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Deliverable 5.3

Title: **DESCRIPTION OF PLAUSIBLE VALUE CHAINS**	
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1 Introduction

1.1. Objective

The BECOOL project aims to develop innovative and sustainable value chains for producing advanced biofuels based on lignocellulosic biomass. An important element of this project is the development of biomass-to-advanced fuel value chains while combining and integrating the different key research activities of the project into a consistent framework. An integrated sustainability and market framework assessment will help to flag opportunities for an optimization of the biomass-to-advanced fuel value chains based on economic and environmental criteria and to identify the most promising value chains under current and future market conditions.

The objective of this deliverable D5.3 is to describe our approach and examples for the compilation of plausible value chains. Following this objective, we will use a twofold approach. Firstly, we want to discuss methodological aspects of defining and describing value chains on different levels of detail. Secondly, we suggest an approach for the description of case studies.

The description of plausible value chains in this deliverable will serve as a basis for the further comparative investigations in WP5 and the assessment for case study areas.

The assessment of the different value chains will take place at different levels:

1) Generic chains will be described on a more aggregate level. This will provide the ground for a high number of different chains to be investigated without going into too much detail of regional structures etc.;
2) For the whole number of case studies defined in the project a detailed environmental and social impact assessment will be carried out. For related biomass-to-end-use value chains, socio-economic investigations, attributional and consequential LCA will be done.

The Deliverable summarises our understanding of the BECOOL value chains and describes their integration into the BECOOL assessment work. So this report contains contents of Deliverables 5.1 "Harmonized data and methodological approaches" (Oehmichen et al. 2018) and D2.1 "Description of full biomass supply chains" (Annevelink et al. 2018).

Glossary:
Value chains. The term value chain means biomass-to-advanced fuel value chains and comprises the entire process chain from biomass cultivation/provision to logistical processes to processing and end use. For simplicity, we speak in the following of value chains and not of biomass-to-advanced fuel value chains. **Value chain class**. The value chain class describes the initial biomass-to-advanced fuel value chains from the biomass perspective. **Feasible value chains**. This term describes only potential combinations of the specific cultivation system in combination with a specific, harvesting technology and a specific conversion technology without different logistical options within the value chain classes. **Plausible value chains.** The integration of the logistic chains into the feasible value chains defines a set of plausible value chains. **Case study.** This term contains the introduction of regional characteristics to define a set of case studies.

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1.2. System boundaries

WP 5 of the BECOOL project is based on a lifecycle perspective and thus, addresses the entire value chain. So, before the actual value chains for the assessment will be described, we will focus on a description of the term value chain in the context of the BECOOL project. The system boundaries for the considered advanced biofuel supply chains within the BECOOL project cover the entire process of biofuel supply, shown in Figure 1, from (i) biomass cultivation (or biomass provision in case of residues use) and (ii) biomass harvesting, through (iii) logistical processes, (iv) conversion processes to (v) distribution and end use. Based on this understanding regarding the system boundaries, we will define the term biomass-to-advanced fuel value chain as a combination of process steps for the production of advanced fuels which comprises the entire process chain from biomass cultivation/provision to logistics to processing and end use (see Figure 1).

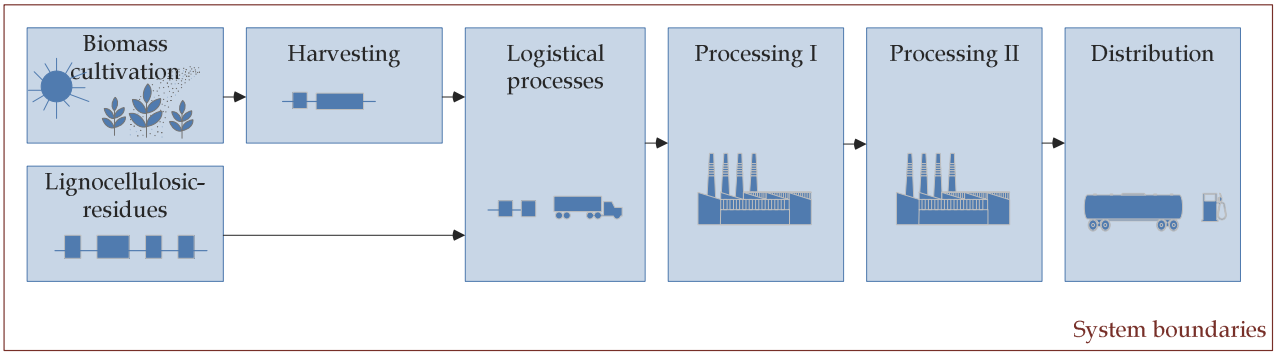

Figure 1 **System boundaries of the biomass-to-advanced fuel value chains.**

2 Work on biomass-to-advanced fuel value chains

2.1. Phase 1 – First idea

The work on the biomass-to-advanced fuel value chains started with preparation for the workshop in Athens during the second BECOOL project meeting in January 2018. Initial data collection sheets have been developed and sent out to the partners responsible for cultivation, harvesting and conversion processes. This requests asked partners to qualitatively assess/evaluate the data collection sheet and to answer the questions regarding the ability to provide the requested data and if there are any suggestions for amendments and comments.

Based on the feedstock and cropping systems defined in WP1 and on the advanced lignocellulosic biofuel conversion technologies considered in WP3 and WP4, there was a first idea of biomass-to-advanced fuel value chains. In Advance of the workshop questions have been defined which should clarify existing dependencies regarding the exchange of data between the single process steps and which data is needed for the description and the assessment of the logistic chains in WP2 (see Figure 2).

To answer these questions is a pre-requirement, in particular with regard to the dependencies between the single process steps, the biomass characteristics after harvesting and the requirements of the conversion

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technology to the feedstock, for the description of initial value chains, which are essential for further work on logistic chains in WP2 and entire value chains WP5.

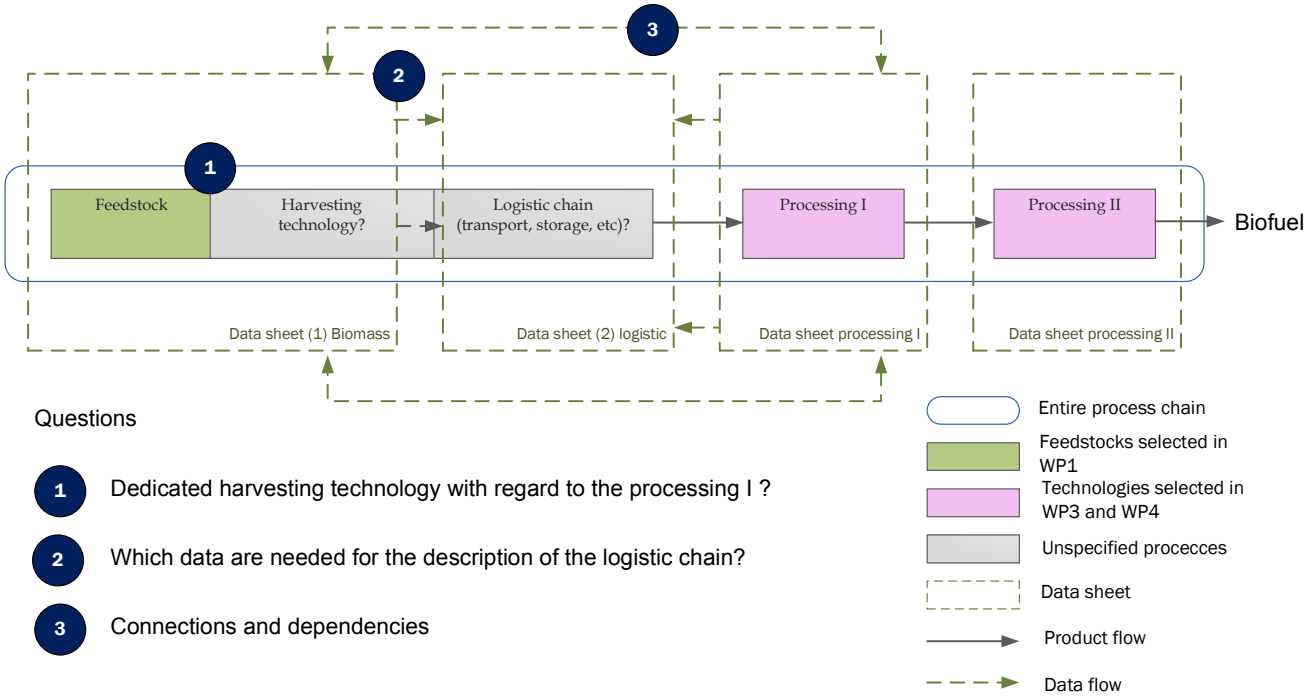

Figure 2 **The first idea of a value chain and the corresponding questions with regard to the dependencies between the single process steps**

2.2. Phase 2 – Biomass-to-advanced fuel value chain classes

The description of initial biomass-to-advanced fuel value chains in Figure 1 was essential for the work on the logistic chains in WP2 and WP5. As mentioned before (see section2.1) initial work on the biomass-to-advanced fuel value chains has been based mostly on the selected feedstocks and cropping systems and the advanced biofuel conversion technologies. In advance of the workshop in Athens, it was decided to start the compilation of the value chains from the feedstock perspective. Thus, the compilation of feasible value chain(s) based on i) giant reed ii) Eucalyptus iii) sorghum and iv) lignin-rich residues was one of the goals of the four dedicated workshops which took place as part of the second BECOOL consortium meeting in Athens (25-26 January 2018). For this purpose, the respective partners in charge were asked to give brief presentations on the corresponding cultivation systems, harvesting technologies and conversion processes.

During the workshops, the essential information (in particular feedstock characteristics and processing requirements) was collected in parallel and the feasible biomass-to-advanced fuel value chains were mapped and discussed, according to a multi-actor approach, at the end of each workshop with all partners.

As an outcome of this discussion, the consortium agreed on a set of value chain elements. Possible combinations of these elements defined a first set of four initial value chains, each based on one of the main feedstocks to be discussed within BECOOL (additional feedstock and thus value chain might follow). From now on, we will refer to these four initial biomass-to-advanced fuel value chains as **value chain classes** (e.g. Giant reed value chain class; Eucalyptus value chain class, Sorghum value chain class and lignocellulosic

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residue value chain class). The following Figure 3 shows two of the defined value chain classes, the giant reed value chain class and the Eucalyptus value chain class.

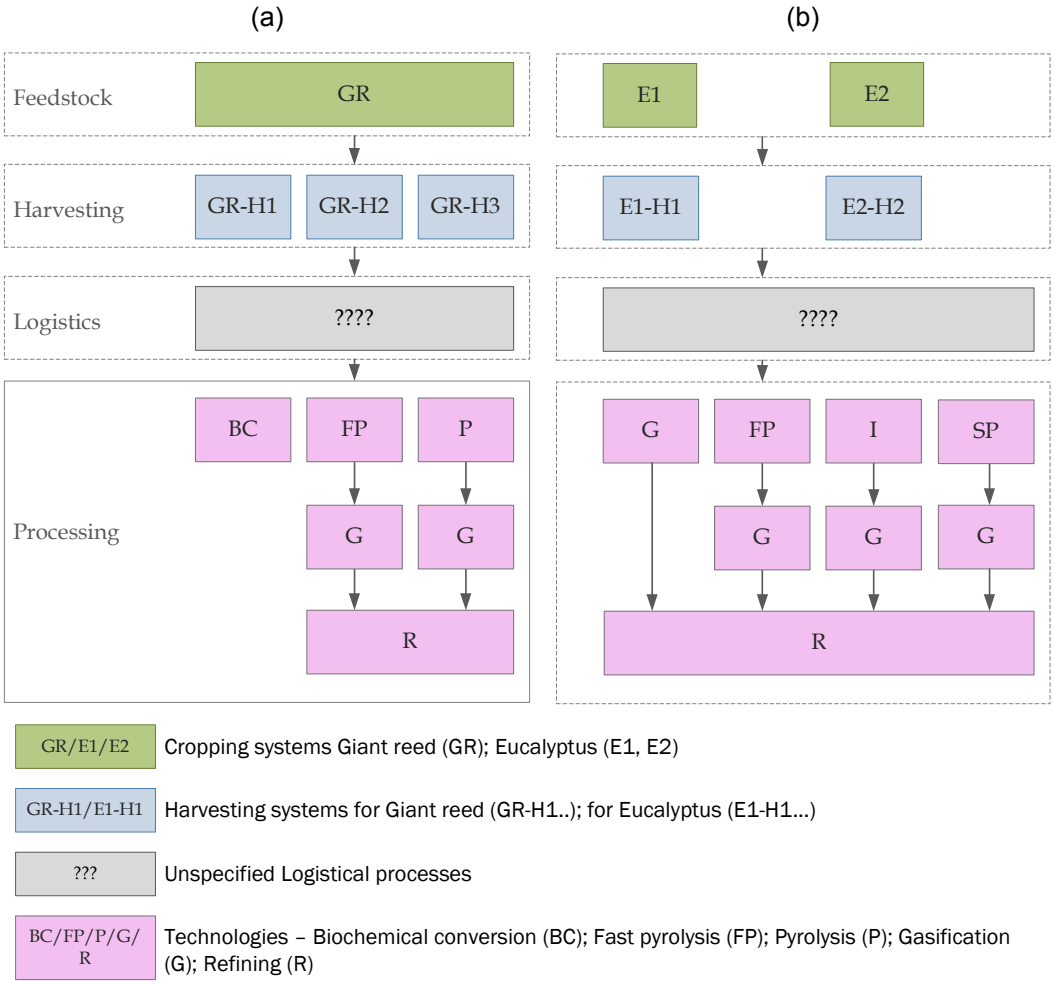

Figure 3 **Examples for the (a) Giant reed value chain class and the (b) Eucalyptus value chain class.**

2.3. Phase 3 – Feasible value chains

The value chain classes describe possible value chains consisting of cropping systems, the corresponding harvesting technologies and technologies suitable to produce advanced biofuel. The potential combinations of the different options for each process step along the value chain (e.g. a specific cultivation system in combination with a specific harvesting technology and connected to through a certain set-up of the logistics to a certain type of pyrolysis, etc.) form a magnitude of potential value chain class alterations. We refer to the sum of potential value chain class alterations as **feasible value chains**.

Two examples of feasible value chains as alterations of value chain class are shown for the (i) giant reed feasible value chains (Figure 4) and the (ii) Eucalyptus feasible value chains (Figure 5). These figures show very clearly the different possibilities and technologies of the individual process steps. Important factors for further work on the feasible value chains are:

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1) Information regarding feedstock characteristic in relation to harvesting technologies (within the giant reed value chain class we have three harvesting options (GR-H1) chipping and loading (GR-H2) matching and baling (GR-H3) mowing, pick-up, shredding and loading) and
2) Requirements for the conversion technology (biochemical processing (BC), fast pyrolysis (FP) and pyrolysis (P)).

This information is the basis for the description of the connecting link, the logistic chains, where feedstock characteristics at roadside and processing requirements at the gate of the production plant will be matched.

Figure 4 Feasible value chains as alterations of the giant reed value chain class.

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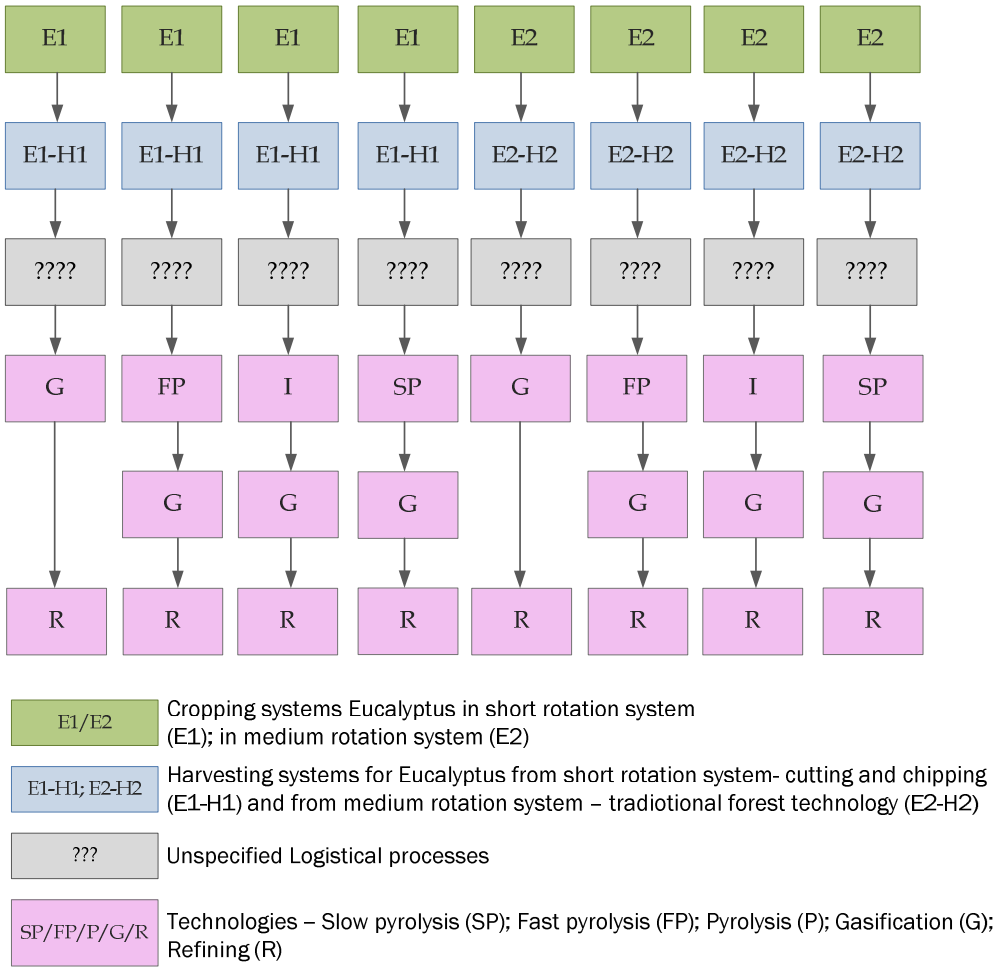

Figure 5 **Feasible value chains as alterations of the Eucalyptus value chain class.**

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Consequently, the potential alterations of the four value chain classes lead to 31 feasible value chains[1] (feasible value chains means (Table 1).

Table 1 Number of feasible value chains

Value chain class	Number of selected cropping systems	Number of selected harvesting technologies	Number of selected conversion technologies	Number of feasible value chains
Giant reed	1	3	3	9
Eucalyptus	2	2	4	8[2]
Sorghum	2	2	3	12
Lignocellulosic residues	1	-	2	2
Sum of feasible value chains				31

2.4. Phase 4 – Plausible value chains

Based on the feasible value chains described in the previous section, information on the general feedstock characteristics after harvesting and on the main requirements of the conversion processes, the logistics chains for the considered concepts (feasible value chains) were developed in WP2. The logistic chain comprises one or more of the components transport, storage, handling and pre-treatment (size reduction and/or drying) within a specific option for the considered biomass from the road side to the gate of the conversion plant.

The design of the logistic chains to match both, biomass feedstock and conversion technology has been carried out by means of a specific biomass-matching tool that facilitates assessment of the suitability of lignocellulosic biomass feedstocks for various conversion technologies and that has been developed within the S2BIOM project (Elbersen et al. 2015).

In Figure 6 an example of some of the possible combinations of giant reed (GR), one of the harvesting techniques (GR-H1), four of the possible logistic chain set-ups (the yellow boxes LO1-LO4) with different set-ups of the three conversion technologies (G1 .. BC4) are presented. As mentioned before, the logistic chain describes the part of the value chain from the road side to the gate of the conversion plant. In the case of logistical option LO4 that comprises the processes drying, storage-indoor and transport. The logistical option LO3 on the contrary comprises only the processes drying and transport. The process storage of the biomass is not included in the logistical option (from road side to plant gate) but takes place at the plant size (e.g G2 –

[1] At this point of value chain development, the term "feasible value chain" describes only potential combinations of the specific cultivation system in combination with a specific, harvesting technology and a specific conversion technology without different logistical options.

[2] Due to the fact that in case of the Eucalyptus value chains the harvesting technologies are dedicated to the specific cropping system there is only 1 combination for each cropping system E1-H1 and E2-H2. That's why the number of feasible Eucalyptus value chains is not 16 but 8.

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that means gasification technology with biomass storage at plant). This explains the different terms for the same technology (pls. see the pink boxes in Figure 6 e.g G1 without storage and G2 with on sites biomass storage). A detailed description of the plausible value chains can be found in (Annevelink et al. 2018).

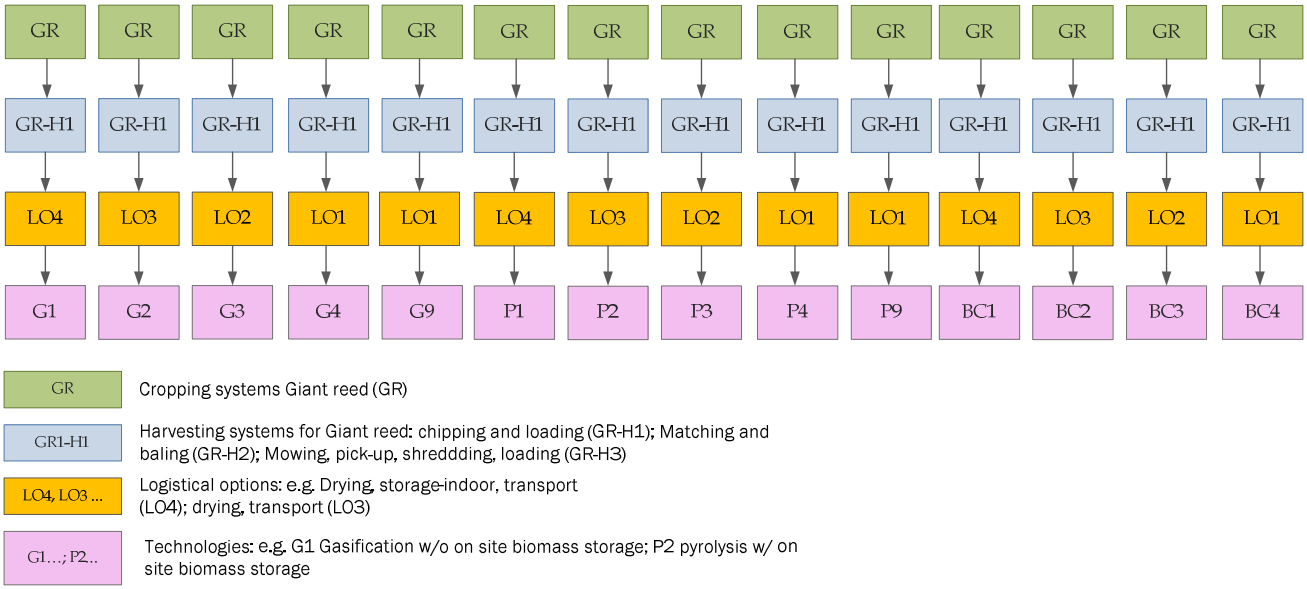

Figure 6 **Example for plausible value chains for giant reed (GR), one specific giant reed harvesting technology (GR-H1), four possible logistic chain set-ups (LO1-LO4) with different set-ups of the three conversion technologies (G1-BC4).**

The integration of the logistics chains into the feasible value chains defines a set of **plausible value chains**. These plausible value chains are one of the important starting points for the assessment task and thus, the identification of the most promising value chains for the production of advanced fuels within BECOOL.

2.5 Phase 5 – Next steps

From the large amount of the plausible value chains described in the Deliverable 2.1, a sub-selection of logistical concepts will made based on the defined criteria. This sub-selection will serve as input for the development and description of the entire value chains and to WP5 where an integrated sustainability assessment of these value chains will be made.

The identification of the most promising (i.e. concerning their economic and environmental performance) value chains in BECOOL will be based on two pillars (Figure 7). The first pillar includes an assessment of the comprehensive set of plausible value chains with regard to a set of defined assessment criteria featuring mainly sustainability, technical, economic and environmental indicators. This exercise will be largely based on data from BECOOL WP 1 to WP 4. Furthermore, it is important to note that the results of this exercise will be largely generic and will help to describe process and value chain specific benchmarking parameters such as for example: process efficiencies, GHG mitigation potential of the advanced fuel produced, etc.

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To support an informed discussion regarding the identification of the most promising value chains, however, additional parameter, which largely influences the real life value chain performance with regards to the selected criteria and indicators shall be considered. For this purpose, regional characteristics will be introduced to define a set of case studies. This will be the second pillar of the assessment task. For now, we define the term case study as a regionalised plausible value chain with both, a clear regional reference for each of the process steps involved and an appreciable individualisation of the process steps due to the introduction of actual process data. This step will complement the generic assessment approach from the first pillar to allow for more detailed recommendations regarding the potential competitiveness of the value chains investigated in BECOOL.

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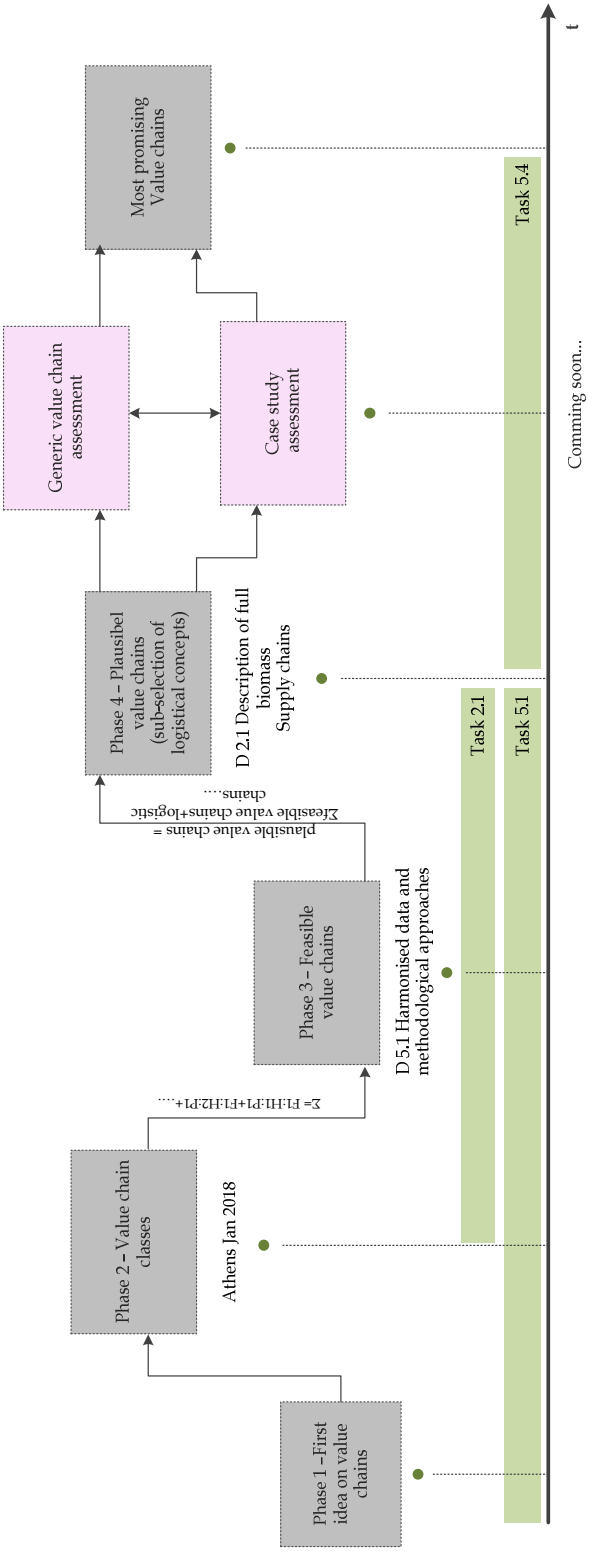

Figure 7 **Work on value chains – previous work and next steps**

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3 Overall summary

The BECOOL project aims to develop sustainable and innovative value chains for producing advanced biofuels based on lignocellulosic biomass. The value chains considered shall include elements from the different key research activities of the project, namely: different types of biomass and biomass cultivation processes, biomass logistics, biomass pre-treatment, pyrolysis and gasification. Based on the research in BECOOL WP 1 to WP 4, various potential combinations do exist to form numerous value chain alteration.

During the BECOOL workshop in Athens, the consortium agreed on a set of value chain elements. Possible combinations of these elements defined a first set of four initial value chains, each based on one of the main feedstocks to be discussed within BECOOL (additional feedstock and thus value chain might follow). From now on, we will refer to these four initial value chains as **value chain classes** (e.g. Giant reed value chain class; Eucalyptus value chain class, Sorghum value chain class and lingo. res. value chain class). The four value chain classes include various options for downstream processes, suitable to produce advanced biofuels from each of the specific feedstock defined.

The potential combinations of the different options for each process step along the value chain (e.g. cultivation system, harvesting technology, type of pyrolysis, etc.) form the magnitude of potential value chain class alterations. We refer to the sum of potential value chain class alterations as **feasible value chains**.

Within BECOOL WP2, potential logistic processes are being developed for the various feasible value chains. The integration of these logistic steps into the feasible value chains defines a set of **plausible value chains**. These plausible value chains are one of the important starting points for the assessment task and thus, the identification of the most promising value chains for the production of advanced fuels within BECOOL.

The identification of the most promising (i.e. concerning their economic and environmental performance) value chains in BECOOL will be assessed based according to two pillars. The first pillar includes an assessment of the comprehensive set of plausible value chains with regard to a set of defined sustainability assessment criteria featuring mainly technical, economic and environmental indicators. To support an informed discussion regarding the identification of the most promising value chains however, an additional parameter, which largely influences the real life value chain performance with regard to the selected criteria and indicators, shall be considered. Regional characteristics will be introduced to define a set of case studies, as the second pillar. This step will complement the generic assessment approach from the first pillar to allow for more detailed recommendations regarding the potential competitiveness of the value chains investigated in BECOOL.

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