ***B.3 Additional indicator on the proportion of biomass issue from organic agriculture and / or processed via certified organic processors.***

The increased consumer demand for organic products and the development of a European-wide legislation ([http://ec.europa.eu/agriculture/organic/eu-policy\\_en](http://ec.europa.eu/agriculture/organic/eu-policy_en)) on organic products and processes, as well as the collection of statistical data on production, open the possibility to develop an “organic fraction indicator” for bio-based products. The delivery of the organic label being based on an environmental (often localised) life cycle analysis, such an indicator, could also be used as a proxy for environmental impact. However, methodologies to quantify such an indicator, at the production stage or in the production of goods of mixed origin, are not yet available.

### ***B.4 Ecosystem Services***

#### **Ecosystem services**

Ecosystems provide a diverse range of goods and services, including food, timber, clean air and water and recreation opportunities. These so-called ecosystem services are vital to our well-being (Millennium Ecosystem Assessment, 2005). The continued and sustainable provision of ecosystem services and the protection of natural capital are increasingly recognized by EU policies as a strategy to cope with potentially changing conditions in the future. Hence, there is substantial overlap between the objectives of a bio-economy and the maintenance or enhancement of ecosystem services under target 2 of the EU Biodiversity Strategy to 2020. Both strategies encompass the sustainable production of renewable biological resources. As a result, reporting under Action 5 of the EU biodiversity strategy should be considered as an important source of information for the Bioeconomy Observatory.

Action 5 of the Biodiversity Strategy foresees that Member States will, with the assistance of the Commission, map and assess the state of ecosystems and their services in their national territory by 2014. The Working Group on Mapping and Assessment on Ecosystems and their Services (MAES) is mandated to co-ordinate and oversee Action 5. In 2013, the working group developed ideas for a coherent analytical framework, including a set of common indicators to assess ecosystem services, to ensure consistent approaches are used across Europe. The Bioeconomy Observatory can profit from the ongoing assessments of ecosystem services at national and EU scale.

Table 6 lists the best available indicators to measure the quantity of ecosystem services in Europe based on the CICES classification. This table is the result of the second MAES paper (draft), which provides guidance on the available indicators that can be used at the EU and MS levels for mapping and assessment of ecosystems and their services. In principle, the indicators listed in Table 1 are available for use.

More information on Action 5 and the MAES working group:

- <http://biodiversity.europa.eu/ecosystem-assessments/european-level>
- [http://ec.europa.eu/environment/nature/knowledge/ecosystem\\_assessment/pdf/MAESWorkingPaper2013.pdf](http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf)

**Table 6: Best available indicators for assessment of ecosystem services across different ecosystems**

<b>Ecosystem services</b>	<b>Indicator</b>
Cultivated crops	● Area and yields of food and feed crops
Reared animals and their outputs	● Livestock
Wild plants, algae and their outputs	● Distribution of wild berries (modelling)
Wild animals and their outputs	● Population sizes of species of interest
Plants and algae from in-situ aquaculture	
Animals from in-situ aquaculture	● Freshwater aquaculture production
<i>Water</i> (Nutrition)	● Water abstracted
<i>Biomass</i> (Materials)	● Area and yield of fibre crops ● Timber production and consumption statistics
<i>Water</i> (Materials)	● Water abstracted
Plant-based resources	● Fuel wood statistics
Animal-based resources	
Animal-based energy	
(Mediation of waste, toxics and other nuisances)	● Area occupied by riparian forests ● N and S removal (forests)
Mass stabilisation and control of erosion rates	● Soil erosion risk or erosion protection
Buffering and attenuation of mass flows	
Hydrological cycle and water flow maintenance	
Flood protection	● Floodplains areas (and record of annual floods) ● Area of wetlands located in flood risk zones
Storm protection	
Ventilation and transpiration	● Amount of biomass
Pollination and seed dispersal	● Pollination potential
Maintaining nursery populations and habitats	● Share of High Nature Value farmland ● Ecological Status of water bodies
<i>Pest and disease control</i>	
Weathering processes	● Share of organic farming ● Soil organic matter content ● Ph of topsoil ● Cation exchange capacity
Decomposition and fixing processes	● Area of N fixing crops ● Gross nitrogen balance
Chemical condition of freshwaters	● Chemical status
Chemical condition of salt waters	
Global climate regulation by reduction of greenhouse gas concentrations	● Carbon storage and sequestration by forests
Micro and regional climate regulation	● Forest area
<i>Physical and experiential interactions</i>	● Visitor statistics ● Extent of protected areas
<i>Intellectual and representative interactions</i>	
<i>Spiritual and/or emblematic</i>	
<i>Other cultural outputs</i>	

Remark: All services are at CICES class level except services in italic, which are at CICES group level. The CICES Division is indicated in brackets. Green-marked indicators are available at national scale, yellow-market indicators are not. The summary table is based on three pilot studies that report on forests, agro-ecosystems and freshwater ecosystems according to the MAES ecosystem typology.