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1 Introduction

This ‘Interim report on definitions and settings’ (Deliverable D6.1) represents the status as of 30 September 2018. It corresponds to the description of work of task 6.1.1 as summarised in the Grant Agreement Annex 1 of the Horizon 2020 project MAGIC (GA no. 727698).

This interim report establishes the definitions and settings to be used by all tasks in work package 6 (WP6) to guarantee a coherent analysis throughout the sustainability assessment. This includes especially the definition of all system boundaries and settings such as geographical and time-related coverage.

On 10 July 2018, an internal project workshop on the definitions and settings was successfully held in Madrid (Spain) where the proposed definitions and settings were intensively discussed and agreed upon. The project partners participated in the definitions and settings, required for the sustainability assessment, by making proposals and raising objections.

Results from this task constituted input for tasks 6.2 to 6.6.

2 Sustainability assessment

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 MAGIC project.

2.1 Motivation for sustainability assessment within the Magic project

The implementation of the value chain concepts proposed by the MAGIC project can have significant impacts on society and environment. This is even more valid since one goal of the project is to provide a basis for a large-scale realisation which might affect millions of hectares of land. Obviously, various advantages but also disadvantages are related to the use of marginal lands for the production of industrial crops. Whether the advantages or the disadvantages predominate cannot be determined a priori. As a result, it is a major aim of WP6 to maximise the impact of MAGIC 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.

2.2 The pillars of sustainability

The most well-known definition of sustainability can be found in the report of the Brundtland Commission: *'sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* [UN 1987]. At the 2005 World Summit it was noted that this requires the reconciliation of environmental, social and economic demands – the 'three pillars' of sustainability. This view has been expressed as a scheme using three overlapping circles indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing (Figure 1).

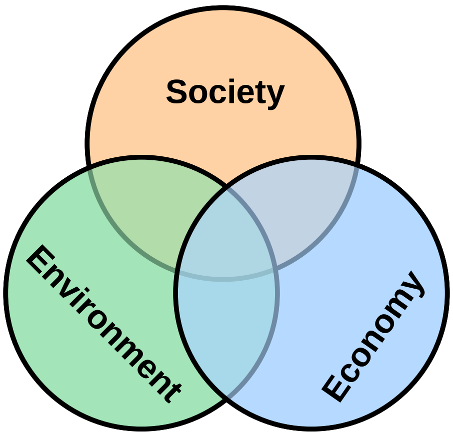

Figure 1: Scheme of sustainable development: at the confluence of three constituent parts.

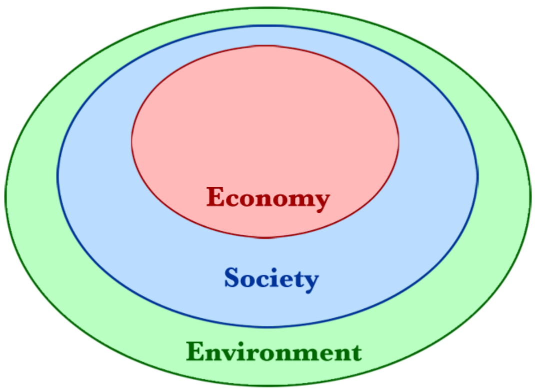

Figure 2: Scheme indicating the relationship between the three pillars of sustainability [Scott-Cato 2008].

The United Nations (UN) definition has evolved and undergone various interpretations. For example, many environmentalists think that the idea of sustainable development is an oxymoron as development seems to entail environmental degradation. From their perspective, the economy is a subsystem of human society, which is itself a subsystem of the ecosphere, and a gain in one sector is a loss from another. This can be illustrated as three concentric ellipses (Figure 2). Nevertheless, other interpretations exist as well.

As a result of the growing pressure on the environment and increased scarcity of natural resources, the sustainability discussion is often focussed on the environment, as both society and economy are constrained by environmental limits. There is abundant scientific evidence that humankind is currently living unsustainably and jeopardising the living conditions of future generations, e.g. by excessive use of resources and excessive use of the environment as a sink, e.g. for greenhouse gas emissions etc. Hence, strong efforts are needed to identify and develop sustainable technologies which are able to reconcile economic, social and environmental demands.

2.3 Implementation of sustainability assessment within the MAGIC project

The sustainability assessment within the project MAGIC is carried out by WP6 entitled 'Integrated sustainability assessment'. The objective of WP6 is to provide a multi-criteria evaluation of the implications on sustainability associated with the MAGIC value chains.

In order to achieve reliable and robust sustainability assessment results, it is inevitable that the principles of comprehensiveness and life cycle thinking (LCT) are applied. Life cycle thinking means that all life cycle stages for products are considered, i.e. the complete supply or value chains, from agricultural production of the industrial crops, through harvesting, pre-treatment, further processing, to product use and – if applicable – end-of-life treatment and final disposal (see Figure 3). Through such a systematic overview and perspective, the unintentional shifting of environmental burdens, economic benefits and social well-being between life cycle stages or individual processes can be identified and possibly mitigated or at least minimised.

Besides this so-called cradle-to-grave approach, a cradle-to-farm gate analysis – focusing on the agricultural production of the crops – is applied for the MAGIC Decision Support System (DSS).

All three pillars of sustainability will be analysed using techniques based on life cycle thinking, e.g. life cycle assessment (LCA), social life cycle assessment (S-LCA) and life cycle costing (LCC). Further details such as the reference products and the credits related to alternative land use are explained in the following sections.

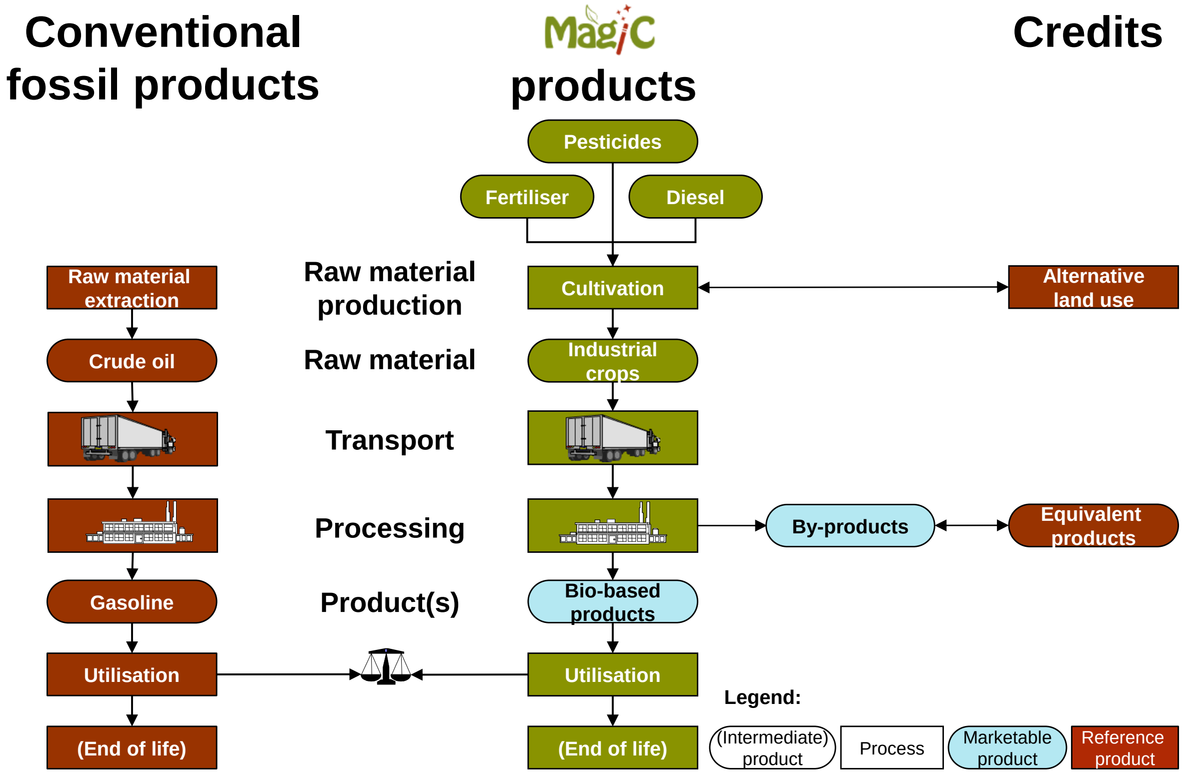

Figure 3: Sustainability assessment within the MAGIC project. The MAGIC bio-based products are compared to conventional reference products, both along the entire life cycle.

The sustainability assessment within the MAGIC project is based on the Integrated Life Cycle Sustainability Assessment (ILCSA) methodology [Keller et al. 2015].
WP6 will:

- analyse technological, environmental, economic, societal, political implications using a variety of methods for the different tasks. The different aspects of the MAGIC value chains will be defined and evaluated and, where appropriate, compared to reference systems. A complementary SWOT (Strengths, weaknesses, opportunities, threats) analysis will identify the key internal and external factors for the success of the MAGIC pathways.
- identify the most sustainable value chains among the MAGIC systems compared to all reference systems via a final integrated assessment based on a multi-criteria evaluation software tool. This is done by a screening using different variants and sensitivity analyses that will also reveal potential ways towards optimisation.

The structure of WP6 is depicted in Figure 4 on the following page.

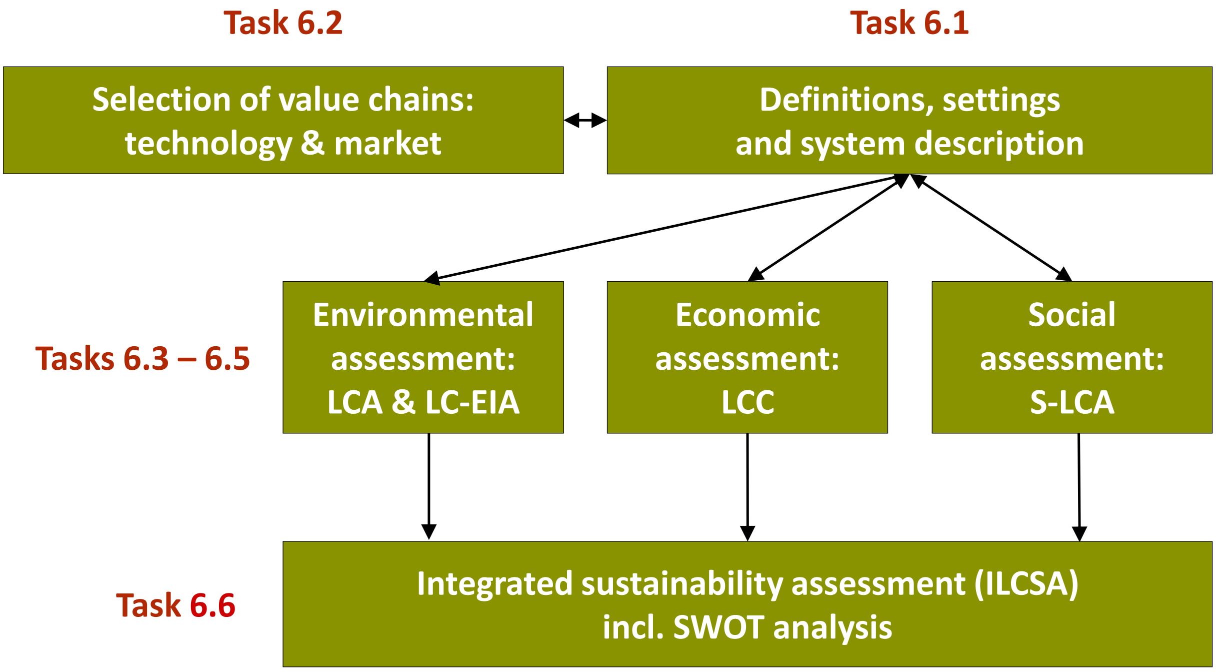

Figure 4: Structure of MAGIC's WP6 on 'Integrated sustainability assessment'.
LCA: Life cycle assessment, LC-EIA: Life cycle environmental impact assessment, LCC: Life cycle costing, S-LCA: Social life cycle assessment, ILCSA: Integrated life cycle sustainability assessment, SWOT: Strengths, weaknesses, opportunities, threats.

2.4 Importance of a common valuation basis

Individual aspects of sustainability (technological, environmental, economic, societal and political) are studied in separate tasks within WP6 and joined into an overall picture in task 6.6. A prerequisite for the compatibility of results from these individual assessments is that the same systems are analysed and that the work is carried out on the basis of common definitions and settings.

As the MAGIC project works on many different aspects of industrial crop cultivation, and since the obtained products and co-products will be suitable for various applications, there is not just one single MAGIC system to be analysed. Instead, there is a wide spectrum of potential implementations combining several of the developed elements. To be able to compare all these possible variants, a set of scenarios has to be defined, each of which depicts a potential MAGIC value chain.

Furthermore, common definitions and settings are needed to ensure consistency of assessments within WP6. Even though internationally standardised assessment techniques such as life cycle assessment (LCA) will be applied, the degree of freedom they offer in terms of methodological or data choices might lead to incomparable evaluations. Thus, the use of common definitions and settings by tasks 6.2 to 6.6 is indispensable.

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.

3 Common definitions and settings

A well-founded sustainability assessment requires common definitions and settings on which the environmental, economic and social assessment will be based. Thus, general definitions and settings lead to an efficient professional communication between the project partners in WP6 and ensure consistent data and results for the sustainability assessment. The goal and scope definition is the first phase of any sustainability assessment and is relevant for all three sub-analyses on the environmental, economic and social impacts.

3.1 Goal definition

The comprehensiveness and depth of the sustainability assessment can differ considerably depending on its goal. Therefore, the intended applications, the reasons for carrying out the study, the decision context as well as the target audiences and the commissioner have to be described within the goal definition.

Intended applications and goal questions

The sustainability assessment within the MAGIC project aims at several separate applications. The subject of the first group of applications is the project-internal support of ongoing production systems development:

- Comparisons of specific cultivation systems, which are potential results of ongoing production systems development, and biomass use options.
- Identification of key factors for sustainable cultivation systems and product chains to support further optimisation.

This makes this study an ex-ante assessment because the systems to be assessed are not yet implemented in this particular form on a relevant scale and for a sufficiently long time.
The second group of applications provides a basis to communicate findings of the MAGIC project to external stakeholders, i.e. science and policy makers:

- Policy information: Which product chains have the potential to show a low environmental impact?
- Policy development: Which raw material production 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 been agreed upon in the internal project workshop on definition and settings (MS6.1 / MS17). They are listed in the following. Their purpose is to guide the sustainability assessment in WP6:

- Which MAGIC value chains (bio-based products and bioenergy from industrial crops cultivated on marginal 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 of the International Organization for Standardization (ISO) and the Society of Environmental Toxicology and Chemistry (SETAC) [Andrews et al. 2009; ISO 2006a; b] and aims at reliable policy recommendations. The second focus on the agricultural stage ('cradle-to-farm gate analysis') has a two-fold aim: first, it aims to prove the compliance with the sustainability criteria set out in Annex V of the Renewable Energy Directive (RED) [European Parliament & Council of the European Union 2009] and second, it aims to evaluate the economic viability for farmers who are the first link in the value chain. The RED has been substantially amended several times and is currently being recast [General Secretariat of the Council 2018]. Within the MAGIC project, the calculation rules of the RED II will be applied, provided that these will become available by M24 (June 2019).

This main question leads to the following sub-questions:

- Which life cycle stages or unit processes dominate the results significantly and which optimisation potentials can be identified?
- Do some MAGIC 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 industrial crops would a farmer choose from an agronomic point of view?
- Which technological, logistical or other potential barriers may hinder the large-scale industrial deployment?
- Which boundary conditions have to be met in order to advocate large-scale cultivation of industrial crops on marginal land from a sustainability point of view?
- Do the MAGIC value chains targeting biofuels and bioenergy comply with the sustainability criteria set out in the RED (I and II)? Should the greenhouse gas (GHG) emission savings threshold equally be applied to biofuels and bioenergy from marginal land?

Target audience

The definition of the target audience helps identifying the appropriate form and technical level of reporting. In the case of the MAGIC project, the target audience can be divided into project partners and external stakeholders (EC staff, political decision makers, interested laypersons).

Decision-context

The decision-context is one key criterion for determining the most appropriate methods for the so-called life cycle inventory (LCI) model, i.e. the LCI modelling principle. The International Reference Life Cycle Data System (ILCD) handbook differentiates three decision-context situations (see Table 1). These situations differ regarding the question whether the LCA study is to be used to support a decision on the analysed system (e.g. product or strategy), and,

- if so: by the extent of changes that the decision implies in the background system and in other systems because of market mechanism. These can be "small" (small-scale, non-structural) or "big" (large-scale, structural).
- if not so: whether the study is interested in interactions of the depicted systems with other systems (e.g. recycling credits) or not.

Consequences are considered large scale if the annual additional demand or supply, triggered by the analysed decision, exceeds the capacity of the annual replaced installed capacity of the additionally demanded or supplied process, product, or broader function, as applicable.

Situation B is considered to apply for the MAGIC value chains, since its main application is policy information and development. It is assumed that the implementation of biomass production and use chains developed within the MAGIC project could have consequences that are so extensive that they overcome threshold – via market mechanism – result in additionally installed or additionally decommissioned equipment / capacity (e.g. production infrastructure) somewhere else.

Table 1: Combination of two main aspects of the decision-context: decision orientation and kind of consequences in background system or other systems [JRC-IES 2010].

<table>
<tr><td rowspan="4">Decision support?</td><td rowspan="3">Yes</td><td colspan="2">Kind of process-changes in background system / other systems</td></tr>
<tr><td>None or small-scale</td><td>Large-scale</td></tr>
<tr><td>Situation A
"Micro-level decision support"</td><td>Situation B
"Meso / macro-level decision support"</td></tr>
<tr><td>No</td><td colspan="2">Situation C
"Accounting"</td></tr>
</table>

Reasons for carrying out the study and commissioner

The sustainability assessment is carried out because the MAGIC consortium has decided to supplement the establishment of suitable innovative land use strategies for a sustainable production of plant-based products on marginal lands with a corresponding analysis. The study is supported by the EU Commission, which signed a grant agreement with the MAGIC consortium.

3.2 Scope definition

With the scope definition, the object of the sustainability assessment (i.e. the exact product or other system(s) to be analysed) is identified and described. The scope should be sufficiently well defined to ensure that the comprehensiveness, depth and detail of the study are compatible and sufficient to address the stated goal.

The analysis of the life cycles within the MAGIC project is based on international standards such as ISO standards on product life cycle assessment [ISO 2006b; a], the International Reference Life Cycle Data System (ILCD) guidelines [JRC-IES 2012], the Renewable Energy Directive (RED) [European Parliament & Council of the European Union 2009], the SETAC code of practice for life cycle costing [Swarr et al. 2011] and the UNEP / SETAC guidelines for social life cycle assessment [Andrews et al. 2009].

For the analysis of the MAGIC scenarios, definitions and settings are necessary. They are used in the subsequent analyses (tasks) to guarantee the consistency between the different assessments of environmental, economic and social implications. The definitions and settings are described and explained below.

3.2.1 Investigated systems and settings for system modelling

The MAGIC project investigates various industrial crops suitable for the cultivation on marginal land under various growing conditions. Also, several energy and material use options are considered. Therefore, there is not just one single MAGIC product system to be analysed. Instead, there is a wide spectrum of potential implementations combining several of the elements leading to 40–80 possible crop-technology combinations. In task 6.2, this large amount is reduced to the nine most promising value chains on the basis of selection criteria such as the technology readiness level (TRL) and the expected market volume. The selection will be done in the framework of an internal project workshop on selection of value chains and interlinkages in M24 (MS6.2 / MS18).

Against this background, the application of a scenario-based assessment is most suitable for the MAGIC WP6. The analysed product systems will represent generic scenarios which consider typical conditions that can be found across Europe (see section 3.2.1.1) so that reliable general statements and recommendations concerning bio-based products and bioenergy from industrial crops cultivated on marginal land in Europe can be derived. When deriving the mass and energy flow data for these generic scenarios, data obtained from field trials, pilot plants, case studies and databases and literature will be taken into consideration, but most likely not be used directly (i.e. only after extrapolation).

The initial elements of the MAGIC scenarios are described in chapter 4.

3.2.1.1 Geographical coverage

Geography plays a crucial role in many sustainability assessments, determining e.g. agricultural conditions, transport systems and electricity generation.

It is the aim of the MAGIC project to establish a basis for cultivation of marginal lands in Europe. For this reason, geographical coverage for the sustainability assessment is focused on European countries and the differing growing conditions and cultivation practises in Europe are taken into account. This is achieved by categorising the various conditions and yield potentials that can be found in Europe based on the climatic zones identified by [Metzger et al. 2005]. For the MAGIC project, these climatic zones are aggregated into three large agro-ecological zones (AEZ) as specified in Figure 5. On the one hand more distinctions would exceed the scope of the analysis and on the other hand conditions vary strongly across Europe.

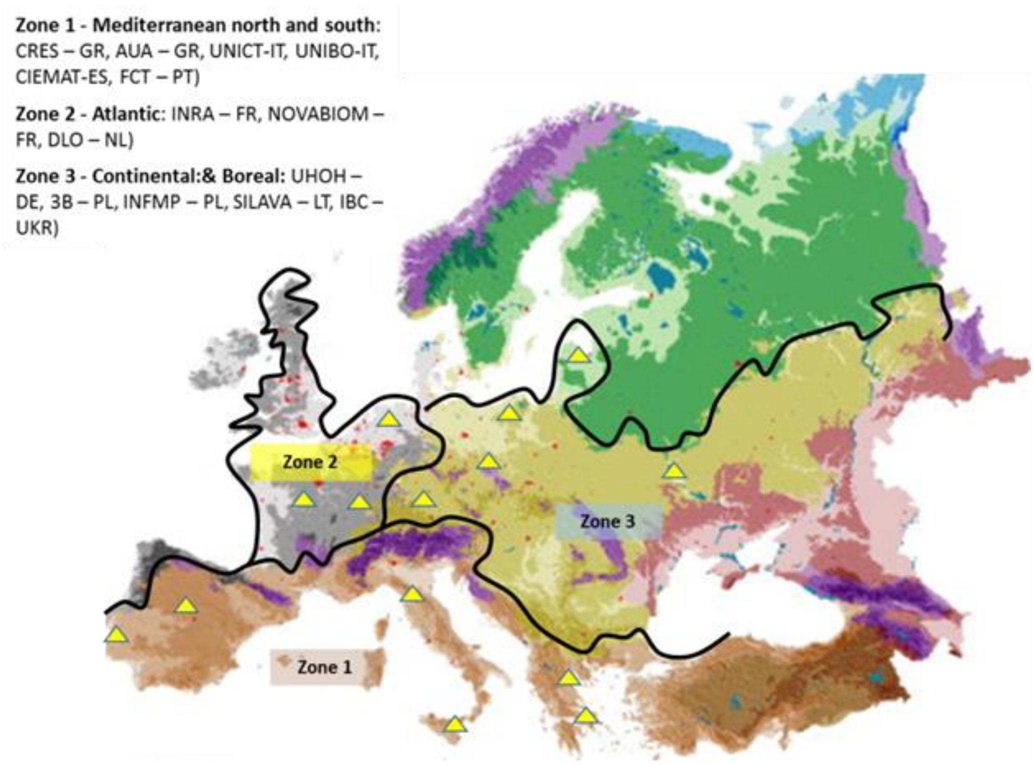

Figure 5: Major geographical/climatic zones in Europe; yellow spots indicate new and established field trials.

The following three aggregated agro-ecological zones are defined for the MAGIC project:

- AEZ 1 – Mediterranean north and south,
- AEZ 2 – Atlantic, and
- AEZ 3 – Continental & Boreal.

With respect to the provision of conventional reference products, the geographical scope is broadened in order to represent the generic (e.g. European or 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 or environmental burdens related to irrigation.

3.2.1.2 Technical reference

The technical reference describes the agricultural practise and the conversion technology to be assessed in terms of development status and maturity.
Assessing the sustainability of a pilot case is not an appropriate approach to answer the key questions listed under the goal definition (section 3.1) because many parameters might differ quite considerably from future implementation. In order to evaluate whether the cultivation of marginal lands is worth being further developed or supported, it is essential to obtain information how future implementations will perform compared to established reference product provision pathways which are operated at industrial scale. This is to avoid an unbiased comparison between the bio-based products and conventional reference products.

Therefore, mature agriculture practise and mature industrial-scale plants are set as technical reference. To cope with uncertainty regarding future technology, a bandwidth of technical efficiency from ‘low’ through ‘typical’ to ‘high’ is considered. ‘Low’ could correspond to current process data whereas for ‘typical’ and ‘high’, extrapolations, estimations, expert visions are needed. The scale of the plant depends on the kind of bio-based product.

3.2.1.3 Time frame

Typically, the time frame has a strong influence on the assessment of pilot projects because it takes several years to ramp up production volumes in order to benefit from economies of scale and to improve production with respect to resource efficiency.
Cultivation and processing of industrial crops on marginal lands are still in an immature state and thus cannot compete with established energy provision production chains. By setting the year 2030 as a reference, undistorted / unbiased comparisons can be achieved and results benefit from a more representative picture of the investigated system’s potential to achieve the goals.

3.2.2 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 based on cut-off criteria. Within the MAGIC project, two alternatives of system boundaries are considered (see Figure 6):

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

Regarding the *cradle-to-grave* approach, the sustainability assessment of the MAGIC system will take into account the products’ entire value chain (life cycle) from cradle to grave, i.e. from 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 (see section 2.3). The system boundary also covers the so-called alternative land use (see section 3.2.3), including land use change effects and associated changes in carbon stocks. 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 concept of life cycle thinking integrates existing consumption and production strategies, preventing a piece-meal approach. Life cycle approaches avoid problem shifting from one life cycle stage to another, from one geographic area to another and from one environmental medium or protection target to another.

Furthermore, greenhouse gas emissions are additionally calculated for the agricultural stage from *cradle-to-farm gate*. These data are implemented in the MAGIC decision support system and allow a compliance-check according RED as well as statements on viability for farmers.

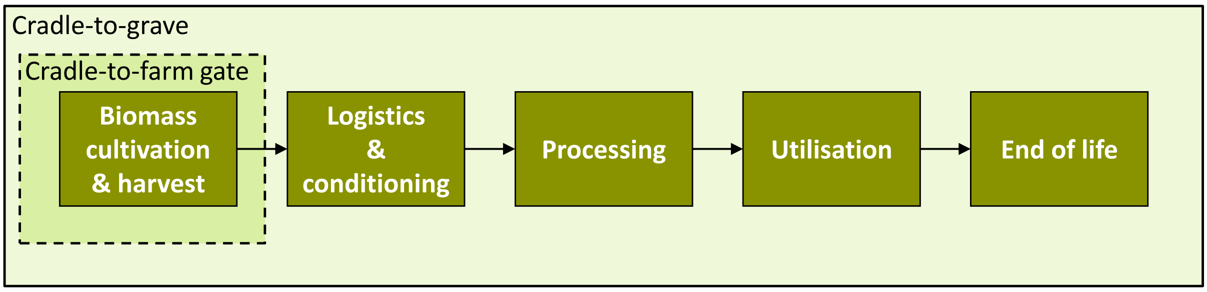

Figure 6: System boundaries from cradle-to-grave and from cradle-to-farm gate applied within the MAGIC project.

3.2.3 Alternative land use

For sustainability assessment of biomass production systems, the alternative land use is a crucial parameter for the outcome of the investigation. The alternative land use describes what the cultivation area would be used for if the crops under investigation were not cultivated [Jungk et al. 2002; Koponen et al. 2018]. If the MAGIC concepts are implemented, land that was formerly used for certain purposes will be used for production of industrial crops instead. By consideration of the alternative land use, the sustainability assessment guarantees a sound evaluation of the implications related to this land use change. The assessment is carried out through a comparison of the proposed agricultural land use with the alternative land use (see Figure 3 on page 8).

Alternative land use and the related environmental, social and economic impacts are taken into account in all scenarios, e.g. by consideration of greenhouse gas emissions, opportunity costs or social impacts on local inhabitants. However, one major benefit of marginal lands is that there is little competition for their use and in many cases they are currently unused.

Therefore, as a baseline setting cultivation is set to take place on former idle land. In this project, idle land is defined as land that is currently not in use. Thus, the MAGIC industrial crops would not displace food or fodder crops to other, previous unused, areas and indirect land use changes (iLUC) can be excluded from this assessment. However, impacts from direct land use changes (dLUC) are considered. In addition to the baseline setting (‘cultivation of industrial crops on former idle land’), the sensitivity analysis will cover different types of alternative vegetation such as woody grassland / shrubland and grassland which covered the land before the cultivation of industrial crops.

3.2.4 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) and life cycle costing (LCC), is vital for comparability and consistency of the individual 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. In the case of lignocellulosic 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, 1 tonne oven-dry biomass could be used as reference unit. In addition, land is a main factor limiting the production of bioenergy and bio-based products in Europe. Therefore, referencing the results to 1 hectare is most suitable.

Hence, these three well-proven reference units for biomass production systems are applied within the MAGIC project:

- an area-based reference unit, e.g. 1 hectare of occupied land for 1 year,
- an input-based reference unit, e.g. 1 oven-dry tonne (odt) of biomass, and
- an output-based reference unit, e.g. 1 MJ fuel (for RED-related analyses).

Results related to these reference units are well comparable to other biomass production systems. Transformation into other reference units will be possible since most transformation factors will be available anyway. Nevertheless, the reference unit determines how the results are presented and interpreted.

3.2.5 Data sources

The sustainability assessment of the MAGIC systems requires a multitude of data. Primary data (on the foreground system) is obtained from the following sources (sub-task 6.1.3):

- Quantitative data on agricultural cultivation, harvesting, logistics and conditioning, up to the biorefinery inlet gate (cradle-to-biorefinery inlet gate) are provided by CRES and CREA.
- Quantitative data on biomass conversion as well as at least qualitative information on use and end of life (biorefinery inlet gate-to-grave) are provided by BTG, ARKEMA and NOVA.

The primary data provided by the project partners are supplemented with data taken from IFEU's internal database [IFEU 2018], commercial databases and literature. Secondary data (on the background system) are obtained from the same.

It is important to note that the original data (e.g. coming from field trials or pilot plants) will most likely not be used directly. However, the data will be evaluated in order to provide a solid basis for the subsequent extrapolation for the year 2030. The extrapolation is done by expert judgements, resulting in data sets which represent mature agricultural practice and industrial processing units (see sections 3.2.1.2 and 3.2.1.3).

4 Initial elements of the MAGIC scenarios

The MAGIC scenarios are based on the nine value chains which will be selected in the framework of an internal project workshop in M24 (MS6.2 / MS18) which is prepared by task 6.2. Therefore, the main focus of the sustainability assessment is on the MAGIC scenarios which represent promising *generic* value chains. However, this does not exclude the use of specific case studies which sometimes can provide useful insights in addition.
These MAGIC scenarios consider the entire life cycle 'from cradle to grave'. The associated scenario elements will be based on the following four life cycle stages (see Figure 6):

- Biomass production and harvesting (section 4.1),
- Logistics and conditioning (section 4.2),
- Biomass conversion and use (section 4.3), and
- End of life (section 4.4).

For comparison purposes, reference systems are needed which are described in section 4.5.

4.1 Biomass production and harvesting

A relevant first step of defining the biomass production is the selection of the most promising industrial crops for marginal lands which were provided by task 1.3 of WP1 [Alexopoulou & Monti 2018]. The selection result in twenty industrial crops, grouped in three categories: oilseeds & specialty, carbohydrate and lignocellulosic (see Table 2). These crops can be used for various products including bioenergy, biofuels, biochemicals and biomaterials.

Table 2: Twenty most promising industrial crops for marginal lands within the MAGIC project [Alexopoulou & Monti 2018].
Crops marked with * are grouped in more than one category.

Category	Selected industrial crops
Oilseeds & specialty	Camelina, crambe, castor bean, Ethiopian mustard, safflower, lupin*, industrial hemp*, cardoon*, pennycress
Carbohydrate	Sweet sorghum*, lupin*
Lignocellulosic	Fibre crops: industrial hemp*, fibre sorghum* Perennial herbaceous crops: switchgrass, miscanthus, giant reed, reed canary grass, cardoon*, tall wheatgrass, wild sugarcane Woody crops: willow, poplar, Siberian elm, black locust

These twenty industrial crops are not all equally suitable for all European regions, so that a closer selection of crops was made for each of the three agro-ecological zones, defined in section 3.2.1.1:

- AEZ 1 – Mediterranean,
- AEZ 2 – Atlantic, and
- AEZ 3 – Continental & Boreal.

In addition, WP4 identify relevant biophysical constraints for each zone that limit the agricultural use of the marginal lands for the biomass production [von Cossel et al. 2018]. The combination of biophysical constraints and agro-ecological zones lead to ten categories of marginal agro-ecological zones (MAEZ) (see Table 3).

Table 3: Definition of marginal agro-ecological zones (MAEZ) [von Cossel et al. 2018].
CL: climate conditions, FE: fertility conditions, RT: rooting conditions, TR: terrain conditions, TX: texture conditions, WT: wetness conditions, CH: Chemical conditions.

Agro-ecological zone (AEZ)	MAEZ code	MAEZ description
Mediterranean (AEZ 1)	CL_1	Adverse climate – dryness
	FE_1	Low soil fertility – low soil organic carbon
	RT_1	Adverse rooting – shallow soils, stoniness, heavy clay
	TR_1	Steep slope
Atlantic (AEZ 2)	RT_2, TX_2	Limitations rooting – soil texture (sandy soils, shallow & organic soils)
	CL_2	Adverse climate – short growing season
	WT_2	Excessive soil moisture
Continental (AEZ 3)	RT_3, TX_3	Limitations in rooting – organic & sandy soils
	CH_3	Adverse chemical conditions - salinity & sodicity
	WT_3	Excessive wetness

The MAGIC scenarios selected in task 6.2 represent promising generic value chains, which are not to be confused with specific case studies. Therefore, each MAEZ doesn't need to be considered for all crops in the MAGIC scenarios because the resulting amount of scenarios would be too large for a detailed sustainability assessment. Therefore, the selection will be limited to two constraints in each agro-ecological zone which are defined by specified growing conditions and yield potentials. For additional information, the growing conditions and yield potentials of areas without constraints (standard land), may also be included into the assessment. The decision on this issue will be taken in M24.

4.2 Logistics and conditioning

Before the material or energy use, the produced biomass has to be processed and transported to the conversion unit. The necessary process steps are mainly determined by the intended use of biomass, the quality of biomass and the local conditions.
Therefore, distinctions are made between the product groups, woody and herbaceous crops and between dry climates (i.e. the Mediterranean and the Continental zone) and moist climates (i.e. the Atlantic zone).
The detailed description of the process steps will be provided in D6.2, due in M30.

4.3 Biomass conversion and use

In general, these four product groups are intended to be considered within the MAGIC project:

- Bioenergy,
- Biofuels,
- Biochemicals, and
- Biomaterials.

Some crops will provide only one product while some crops (i.e. hemp) can be used for more than one application fields (i.e. biochemicals and biomaterials). For each crop, an average about two to four appropriate conversion technologies are expected. Furthermore, each of these conversion technologies are differed regarding the technological efficiency between the three levels ‘low’, ‘typical’ and ‘high’ (see section 3.2.1.2).
The specific conversion and use processes will be described qualitatively and quantitatively in D6.2 (due in M30).

4.4 End of life

The end of life of all bio-based products is taken into account in the sustainability assessment within the MAGIC project. If the bio-based products are used for material purposes, there can be different options of end of life after the use phase. These potential options will also be described in detail in task 6.2 (due in M30).

4.5 Reference systems

For the comparison of the MAGIC systems, the definitions of the reference systems are required. On the one hand, the reference system for land use is described in section 4.5.1. On the other hand, the reference products are determined in section 4.5.2.

4.5.1 Reference land use

For the outcome of the sustainability assessment, the alternative land use is usually a major factor which determines the results significantly (see section 3.2.3). For instance, GHG emissions due to initial clearing and plantation establishment are linked to the alternative vegetation. Also, impacts on biodiversity caused by biomass cultivation are determined by alternative land use. For these reasons, alternative vegetation and alternative land use are included in the MAGIC scenarios.
Within the MAGIC project, the alternative vegetation on marginal land is defined as either grassland or woody grassland / shrubland. Furthermore, it is defined, that the marginal land has been idle and no food or feed crops are displaced (see also section 3.2.3). Nonetheless, wheat is chosen as reference crop in the economic assessment, because the revenue of a common crop like wheat helps farmers to judge the economic advantage or disadvantage of industrial crops.

4.5.2 Reference products

The conventional reference product represents the product that is replaced by the proposed biomass production chain. The appropriate definition of the conventional reference products is an essential part of the life cycle comparison approach illustrated in Figure 3. It highly affects the sustainability results of a given system to be investigated.

For instance, the GHG emissions caused by the provision and combustion of natural gas are saved in case poplar pellets are used for heating. These savings can be credited to the poplar pellets. The balance between the burden for the provision of the poplar pellets and the credits for saving the natural gas express the potential advantage or disadvantage of a shift towards poplar.

For each biomass use option conventional reference systems are defined, to which the bio-based systems can be compared. In general, the conventional reference systems shall represent the marginal technology that would most likely be replaced first due to economic and political boundary conditions when additional bio-based products as suggested by the MAGIC approach was used. With respect to life cycle assessment, this approach is called 'consequential modelling'. Across Europe, the boundary conditions vary strongly so that default options are defined which aim at representing average conditions in Europe and from which robust statements in terms of sustainability impacts can be derived.

Within the MAGIC project, the conventional (fossil) reference systems are specified in task 6.2 within the selection of MAGIC value chains and the qualitative description of the most appropriate technologies for conversion into promising intermediate and end products. The project partner BTG will focus on the comparator of the lignocellulosic crops, ARKEMA on those of the oil and specialty crops, and NOVA on those of carbohydrate and fibre crops.

5 Conclusion

This ‘Interim report on definitions and settings’ (Deliverable D6.1) describes important common definitions and settings for the integrated sustainability assessment (WP6) within the MAGIC project and forms the basis for task 6.2 (starting in M6) as well as for tasks 6.3 to 6.5 (starting in M13). The early agreement on fundamental definitions and settings by all project partners is important for being able to finally join the results of each of these tasks in task 6.6 (starting in M25). Since the entire MAGIC consortium is affected by these decisions, an internal project workshop on the definitions and settings was successfully held in Madrid (Spain) on 10 July 2018. During the workshop, relevant definitions regarding the goal and scope of the integrated sustainability assessment as well as specifications of initial elements of the scenarios were agreed upon by all project partners.

A detailed qualitative and quantitative system description of the scenarios is still pending since an extensive screening of potential value chains (due in M24) is still ongoing. This screening will result in the selection of the nine most promising value chains which will subsequently be investigated in detail in tasks 6.3 to 6.5. Therefore, the analyses in tasks 6.3 to 6.5 will only start in the second half of the project, as foreseen in the grant agreement.

6 Abbreviations

AEZ	Agro-ecological zone
DSS	Decision support system
dLUC	Direct land use change
GHG	Greenhouse gas
ILCD	International Reference Life Cycle Data System
ILCSA	Integrated life cycle sustainability assessment
iLUC	Indirect land use change
ISO	International Organization for Standardization
LCA	Life cycle assessment
LCC	Life cycle costing
LC-EIA	Life cycle environmental impact assessment
LCI	Life cycle inventory
LCT	Life cycle thinking
MAEZ	Marginal agro-ecological zones
RED	Renewable Energy Directive
SETAC	Society of Environmental Toxicology and Chemistry
SWOT	Strengths, weaknesses, opportunities, threats
S-LCA	Social life cycle assessment
UN	United Nations
UNEP	United Nations Environment Programme
WP	Work package

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