GOLD

Growing energy crops on contaminated land for biofuels and soil remediation

D3.6

Setting and definitions for the integrated sustainability assessment - final version

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Executive Summary

This final version of the 'Setting and definitions for the integrated sustainability assessment' (Deliverable D3.6) represents the status as of 4 July 2023. It corresponds to the description of work of task 3.3 Integrated Sustainability Assessment, which is part of WP3 - Integrated sustainability assessment for bridging the gap of the project GOLD (Grant Agreement no. 101006873).

This final[t] version report establishes the settings and definitions that will be used by several tasks of WP3 that will be studying the sustainability of the different value chains selected from the GOLD project, to guarantee a consistent evaluation throughout the assessment. This report was based on the D3.5 report – 1st version of "Setting and definitions for the integrated sustainability assessment" that was concluded in December 2022, and on the discussions that were held in the meeting of the Gold Project, in Bologna, in June 2023. In the report, the definition of all system boundaries and settings such as geographical and time-related coverage and the setting of reference systems (conventional-fossil based reference systems and biomass-based), is presented.

As the GOLD project works on many different aspects of industrial crop cultivation techniques to improve the phytoremediation action, and with different processing options, to retrieve contaminants, along with the production of biobased products and/or bioenergy, since the obtained products and co-products will be suitable for various applications, different value chains from GOLD project should be analysed. In the assessment, a cradle-to-grave approach will be applied and to each selected value chain, all stages, cultivation, harvesting, pre-treatment, processing, end-of-life treatment and final disposal, will be evaluated. The conventional reference systems shall represent the conventional value chain that would most likely be replaced first, due to economic and political boundary conditions when additional bio-based products as suggested by the GOLD approach will be used. Within the GOLD project, the conventional reference systems will be specified in task 3.2 within the selection of GOLD value chains and the qualitative description of the most appropriate technologies for conversion into promising intermediate and end products. The cropping systems can be also compared with conventional soil treatment systems, to understand the impact of the phytoremediation action. Geographical coverage for the sustainability assessment is focused on European countries, and the differing growing conditions, yield potentials and cultivation practices in Europe will be taken into account. Considering the immature state of the production of bio-based products from contaminated land, the year 2030 is set as a reference, so that a more representative picture of the investigated system's potential to achieve the goals can be achieved. Within the GOLD project, three reference units can be applied. In the case of the biomass used as biofuel, a typical output-related functional unit could be the provision of 1 MJ of fuel energy. If the focus is set on the input, 1 ton oven-dry biomass could be used as reference unit. As land is a main factor limiting the production of bio-based products in Europe, referencing the results to 1 hectare is also a suitable functional unit to be applied in the GOLD project. Identification of the environmental burdens, the economic benefits and the social welfare along the different individual processes or life cycle steps will be recognized and mitigation or minimization options will be named. Ultimately, the integrated sustainable assessment will provide info on the findings of the GOLD project to key stakeholders, i.e. regional authorities and policy makers, industrial and RTD establishments, farmers cooperatives, governmental bodies, among others, and will alert the recipients on which policies should be developed.

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1 Context

The final version of the ‘Setting and definitions for the integrated sustainability assessment’ (Deliverable D3.6), corresponds to the work described in Sub-task 3.3.1: System boundaries and settings (Leader: FCT, partners: CRES, RE-CORD, WR, POLITO) of task 3.3 Integrated Sustainability Assessment, included in WP3 - Integrated sustainability assessment for bridging the gap of the project GOLD (Grant Agreement no. 101006873). This work aims to establish the settings and definitions that will be used by several tasks of WP3 that will be studying the sustainability of the different value chains selected from the GOLD project, to guarantee a consistent evaluation throughout the assessment. This report was based on the D3.5 report – 1st version of “Setting and definitions for the integrated sustainability assessment” that was concluded in December 2022, and on the discussions that were taken during the GOLD meeting, held in Bologna, in June 2023. In the report, the definition of all system boundaries and settings such as geographical and time-related coverage, will be presented.

2 Integrated Sustainability Assessment

The aim of Task 3.3 is to perform an integrated sustainability assessment for selected value chains taken from the GOLD project, including the environmental, economic and social dimensions of sustainability. Indeed, the implementation of the selected value chains proposed by the GOLD project can have significant impacts on environment, economy and society. As a result, it is a major aim of WP3 to maximise the impact of GOLD through provision of objective information regarding all important sustainability aspects (covering environment, society and economy) of the value chains using scientific, transparent and reproducible methodologies. Modelling techniques such as life cycle assessment (LCA), life cycle costing (LCC), social life cycle assessment (S-LCA) and SWOT analysis will be used to determine the impacts on sustainability, followed by integration. Interpretation of the results obtained in this assessment will allow to identify the implications from the solutions proposed (the most promising value chains) from a consequential perspective, including cost effective analysis and the key-sustainability indicators. Information retained will allow identifying which parameters are of particular relevance and which options for improvement exist to feed in task 3.4 (Interpretation, strategy and recommendations). Sustainability assessment is a comprehensive topic which can be interpreted and applied in different ways depending on the project goals. Therefore, the following sections describe the approach of sustainability assessment within the GOLD project.

2.1 Approach

Sustainability has become increasingly important to the public. Well-known international targets to a more sustainable future are the Sustainable Development Goals (SDGs) [1], as reference for the United Nations 2030 sustainability agenda. Together with the targets, assessment approaches can help define the sustainability of systems. Several approaches for comprehensive sustainability assessments of products or processes along their whole life cycles have been suggested [2-4]. Life Cycle Sustainability Assessment (LCSA) is an assessment framework by which it is possible to measure the sustainability performance of a product or service over its entire life cycle [5]. LCSA enables the evaluation of both positive and negative impacts [6-8]. The framework complements the one-dimensional environmental sustainability assessment (Life Cycle Assessment (LCA)), with the economic (Life Cycle Costing (LCC)) and social dimension (Social Life Cycle Assessment (S-LCA)) [2,4]. The reconciliation of environmental, social and economic demands – the 'three pillars' of sustainability, can be expressed as a diagram using three overlapping circles indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing (Figure 1).

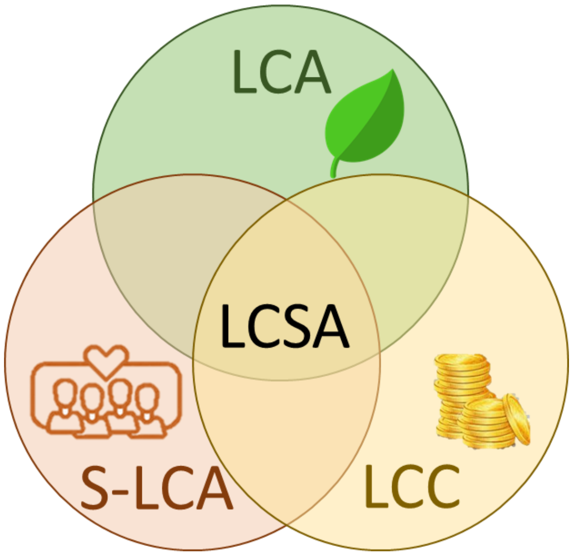

Figure 1. Life Cycle Sustainability Assessment (LCSA), a combination of methods to evaluate environmental (LCA), economic (LCC) and social impacts (S-LCA) across the whole life cycle of products. [adapted from 9]

From another perspective, LCSA can be considered the sum of LCA, LCC and S-LCA (Figure 2).

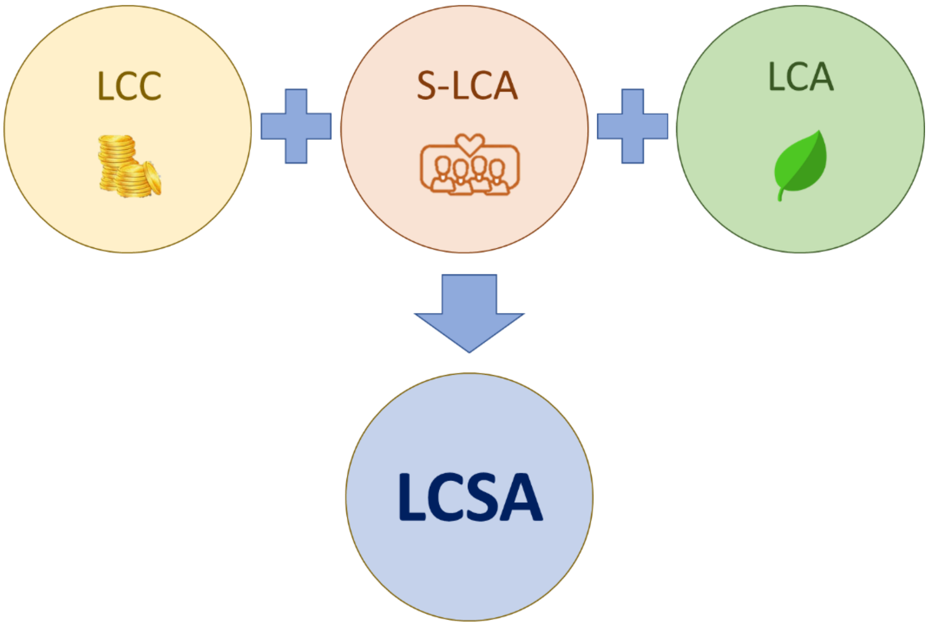

Figure 2. Life Cycle Sustainability Assessment (LCSA), as the sum of the environmental (E-LCA), economic (LCC) and social impacts (S-LCA) across the whole life cycle of products.[adapted from 10]

LCA provides a structured approach to assess processes and systems and quantifying environmental emissions and impacts [11]. A wide range of impact categories is covered, providing a comprehensive picture of the product's environmental implications. The assessment includes the product's entire life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal. The approach is therefore often called cradle-to-grave, well-to-wheel (fuels) or farm-to-fork (food). This so-called life cycle thinking helps avoiding a shifting of environmental burdens between life cycle stages, between geographical regions or between impact categories.

LCA is internationally standardized through ISO standards 14040:2006 and 14044:2018 [11,12] and can among others assist in

• identifying opportunities to improve the environmental performance of products at various points in their life cycle and

• informing decision-makers in industry, government or non-government organisations (e.g. for the purpose of strategic planning, priority setting, product or process design).

Although well established and suitable for the assessment of global and supra-regional environmental impacts, standard LCA methodology to date is not yet able to address local and site-specific impacts on environmental factors like biodiversity, water and soil. As long as methodological developments into this direction are still ongoing, classical LCA should be supplemented with an assessment of local and site-specific impacts based on elements borrowed from Environmental Impact Assessment (EIA) [13-15]. Environmental Impact Assessment focuses on local environmental effects. Data are collected and evaluated on that level. There is not a general list of criteria to assess the environmental impact nor a general description of methods to be used. Usually criteria address emissions to soil, ground and surface waters and air, effects on living environment and health of people in the surroundings, effects on surrounding ecosystems, and effects on cultural assets [13].

LCC focuses on the flows associated with the production and consumption of goods and services [16] and follows the systematics of LCA, capturing costs over the entire life cycle. Economic analysis examines the profitability and sustainability of projects in order to assess the attractiveness of financing alternative investment opportunities. In particular, the economic examination of a project requires the estimation of all costs and revenues generated in each and every year during the economic life of the project and the necessary size and the timing of the required investment. The economic methodology requires the decomposition of the project into a number of operations or activities, which sufficiently describe crop instalment, cultivation, harvesting and storage activities, processing, and end use. Each operation is characterised by its timing and its needs for land, labour, equipment and materials. In order to summarize the findings of economic analysis, it is useful to estimate economic indices which reveal the potential and viability of the investments. Generally accepted indices (e.g., Return on Investment (ROI); Payback Period), also provide a basis for comparison between alternative investment plans.

The socio-economic aspects are interlinked with the economic analysis and assess the socio-economic impacts focusing on both quantitative (jobs, direct, indirect and induced) and qualitative parameters (contribution to rural economy, local embedding and proximity to markets) [17]. Usually methodological approaches combine qualitative and quantitative assessment and evaluate respective impacts in two categories, i.e. employment effects (e.g. jobs creation/maintenance) and social sustainability (e.g. contribution to rural economy).

For a comprehensive sustainability assessment of products or processes along their whole life cycles, several approaches can be followed [2-4]. Yet, most methodologies for sustainability assessment were developed for assessing existing systems. When dealing with potential future systems (i.e. decision options) each option have to be compared to each other in the form of scenarios. In the work of Fernando et al. [17] a description was made on how an “integrated sustainability assessment” can be performed following a practicable methodology. This methodology follows a scenario-based approach and aims to yield valuable comprehensive decision support with manageable effort [18].

The assessment procedure can be divided in three steps:

1. Definitions and settings

Common definitions and settings are specified that apply to all parallel assessments of the various sustainability aspects to ensure the compatibility of results. This includes goal and scope questions, descriptions of assessed scenarios and further definitions and settings. Importantly, scenarios depict potential future implementations of mature technology, i.e. the alternatives relevant to the current status of development.

2. Parallel assessment of various sustainability aspects

The assessments include impacts on environment, economy and society, which are commonly referred to as the three pillars of sustainability. The implementation of scenarios that are found to be sustainable in a sustainability assessment may however still cause unexpected and sometimes undesirable consequences if they cannot be implemented in the intended form or if operations stop after a short time. To increase the value for decision support, the scenarios are additionally assessed for several barriers that could hinder their implementation in the intended form, e.g. technological aspects and biomass potentials. An additional SWOT (strengths, weaknesses, opportunities, threats) analysis can be helpful in the assessment.

3. Result integration

A dedicated procedure has to be developed to join all assessment results into an overall picture and derive conclusions and recommendations for decision support. The main aim will be the identification of the most sustainable value chains which are able to reconcile economic, social and environmental demands.

2.2 Implementation

The sustainability assessment within the project GOLD is carried out in WP3 entitled 'Integrated sustainability assessment for bridging the gap'. Specifically, the assessment is the aim of task 3.3, that seeks to perform an integrated sustainability assessment for selected value chains, including the environmental, economic and social dimensions of sustainability. A set of robust methodologies and modelling techniques such as life cycle assessment (LCA), life cycle costing (LCC), social life cycle assessment (S-LCA) and SWOT analysis will be used to determine the impacts on sustainability, followed by integration. Interpretation of the results obtained in this assessment will allow to identify the implications from the solutions proposed (the most promising value chains) from a consequential perspective, including cost effective analysis and the key-sustainability indicators. Information retained will allow identifying which parameters are of particular relevance and which options for improvement exist to feed in task 3.4. How task 3.3 will be performed and how it is linked with other tasks is presented in Figure 3.

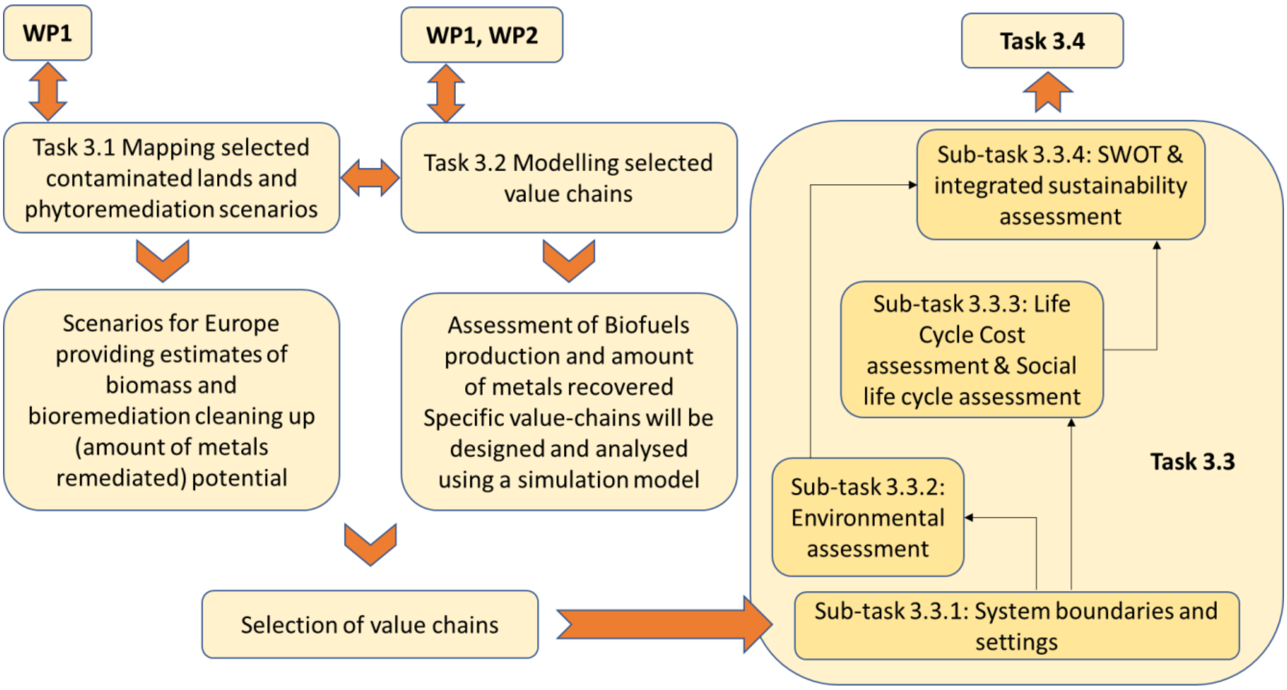

Figure 3. Integration of task 3.3 in WP3 (SWOT: Strengths, weaknesses, opportunities, threats)

At the beginning, the selected contaminated sites and their detailed characteristics will be mapped (Task 3.1) and this will be used to assess the upscale in potential of the pilot trial results of the selected energy crops (WP1). The mapping will be further translated into scenarios for Europe providing estimates of biomass and bioremediation cleaning up (uptake of metals remediated from the soil, degradation of other pollutants) potentials. Biofuels production and the amount of metals recovered will be assessed in task 3.2, representing the full range of activities needed to produce biofuels and recovered metals (as co-products). Specific value-chains will be designed and analysed using a simulation model (developed for the project). The model will provide detailed representation of the whole chain setup in process flow charts, as well as the economic and logistical feasibility of the whole production chain (biomass and biofuel production in relation to land decontamination). An integrated sustainability assessment for the above-mentioned value-chains will be carried out including: LCA, S-LCA, LCC and a SWOT analysis (Task 3.3). In task 3.4 all the outcomes of the tasks 3.1-3.3 are integrated and translated into cross-sector strategies for phytoremediation and clean biofuel production. The strategies will analyse impacts and synergies for a number of global initiatives including Mission Innovation Challenge 4 on biofuels and the Sustainable Development Goals.

As the GOLD project works on many different aspects of industrial crop cultivation techniques to improve the phytoremediation action, and with different processing options, to retrieve contaminants, along with the production of biobased products and/or bioenergy, since the obtained products and co-products will be suitable for various applications, different value chains from GOLD project should be analysed (Figure 4). To be able to compare all these possible variants, a set of scenarios has to be defined, each of which depicts a potential GOLD value chain. In the assessment, a cradle-to-grave approach will be applied and to each selected value chain, all stages, cultivation, harvesting, pre-treatment, processing, end-of-life treatment and final disposal, will be evaluated (Figure 5). The cropping systems can be also compared with conventional soil treatment systems, to understand the impact of the phytoremediation action.

Identification of the environmental burdens, the economic benefits and the social welfare along the different individual processes or life cycle steps will be recognized and mitigation or minimization options will be named. The reference products and the credits that might be obtained will be explained in the following sections. In addition, common definitions and settings are needed to ensure consistency of assessments within WP3. The common definitions and settings are also relevant for the entire consortium since all partners responsible for process design are asked to deliver mass and energy flow data in compliance with these common definitions and settings. Moreover, the settings will affect the outcomes of the sustainability assessment and hence are of high importance for the project.

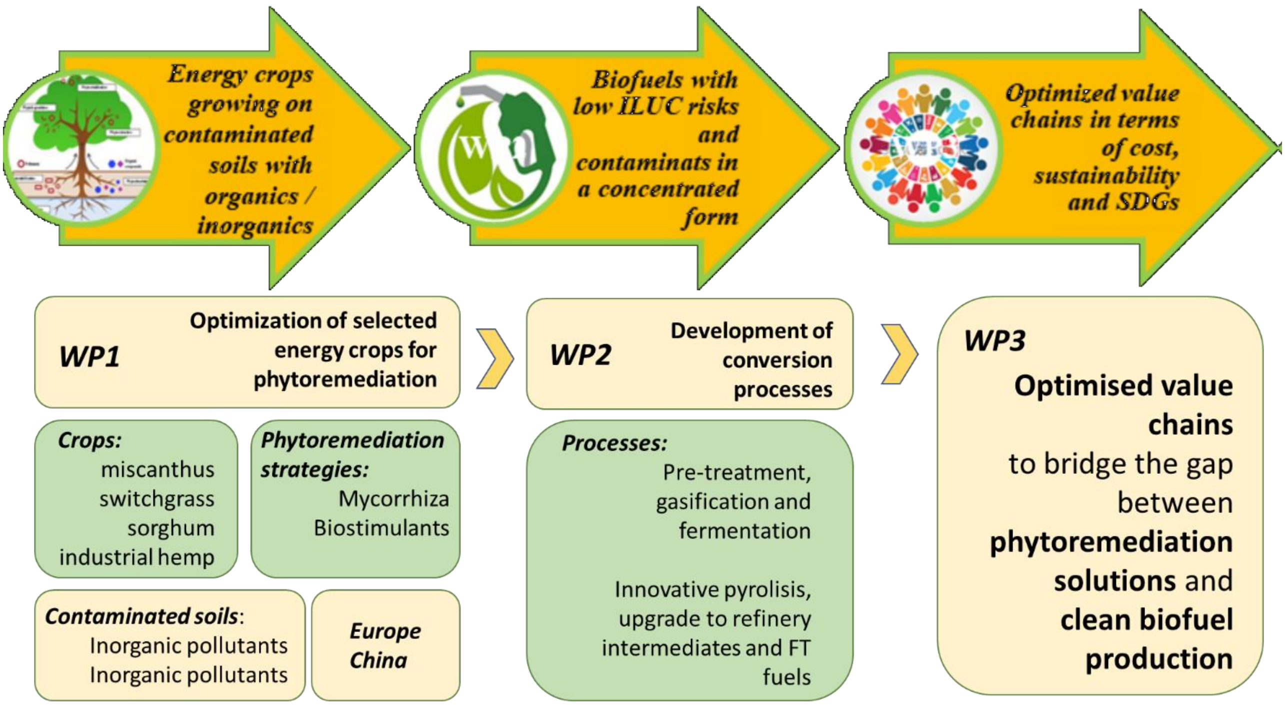

Figure 4. GOLD pillars [adapted from 19]

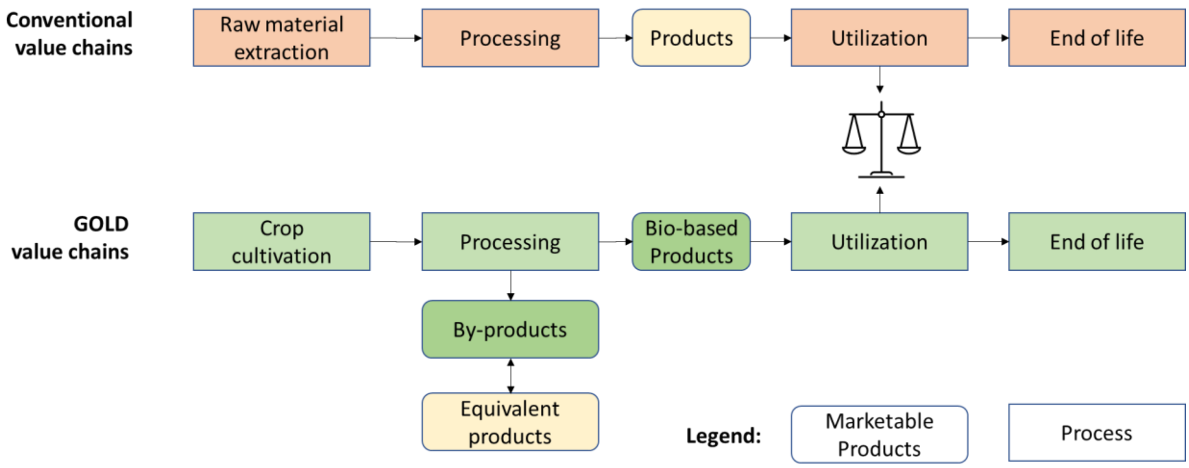

Figure 5. Sustainability assessment within the GOLD project. The GOLD bio-based products are compared to conventional reference products, both along the whole life cycle

3 Common definitions and settings

A sustainability assessment requires common definitions and settings on which the environmental, economic and social assessment will be based. Thus, general definitions and settings will allow an efficient communication between the project partners in the GOLD project, and inside WP3 and ensure consistent data and results for the sustainability assessment. The first phase of the sustainability assessment is the goal and scope definition which is relevant for the environmental, economic and social impact assessment.

3.1 Goal definition

Goal questions

The sustainability assessment within the GOLD project aims several purposes.

The subject of the first purpose, that GOLD project will aim to achieve, is related with the optimization of the phytoremediation action along with the production of clean biofuels. A comparison of specific cultivation systems, will bring results for production systems development, including biomass use options and obtainment of the contaminants in a concentrated form. The analysis will allow the identification of key factors for sustainable cultivation systems and product chains to support further optimisation.

The second purpose of the integrated sustainability assessment is to provide info on the findings of the GOLD project to key stakeholders, i.e. regional authorities and policy makers, industrial and RTD establishments, farmers cooperatives, governmental bodies, among others, and also to alert the recipients on how policies should be developed:

- Policy information: Which value chains have the potential to show a low environmental impact?
- Policy development: Which crop cultivation strategies and biomass use technologies may emerge, what are their potential environmental impacts, and how could policies guide this development?

In this context, a number of goal questions have to be agreed upon in internal project workshop on the description of the value chains that will be used throughout task 3.3 and that will be carried out during the 3rd project technical meeting. Their purpose is to guide the sustainability assessment in WP3:

- Which GOLD value chains (bio-based products and bioenergy from industrial crops cultivated on contaminated land) are sustainable from an environmental, societal and economic point of view,
    a) along the entire life cycle ('cradle-to-grave analysis')?
    b) in the agricultural stage ('cradle-to-farm gate analysis')?

The assessment along the entire life cycle ('cradle-to-grave analysis') follows internationally accepted guidelines and aims at reliable policy recommendations. The second focus on the agricultural stage ('cradle-to-farm gate analysis') aims to evaluate the viability/sustainability of the production of a biomass in a contaminated site and how the cropping systems can assure the decontamination of polluted areas. Other questions may arise from the study:

- Which life cycle stages or unit processes dominate the results significantly and which optimisation potentials can be identified?
- Do some GOLD value chains show a better 'life cycle sustainability performance' than others?
- Which trade-offs within and between the three pillars of sustainability have to be made?
- Which technological, logistical or other potential barriers may hinder the phytoremediation action, the biomass production and the large-scale industrial deployment of selected value-chains?
- Which boundary conditions have to be met in order to advocate large-scale cultivation of industrial crops on contaminated land from a sustainability point of view?
- Do the GOLD value chains targeting bio-based products and bioenergy comply with the SDG targets? And with the European Green Deal targets?

Target audience and Decision-context

The definition of the target audience helps identifying the appropriate form and technical level of reporting. In the case of the GOLD project, the target audience can be divided into project partners and key stakeholders (EC staff, political decision makers, governmental bodies, regional authorities, industrial and RTD establishments, farmers cooperatives, interested persons). The decision-context is one key criterion for determining the most appropriate methods for the so-called life cycle inventory (LCI) model. In the GOLD project, its main application is to provide information for further development. It is assumed that the implementation of biomass production and value chains developed within the GOLD project could have significances that can be applied at large-scale [20].

3.2 Scope definition

With the scope definition, the object of the sustainability assessment (i.e. product or system) is identified and described. The scope should be sufficiently well defined to ensure that the study will address the stated goal. For the implementation of the sustainability assessment, definitions and settings are necessary. They are used to guarantee the consistency among the different assessments (environmental, economic and social). Following, the definitions and settings are described and explained.

Investigated systems and settings for system modelling

The GOLD project investigates various industrial crops suitable for the cultivation on contaminated land under different phytoremediation approaches. Also, several processing options will be studied and several bio-based products are considered. Therefore, there is a wide spectrum of potential combination of these elements which may lead multiple possible crop-technology combinations. In task 3.2, this large amount is reduced to the most promising value chains. The selection will be done in the framework of an internal project workshop on selection of value chains and interlinkages in between M20 and the 3rd project meeting (February-March 2023). Generic scenarios will be built, to analyse the investigated systems, based on the knowledge acquired in the framework of WP1, WP2 and WP3, partners own experience on industrial crops cultivation, processing and use, and on additional information retrieved from past projects and literature. The scenarios will consider typical conditions so that reliable general statements and recommendations concerning the production of biofuels using biomass from contaminated land, land decontamination and collection of contaminants in concentrated form, can be derived.

The conventional reference systems shall represent the conventional value chain that would most likely be replaced first, due to economic and political boundary conditions when additional bio-based products as suggested by the GOLD approach will be used. Within the GOLD project, the conventional reference systems will be specified in task 3.2 within the selection of GOLD value chains and the qualitative description of the most appropriate technologies for conversion into promising intermediate and end products

Geographical coverage

It is the aim of the GOLD project to establish optimised value chains to bridge the gap between phytoremediation solutions and clean biofuel production. And the contaminated sites studied in GOLD cover a wide variety of climatic conditions located worldwide (Europe and China) (Figure 6).

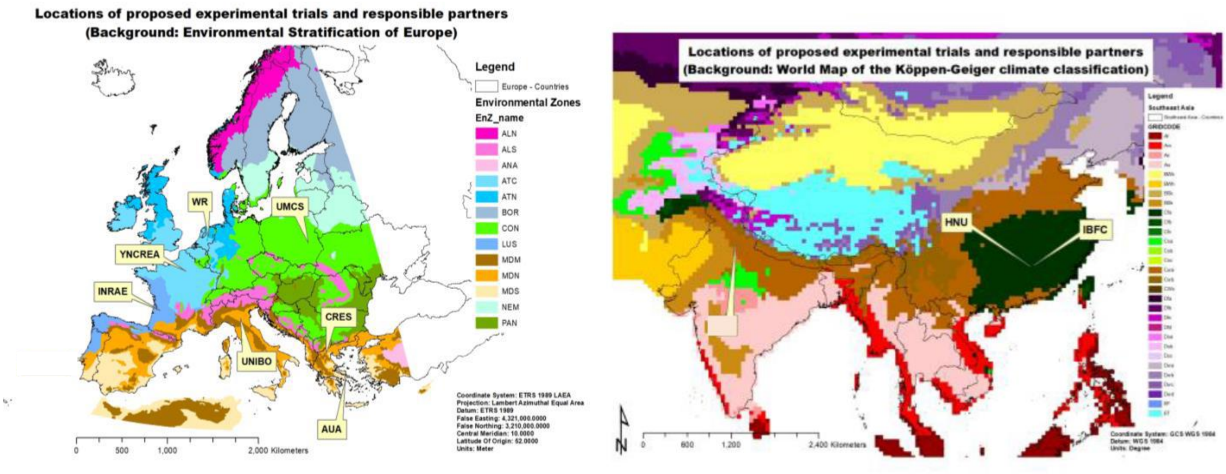

Figure 6. Locations of proposed experimental trials in Europe (left image) and China (right image). [adapted from 19]

It was decided that, to avoid excess of information, that geographical coverage for the sustainability assessment will be focused on European countries, and the differing growing conditions, yield potentials and cultivation practices in Europe will be taken into account. The following climatic zones will be covered in Europe:

- In Europe (based on [21]): a) Mediterranean North and South, that has short precipitation periods, long hot and dry summers, long growing season and air temperatures favourable for growing a wide range of crops, b) Continental, that covers most part of Europe and is characterized by high temperatures in summer and very low in winter, followed by relatively high precipitation and c) Atlantic, generally features cool summers (relative to their latitude) and cool but not cold winters, a more temperate climate through the year with high precipitation levels.

With respect to the provision of conventional reference products, the geographical scope is broadened in order to represent the generic (e.g. global) production of each replaced commodity. In some cases, country-specific conditions may be chosen for the estimation of a single parameter's influence on the overall results, e.g. related to labour costs.

Technical reference

The technical reference describes the different stages of the value chains (agricultural practises and the conversion technologies) to be assessed in terms of development status and maturity. To answer the key questions listed under the goal definition, mature agriculture practise and mature industrial-scale plants should be set as technical reference. Currently, the phytoremediation options and the technological systems to be assessed are positioned at different Technology Readiness Levels; some of them have not yet been implemented on a relevant scale and for a sufficiently long time. Therefore, it is essential to obtain information on how future implementations are expected to perform, compared to established reference products/systems, which are operated already at a relevant scale and for a sufficiently long time. To deal with this insecurity, expert opinions will be needed from WP1 partners and WP2 partners, to provide inputs on the technical reference.

Time frame

When assessing pilot projects, a time frame should be set to buffer the years needed to improve production and to benefit from economies of scale. In this respect, and considering the immature state of the production of bio-based products from contaminated land (that cannot compete with established reference products provision production chains), by setting the year 2030 as a reference, a more representative picture of the investigated system's potential to achieve the goals can be attained. The year 2030 will be considered as the moment in which the value chains could start to be fully operative. Of course that, in the assessment, the duration of the remediation activities will be also considered. Indeed, the duration of remediation activities should be of interest since it has to be compared with a typical business plan timeframe (i.e 20-30 years), as well as with expected technological lifetime of the process. Moreover, if the remediation timeframe is quite long, there would be the possibility to appreciate successive technology upgrades, I.e. in terms of yield increase and cost decrease.

System boundaries

System boundaries specify which unit processes are part of the production system and thus included into the assessment settings as well as the processes excluded. Within the GOLD project, two alternatives of system boundaries are considered (Figure 7):

a) Cradle-to-grave approach and
b) Cradle-to-farm gate approach.

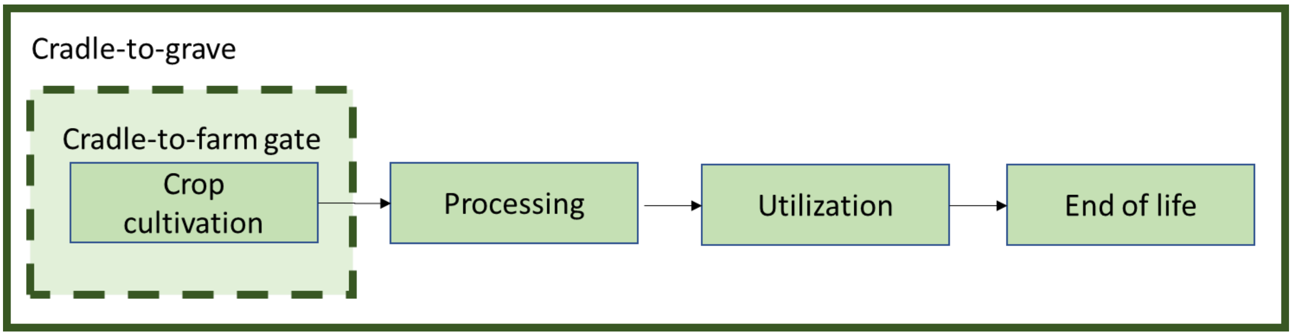

Figure 7. System boundaries from cradle-to-grave and from cradle-to-farm gate applied within the GOLD project

Looking into the cradle-to-grave approach, the sustainability assessment of the GOLD system will take into account the products' entire value chain (life cycle) from cradle to grave, i.e. from plantlets production and seeds, and resource extraction for fertilisers applied during cultivation, to the utilisation and end of life of the bio-based products following the principle of life cycle thinking [20]. Also, for the equivalent conventional reference products, the entire life cycle is taken into account. The cradle-to-grave analysis is carried out for selected value chains.

The system boundary will also cover the so-called alternative land use, including land use change effects and associated changes in carbon stocks. The alternative land use describes what the cultivation area would be used for if the crops under investigation were not cultivated [15]. When GOLD models are to be employed, contaminated land will be used for production of industrial crops, and one major benefit is that there is little competition for their use and in many cases the land is currently unexploited. In the GOLD project, a baseline setting cultivation is set to take place on former idle land, defined as land that is currently not in use. Thus, the GOLD industrial crops would not displace food or fodder crops to other, previously unused areas and indirect land use changes (iLUC) can be excluded from this assessment. However, impacts from direct land use changes (dLUC) are considered (the positive and the negative). For example, GHG emissions due to initial clearing and plantation, and impacts on biodiversity, landscape and soil erosion determined by alternative land use [14, 15, 22]. In addition to the baseline setting ('cultivation of industrial crops on former idle land'), the sensitivity analysis will go through different types of alternative vegetation such as grassland or woody grassland / shrubland, which may have covered the land before the cultivation of industrial crops.

Looking into the cradle-to-gate approach, the assessment will allow to identify the impacts of the phytoremediation action and of the cultivation of the industrial crops. The information gathered will provide recommendations and statements in viability for farmers and also for Environmental management authorities, land reclamation & waste management companies and others.

In the interest of the phytoremediation action, equivalent conventional remediation processes to clean up soil will be also evaluated in the assessment (Figure 8). The analysis of the conventional soil treatment systems will bring information on the opportunities and long-term benefits for land recovery, biodiversity, and climate change mitigation through phytoremediation action.

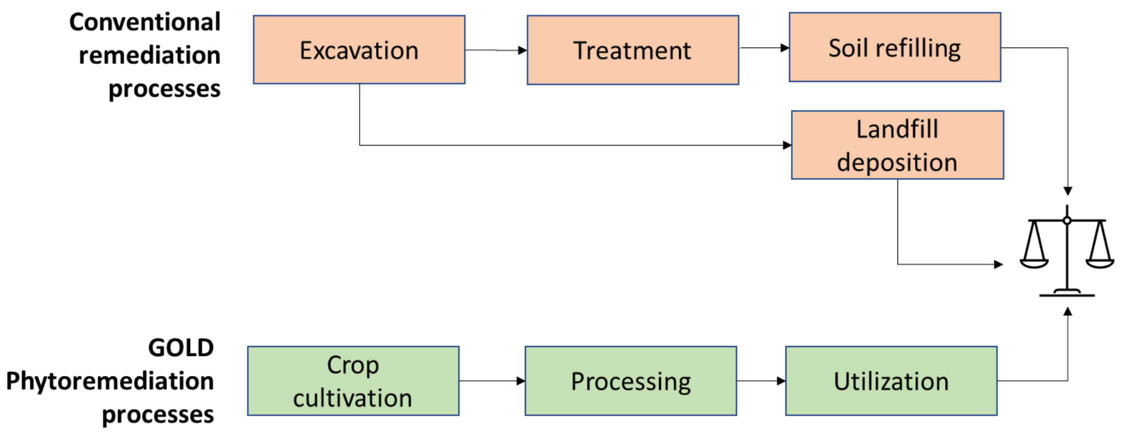

Figure 8. Sustainability assessment within the GOLD project. The GOLD phytoremediation actions are compared to conventional remediation processes, both along the whole life cycle.

In the assessment of the phytoremediation actions, the environmental pros and cons of both the GOLD system and the conventional systems will be analysed. It will be discussed with partners of WP3, after the selection of value chains, how this assessment will be made, if by considering only the life cycle – environmental impact assessment (LC-EIA), or if also by including the remaining sustainability assessments, i.e. life cycle assessment (LCA), life cycle costing (LCC), and social life cycle assessment (S-LCA).

Function, functional unit and reference unit

Defining a common reference unit for all sustainability assessments, i.e. life cycle assessment (LCA), life cycle – environmental impact assessment (LC-EIA), life cycle costing (LCC) and social life cycle assessment (S-LCA), is important for comparability and consistency of the results.

In LCA-studies, results are usually referenced to the so-called functional unit, which is typically a measure for the function of the studied system. It quantifies the function (i.e. utility) of the products provided by the investigated system. Within the GOLD project, three reference units can be applied. In the case of the biomass used as biofuel, a typical output-related functional unit could e.g. be the provision of 1 MJ of fuel energy. If the focus is set on the input or on the mass-balance of the process, 1 ton oven-dry biomass could be used as reference unit. In addition, land is a main factor limiting the production of bio-based products in Europe. Therefore, referencing the results to 1 hectare is most suitable. In addition, and considering the phytoremediation actions, the functional unit considered can be the decontamination of 1 ha of the considered soil (at a certain depth, e.g. 20 cm) up to the maximum concentration allowed by the government regulations. Nevertheless, the reference unit determines how the results are presented and interpreted.

Data sources

The sustainability assessment of the GOLD systems requires data from the agronomic phase, the processing phase and the utilization phase. The data will be provided via tasks 3.1 and 3.2, supplemented with data taken from previous projects, literature and databases.

4 Conclusions and further steps

This report on 'Setting and definitions for the integrated sustainability assessment - final report' (Deliverable D3.6) describes important common definitions and settings for the integrated sustainability assessment (task 3.3) within the GOLD project and forms the basis for sub-task 3.3.2, sub-task 3.3.3 and sub-task 3.3.4. This report is the final version on fundamental settings and definitions. After the selection of the value chains, specifications of the reference products and of initial elements of the scenarios will be agreed upon all project partners. The system description of the scenarios will be made available after the selection of the most promising value chains

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