SWEETFUEL:

Sweet Sorghum: an alternative energy crop

Deliverable 6.1:

Interim report on all tasks and interlinkages

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November 30, 2011

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Authors:

Reinhardt, Guido	IFEU	(WP-Leader, leader Task 6.2)
Braconnier, Serge	CIRAD	(Leader Task 6.1)
Basavaraj, G.	ICRISAT-IN	(Leader Task 6.3)
Janssen, Rainer	WIP	(Leader Task 6.4)
Rettenmaier, Nils	IFEU	(Leader Task 6.5)

Amaducci, Stefano	UCSC
Avelino, José	EMBRAPA
Bursztyn, Marcel	University of Brasilia
Detzel, Andreas	IFEU
Garcia-Zambrano, Eduardo A.	UANL
Gutierrez-Diez, Adriana	UANL
Köppen, Susanne	IFEU
Magalhaes, Jurandir	EMBRAPA
Monti, Andrea	UNIBO
Parrella, Rafael	EMBRAPA
Parthasarathy Rao, P.	ICRISAT-IN
Purcino, Antonio Alvaro C.	EMBRAPA
Reddy, Belum V.S.	ICRISAT-IN
Rodrigues, Jose A.	EMBRAPA
Rutz, Dominik	WIP
Schaffert, Robert	EMBRAPA
Simeone, Maria Lucia F.	EMBRAPA
Srinivasa Rao, P.	ICRISAT-IN
Trevino-Ramirez, Jose Elias	UANL
Zacharias, Arndt	KWS
Zavala-Garcia, Francisco	UANL
Zegada-Lizarazu, Walter	UNIBO

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Table of Contents – Overview*

*for a detailed table of content see next page

Table of Contents in detail

1 Introduction and work package structure

Bioethanol is one part in the increasing use of biofuels. Worldwide, sugar cane is the main source of bioethanol. However, the cultivation of this crop cannot be realized in water-limited or temperate regions. On this background, sweet sorghum has several advantages due to its high water use and nutrient efficiency. Furthermore, the production of food, feed and fuel can be combined in one crop. This is an important asset on the background of the currently increasing discussion on fuel production and food security.

As the more widespread use of sweet sorghum for bio-ethanol production is primarily limited by the lack of varieties specifically bred for this purpose, the SWEETFUEL project aims at developing sweet sorghum breeds for improved cultivars and hybrids for temperate, tropical semi-arid and tropical acid soil environments. The focus lies on tolerance to cold, drought and acid soil as well as on a high production of stalk sugars, easily digestible biomass and grains – depending on the environmental region the crop shall be cultivated in and the purpose it shall be used for.

Accompanying the development of new sweet sorghum breeds, WP 6 “Integrated assessment” of the European Commission funded project “SWEETFUEL: Sweet Sorghum: an alternative energy crop” provides a multi-criteria evaluation of the sweet sorghum production and use pathways taking into account technological, environmental, economic and social aspects. The outcome of the integrated assessment will be a set of optimized, sustainable sweet sorghum production and use systems.

1.1 Work package 6: Integrated assessment

The main objective of work package 6 “Integrated assessment” of the SWEETFUEL project is to provide a multicriteria evaluation of the sustainability of the sweet sorghum production and use routes taking into account technological, environmental, economic and social aspects. This integrated assessment of sustainability will generate optimized sweet sorghum production and use systems.

Work package 6 “Integrated assessment” will provide a full appreciation of the various impacts of the sweet sorghum production and use chains and alternative production systems for biomaterials, food, fibres and biofuels. Importantly, this analysis should clearly establish to what an extent the activities on sweet sorghum improves the current state of sweet sorghum production and use patterns and how the benefits/limitations of this advanced approach compare to other concepts such as the production of competing biofuels or producing food, feed and/or fibres. With this, finally, the most promising sweet sorghum routes will be depicted in terms of being most sustainable.

In detail, the integrated assessment will give answers to a number of key questions which were defined by the SWEETFUEL consortium.

Following core question shall be answered by the integrated assessment:

- Which are the best ways to produce and use sweet sorghum for energy from an environmental, economic and social point of view?

To address the core question, the following issues will be assessed:

- How should the sweet sorghum products be used from a sustainability point of view?
- What is the influence of different environmental and climatic conditions, like tropical and temperate climates, on the overall results and where should sweet sorghum be cultivated and used?
- What is the influence of different usage pathways for the by-products on the overall results and which usage shall be preferred from a sustainability point of view?
- What are the differences of the results between decentralized and centralized energy production from sweet sorghum and which options should be preferred from a sustainability point of view?
- What is the relative importance of various life cycle steps on the overall results and which optimization potentials can be identified from a sustainability point of view?

1.2 Task description in detail

Work package 6 “Integrated assessment” consists of 5 tasks (Fig. 1-1):

- Technological assessment
- Environmental assessment
- Economic assessment
- SWOT analysis (on strengths, weaknesses, opportunities and threats)
- Integrated assessment

1.2.1 Task 6.1: Technological Assessment

This task will provide the definitions and settings necessary for the completion of the whole WP. These include the definition of system boundaries and settings (IFEU), the definition and description of sweet sorghum scenarios (CIRAD) and the definition and description of reference systems (IFEU). These settings and definitions will take into account all aspects associated with the project. Concerning the sweet sorghum scenarios, all target systems and corresponding sweet sorghum ideotypes will be considered. Particular attention will be paid to the logistics aspects, as transportation of stalks from field to plant represents an essential when considering economical balance or environmental impact.

Concerning the reference systems, all by-products such as bagasse and all alternative land use scenarios and biofuels thereof will be assessed. A project workshop will be held to discuss and agree upon a first set of settings and definitions to ensure best possible and

efficient work in the other tasks. Results from this part of this task will constitute input for Tasks 6.2 to 6.4 and will provide data for a technological assessment of all systems under investigation (CIRAD). The technological assessment will include the analysis of potentials and technological constraints of all systems under investigation. There will be a strong interlinkage to WP5 to define the qualitative system boundaries and to use data obtained in WP5 in this work package. To ensure in-depth analyses and interlinkages in both directions, a project workshop dealing with these interlinkages will be held.

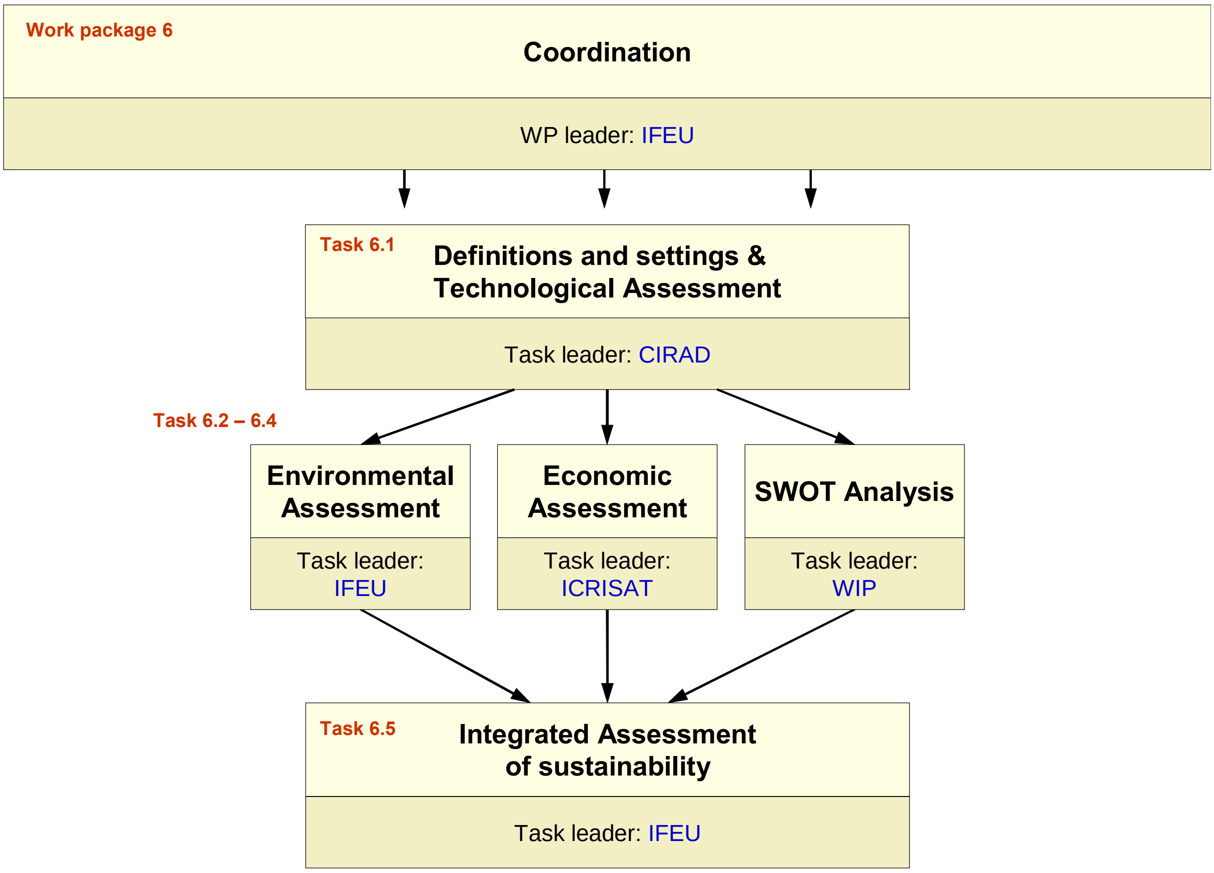

Fig. 1-1 Structure of SWEETFUEL work package 6 „Integrated assessment"

1.2.2 Task 6.2: Environmental Assessment

This task investigates the environmental implications of all sweet sorghum scenarios including all reference systems and will provide input for task 6.5. Beneficiaries contribute by delivering quantitative data specific to their expertise and necessary for the assessment. Environmental implications and the potential for their optimisation will be determined for the sweet sorghum production and use chains and for reference systems defined in task 6.1. First, environmentally-specific system boundaries and parameters will be defined and then

life cycle assessments (taking into account the international ISO 14040/44 norms on life cycle assessments) will be performed. Likewise, the environmental implications will be analysed on an area, raw material and usage basis. Additionally, site-specific environmental issues linked to feedstock production and transformation will be addressed using elements of an environmental impact assessment (EIA). Overall, weak points will be identified and the best (or optimised) sweet sorghum systems will be identified through the analysis of different scenarios.

1.2.3 Task 6.3: Economic Assessment

This task covers the economic implications of the sweet sorghum systems under investigation and provides input for Task 6.5. The economic implications of cultivation will be assessed by collecting information on all paid out costs and imputed value of family and owned bullocks /machinery. Gross returns will be worked out for both grain and stalk as appropriate. Break even yield and prices will be worked out for recovering fixed and variable costs. Additional costs and returns from use of bagasse for cogeneration, animal feed etc will be worked out to arrive at overall returns from production of sweet sorghum. The benefits accruing to farmers and industry will be partitioned to better understand the equity aspects of growing sweet sorghum. Beneficiaries will contribute by delivering quantitative data specific to their expertise and necessary for the assessment. Having fixed the system boundaries and specific economic parameters, a cost analysis of all sweet sorghum systems will be carried out and compared to that of conventional production systems and all reference systems under investigation (defined in task 6.1). As before, several subscenarios will be investigated taking into account future opportunities for optimisation. Finally, different scenarios for sweet sorghum and conventional production and use lines will be generated using different revenue levels. Results will be useful in determining areas /regions with differing rainfall and soil moisture regimes, and cropping patterns where sweet sorghum production would have a comparative advantage over other traditional systems. The revenue levels would also include different pricing scenarios and would thus be useful for policy makers and industry in fixing prices for procuring sweet sorghum grain /stalk.

1.2.4 Task 6.4: SWOT Analysis

This task analyses the key internal and external factors that determine the success of the whole sweet sorghum production and use chains and most promising reference systems under investigation not yet covered in the tasks 6.1 to 6.3 such as social and other qualitative implications. To do this an analysis on strengths, weaknesses, opportunities, and threats (SWOT) will be performed. It consists of several steps: a screening SWOT analysis on the systems defined in task 6.1 including a separate investigation on the competition between the biomass uses for food, feed, fibres, and biofuels. Based on this analysis, the biomass potentials will be analysed in the light of competition between different uses of both, the raw material and between possible alternative land uses. The leader will setup a questionnaire which will supplemented by IFEU. All Beneficiaries will contribute by delivering qualitative data and information specific to their expertise. In order to discuss these analyses with

relevant stakeholders being experts in their field of socio-economic aspects in biomass usage, a workshop, preferably in Europe, will be organised. An update of the SWOT analysis will follow taking into account the outcomes of the workshop. The results are used in task 6.5.

1.2.5 Task 6.5: Integrated Assessment

In the integrated assessment, the results from the environmental, economic, and SWOT analysis are taken into account in order to identify and depict the most sustainable pathways among the sweet sorghum systems compared to all reference systems including such for food, feed, fibres and biofuels. A thorough overview of the research, assessments and analyses concerning the environmental and economic aspects of all the sweet sorghum and conventional systems will be conducted. This includes both the sweet sorghum system with its multiple outputs such as sugar, starch, bagasse etc. and the different production paths of their conventional equivalents. Different variations and sensitivity analyses will be derived in order to identify the main parameters influencing the economic and environmental performance of the systems under investigation and to show optimisation potentials of the systems. With this, the results of the technological assessments had already been taken into account, while the results of the SWOT analysis will complement the outcomes at this stage of the project and a recursive overall optimization finalizes the integrated assessment of sustainability. From these analyses, the most sustainable pathways are depicted. Finally, a conclusive report will summarise the findings of the work package including the single results listed in the task reports for the environmental, the economic, and the SWOT analysis. Whereas the leader is responsible for writing the report, all Beneficiaries are obliged to review.

2 Sustainability assessment in SWEETFUEL

2.1 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 ellipses indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing (Fig. 2-1).

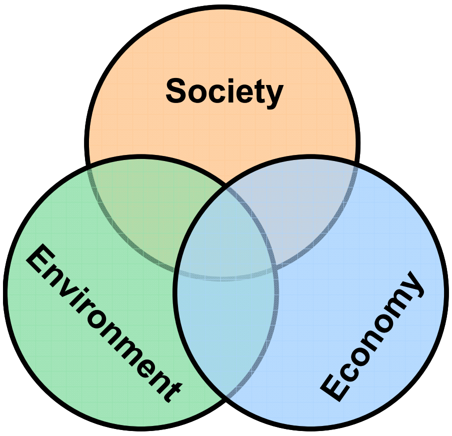

Fig. 2-1 Scheme of sustainable development: at the confluence of three constituent parts

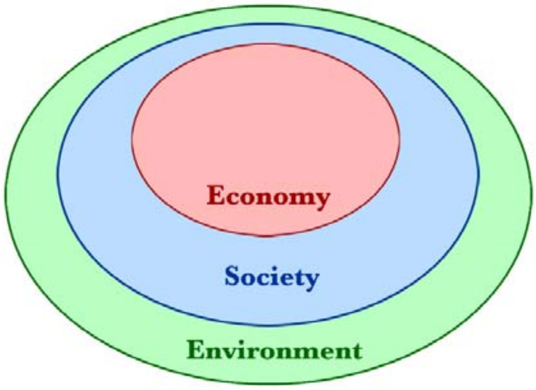

Fig. 2-2 Scheme indicating the relationship between the three pillars of sustainability /Scott Cato 2009/

The UN definition is not universally accepted and has undergone various interpretations. For many environmentalists the idea of sustainable development is an oxymoron as development seems to entail environmental degradation. From this 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 circles (Fig. 2-2).

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 mankind 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.

2.2 Sustainability assessment within SWEETFUEL

The sustainability assessment in the SWEETFUEL project is carried out in WP 6 “Integrated assessment”. Herewith all three pillars of sustainability as listed above are taken into account.

The analysis in WP 6 takes into account the entire life cycle (“life cycle thinking”), from the “cradle” (=biomass cultivation) to the “grave” (e.g. end-of-life treatment) of the biomass, (Fig. 2-3). All pillars of sustainability will be applied to all sweet sorghum life cycles under investigation. For this, in task 6.1 “Technological assessment”, all life cycle comparisons to be assessed will be defined.

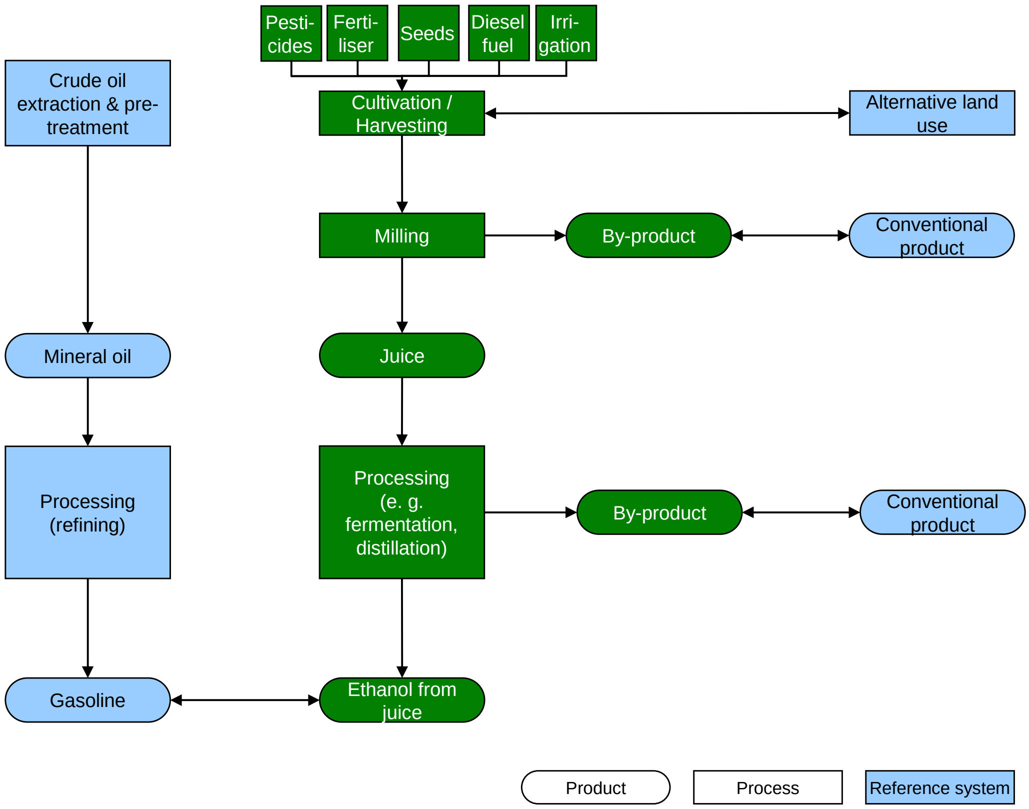

Fig. 2-3 Sustainability assessment in SWEETFUEL: The concept of life cycle assessment.

2.3 Summary on work status

The work done within the work package 6 “Integrated assessment” listed in this report covers 4 tasks (status: November 30, 2011):

- Task 6.1: Technological assessment
- Task 6.2: Environmental assessment
- Task 6.3: Economic assessment

– Task 6.4: SWOT analysis (on strengths, weaknesses, opportunities and threats)

Work on Task 6.5 “Integrated assessment” started recently. Therefore there are no significant results available for reporting on this task.

Concerning tasks 6.1 to 6.4, all work foreseen for the reporting period has been done and the present status including results is listed in the respective chapters 3 to 6.

2.4 References

/UN 1987/ United Nations 1987: Report on the world commission on Environment and Development: Our Common future (Brundtland Report). Transmitted to the General Assembly of the United Nations as an Annex to document A/42/427.

Scott Cato 2009/ Scott Cato, M.: Green Economics - An Introduction to Theory, Policy and Practice. Earthscan, London

3 Interim results task 6.1: Technological assessment

Authors:

Braconnier, Serge (CIRAD); Reinhardt, Guido (IFEU); Köppen, Susanne (IFEU); Rettenmaier, Nils (IFEU); Detzel, Andreas (IFEU); Monti, Andrea (UNIBO)

With contributions of:

Amaducci, Stefano (UCSC); Avelino, José (EMBRAPA); Basavaraj, G. (ICRISAT-IN); Bursztyn, Marcel (University of Brasilia); Garcia-Zambrano, Eduardo A. (UANL); Gutierrez-Diez, Adriana (UANL); Janssen, Rainer (WIP); Magalhaes, Jurandir (EMBRAPA); Parrella, Rafael (EMBRAPA); Parthasarathy Rao, P. (ICRISAT-IN); Purcino, Antonio Alvaro C. (EMBRAPA); Reddy, Belum V.S. (ICRISAT-IN); Rodrigues, Jose A. (EMBRAPA); Rutz, Dominik (WIP); Schaffert, Robert (EMBRAPA); Simeone, Maria Lucia F. (EMBRAPA); Srinivasa Rao, P. (ICRISAT-IN); Trevino-Ramirez, Jose Elias (UANL); Zacharias, Arndt (KWS); Zavala-Garcia, Francisco (UANL); Zegada-Lizarazu, Walter (UNIBO)

This chapter summarises the work done in the Task 6.1 “Technological assessment” – status: November 30, 2011. A detailed task 6.1 description can be found in chapter 1.2.

The work done in this task so far consists mainly of two components:

- Identification and agreements on common settings and definitions
- Identification of interlinkages between WP 5 and WP 6 as well as between the different tasks of WP 6.

Whereas the “identification and agreements on common settings and definitions” are fully agreed by the whole consortium (as an output of a special workshop on this matter and listed in detail in milestone 6.1) the “Identification of interlinkages between WP 5 and WP 6 as well as between the different tasks of WP 6” is still under its way. A final decision on this will be taken at the special workshop on this matter in April 2012 in Bologna, Italy. Beside this, an update of the “Identification and agreements on common settings and definitions“ will be due in early 2013.

Further details and results are listed in the following chapters 3.1 “Definitions and settings” and 3.2 “Interlinkages”.

3.1 Definitions and Settings

3.1.1 Introduction, the purpose of this document

Bioethanol is one part in the increasing use of biofuels. Worldwide, sugar cane is the main source of bioethanol. However, the cultivation of this crop cannot be realized in water-limited or temperate regions. On this background, sweet sorghum has several advantages due to its high water use and nutrient efficiency. Furthermore, the production of food, feed and fuel can be combined in one crop. This is an important asset on the background of the currently increasing discussion on fuel production and food security.

As the more widespread use of sweet sorghum for bio-ethanol production is primarily limited by the lack of varieties specifically bred for this purpose, the SWEETFUEL project aims at developing sweet sorghum breeds for improved cultivars and hybrids for temperate, tropical semi-arid and tropical acid soil environments. The focus lies on tolerance to cold, drought and acid soil as well as on a high production of stalk sugars, easily digestible biomass and grains – depending on the environmental region the crop shall be cultivated in and the purpose it shall be used for.

Accompanying the development of new sweet sorghum breeds, *WP 6 “Integrated assessment”* of the European Commission funded project “SWEETFUEL: Sweet Sorghum: an alternative energy crop” provides a multi-criteria evaluation of the sweet sorghum production and use pathways taking into account technological, environmental, economic and social aspects. The outcome of the integrated assessment will be a set of optimized, sustainable sweet sorghum production and use systems.

Importance of common settings and definitions

The sustainability assessment for the SWEETFUEL systems is mainly carried out by WP 6 (integrated assessment), but to some extent also in WP 5. WP 5 will develop a crop model for sorghum that will be delivered to WP 6 and integrated into the overall assessment. Due to this SWEETFUEL-specific division of sustainability assessment between WP 6 and WP 5, common settings and definitions are essential to ensure consistency of results between WP 6 and WP 5.

Furthermore, common settings and definitions are needed to ensure consistency of all assessments within WP 6, as most of the tasks will be using life cycle assessment (LCA) methodology (environmental LCA in task 6.2, life cycle costing in task 6.3, and SWOT analysis in task 6.4). Even though internationally standardised assessment techniques such as life cycle assessment (LCA) will be applied in all three tasks, the degree of freedom they offer in terms of methodological or data choices might lead to incomparable evaluations. As the findings of tasks 6.2 to 6.4 are used by task 6.5 to identify and depict the most sustainable pathways and the most promising optimization potentials, the use of common settings and definitions by tasks 6.2 to 6.4 are an indispensable prerequisite.

The common settings and definitions are also relevant for the whole consortium as the partners responsible for breeding and optimization of productivity traits (WP 1-4) have to deliver mass and energy flow data in compliance with these common settings and definitions. Therefore, the common settings and definitions need the agreement of all partners. Another reason for discussing the settings with the whole consortium is the fact that the general settings will affect the outcomes of the sustainability assessment and hence are of high importance for the whole project.

Goal and scope of this report

This report is the outcome of *Task 6.1: Technological assessment* of the SWEETFUEL project. It provides general definitions and settings as a basis for the whole work package. Included are the description of system boundaries and settings, the definition and description of sweet sorghum scenarios as well as the definition and description of respective reference systems.

The contents of this report comprises results agreed upon at a specific “workshop on definitions and settings” held on the occasion of the SWEETFUEL annual meeting on 21-24 February 2011 in Potchefstroom, South Africa (for details see milestone M 6.1 of the SWEETFUEL project which contains all details of the workshop including a handout).

This document contains the final set of specifications for general definitions and settings for parameters which are harmonized between all WP 6 tasks and WP 1-5. The objective of this report is in particular:

- to define the definitions and settings needed for sustainability assessment
- to facilitate cooperation between WP 6 partners and
- to facilitate cooperation between WP 6 and WP 5 (and all other partners).

It was composed by CIRAD in collaboration with IFEU and with contributions from all SWEETFUEL partners.

3.1.2 General definitions and settings

As described above, common definitions and settings are a necessary element of an overall sustainability assessment and highly affect the assessment results. The settings are used in the subsequent analyses to assess environmental, economic and social implications and ensure their consistency.

This paper is the outcome of *Task 6.1: Technological assessment*. It provides general definitions and settings as a basis for the whole work package. Included are the description of system boundaries and settings, the definition and description of sweet sorghum scenarios as well as the definition and description of respective reference systems.

3.1.2.1 Goal & scope questions

The integrated assessment (WP 6) will give answers to a number of key questions which were defined by the SWEETFUEL consortium.

The following core question shall be answered by the integrated assessment:

- Which are the best ways to produce and use sweet sorghum for energy from an environmental, economic and social point of view?

To address the core question, the following issues will be assessed:

- How should the sweet sorghum products be used from a sustainability point of view?
- What is the influence of different environmental and climatic conditions, like tropical and temperate climates, on the overall results and where should sweet sorghum be cultivated and used?
- What is the influence of different usage pathways for the by-products on the overall results and which usage shall be preferred from a sustainability point of view?
- What are the differences of the results between decentralized and centralized energy production from sweet sorghum and which options should be preferred from a sustainability point of view?
- What is the relative importance of various life cycle steps on the overall results and which optimization potentials can be identified from a sustainability point of view?

3.1.2.2 General specifications, settings and definitions

For the analysis of the SWEETFUEL scenarios, general definitions and settings are necessary. They are used in the subsequent task analyses to assess environmental, economic and social implications and guarantee their consistency. The general definitions and settings are described and explained below. Definitions and settings specific for each - the environmental, economic and social assessment - will be described and explained within the reports of these tasks.

3.1.2.2.1 Time frame

In this project the use of sweet sorghum for both, 1st generation as well as 2nd generation, fuel technologies is assessed. The former, i. e. the production of bioethanol is already well-established. In contrast, second generation technologies such as the production of ethanol from lignocellulose or the biomass gasification for so-called BtL[1] fuels are not yet existent and still in their pilot phase. For analyzing and comparing mature technologies, 2014 is set as reference year because this is the time at the end of the project. An outlook shall be given for 2020.

3.1.2.2.2 Geographical coverage

As the project aims at developing optimized sweet sorghum genotypes for specific climates, the scenarios are oriented at these specific climatic regions. Three scenarios are defined covering the tropical as well as the temperate climates, respectively:

– One scenario examines a temperate climate,

– a second scenario covers a subtropical / semi-arid climate with around 700 mm rainfall,

[1] BtL: Biomass-to-Liquid; synthetic biofuels produced via biomass gasification

– and a third scenario refers to a tropical climate with around 1,200 mm rainfall per year.

However, within these regions there might be great differences due to differences in environmental conditions as well as due to varying production practices and conditions in different countries. These differences are captured by sub-scenarios and sensitivity analyses taking into account different yields, uses of the (by-)products or production costs, etc. It is outside the scope of the project to analyze every single country where sweet sorghum could be produced. However, if it becomes evident that country specific conditions have a significant influence on the results, for the geographical coverage single countries may be chosen to show these dependencies. This might be the case for labour costs or emissions from electricity generation. For those cases, additional settings have to be agreed upon between the task partners in WP 6, namely task 6.2 (environmental assessment), task 6.3 (economic assessment) and task 6.4 (SWOT analysis).

3.1.2.2.3 Functional unit

The functional unit has to be chosen depending on the questions to be answered. As the project aims at increasing the output of the crop by developing improved varieties and since land usually is the limiting factor, the use of sweet sorghum from 1 hectare of land is assessed.

3.1.2.2.4 Alternative land use

The alternative land use defines how the land would be used if sweet sorghum was not cultivated. It also comprises any change in land cover induced by the cultivation of sweet sorghum. As agricultural land is becoming increasingly scarce, more and more natural land (e. g. forests or grass land) is transformed into arable land. Such land use and land cover changes may have considerable influences on the outcomes of the ecological assessment since e. g. the area’s carbon stock or biodiversity are influenced. For example, a decline in above-ground and below-ground carbon stock leads to greenhouse gas emissions, which have to be included in the greenhouse gas balance. Beside direct land use changes also indirect changes can occur. This is the case if for example the cultivation of sweet sorghum displaces the production of a food crop to other areas. Depending on use and/or land cover of that area, the displacement can cause different environmental effects.

The alternative land use also needs to be taken into account if sweet sorghum is cultivated on areas that become free due to the intensification of existing land use. Since on these areas, natural ecosystem could emerge if sweet sorghum was not cultivated, these potential ecosystems need to be taken into account as reference systems.

The following land uses are regarded as reference systems:

- Tropical / subtropical climate:

- In the tropical /subtropical climate the objective is to grow sweet sorghum in wet to dry savannah. In order to derive a bandwidth of different vegetation types and thus amounts of carbon stored, three reference systems are identified:
    - Dense thickets / sparse forests (carbon storage around 60 t carbon / hectare)
    - Wooded grassland / planted pastures / (carbon storage around 15 t carbon / hectare)
    - Degraded soils (carbon storage close to zero)

  This classification is mainly oriented at the carbon content of the vegetation but it refers to some extent also to the vegetation type. The carbon contents given here serve the purpose to characterize the reference systems. They don’t reflect real carbon contents but serve as an indicative differentiation between the reference systems defined.

- Additionally to the reference systems listed above sweet sorghum may be grown on fields already used for agricultural purposes and, therefore, replacing food crops. This is the case e.g. in South Africa (grain sorghum), Mexico (grain sorghum and corn), Brazil (soy or peanuts, which are suitable crops as well to interact as a intermediate food crop after a 5 year sugar cane cycle) and India (cotton or soy). With this given, two additional reference systems will be considered:
    - Replacing grain sorghum
    - Replacing other food crops such as soy, peanuts, and cotton.

* Temperate climate
    - Fallow land is regarded as reference scenario.

      Forest conversion is forbidden in all countries within Europe. Also, a large scale conversion of grassland is undesired from a nature protection point of view and forbidden throughout Europe. Therefore, forest and grassland will not be assessed as agricultural reference systems.

Concerning the indirect land use change, no general definition is done at the present state of the project as the international debate on how to integrate the indirect land use change into life cycle assessments is still running. This issue will be taken into account at a latter stage of the project. Concerning specific indirect land use changes they may occur in the reference system no. 5 listed above: replacement of food production. For this, one or two indirect land use change scenarios will be considered such as clearing of virgin land, e.g. containing 15 t of carbon per hectare. This has to be agreed upon at a latter stage of the project.

3.1.2.2.5 Technical reference

The technical reference describes the technology to be assessed in terms of plant capacity and development status / maturity. As the SWEETFUEL scenarios cover both, “central” and

“decentralized production on village level” two main technical references have to be defined. It is suggested to assess following capacities[2]:

- 25,000 – 120,000 t ethanol per year in the case of centralized production
- 1 t ethanol per day in the case of decentralized production.
- 3 t syrup per day in the case of decentralized production.

For all plant capacities, mature, full industrial plant will be assessed.

3.1.3 SWEETFUEL scenarios

In the following chapters, all SWEETFUEL scenarios are presented and described with flow charts and some short explanations. The numbers in the flow charts indicate the scenario numbers. An overview of all scenarios with the respective numbers is given in chapter 3.1.3.5.

3.1.3.1 Basis: Life cycle comparison

The scenario descriptions and the flow charts presented in the following chapters follow the principle of so-called life cycle comparisons. A schematic overview can be seen in Fig. 3-1. The whole life cycle of a product (e. g. of sweet sorghum ethanol) is assessed – starting from cultivation through production, use, end-of-life treatment, recycling and final disposal (“cradle-to-grave approach”). All inputs into and outputs from the system are taken into account. During production, several by-products may be obtained. For example, in ethanol production from sweet sorghum, bagasse is derived as a by-product. The by-products substitute conventionally produced equivalent products. For bagasse, this may be electricity from the grid if bagasse is combusted for bioenergy production. These conventional products do not have to be produced any more. In the environmental assessment, this substitution is included with a credit that is given for the energy and emission savings, in the economic assessment, by-products are considered via market prices.

At the end, the whole life cycle of the product is compared to the use (and thus to the life cycle) of a conventional product that is replaced. As an example, sweet sorghum ethanol replaces conventional gasoline, thus both life cycles are compared.

In order to understand and consequently optimize the SWEETFUEL scenarios, selected life cycle stages are varied and different production and use conditions are assessed with sensitivity analyses.

[2] The exact capacity numbers have still to be agreed upon between the partners

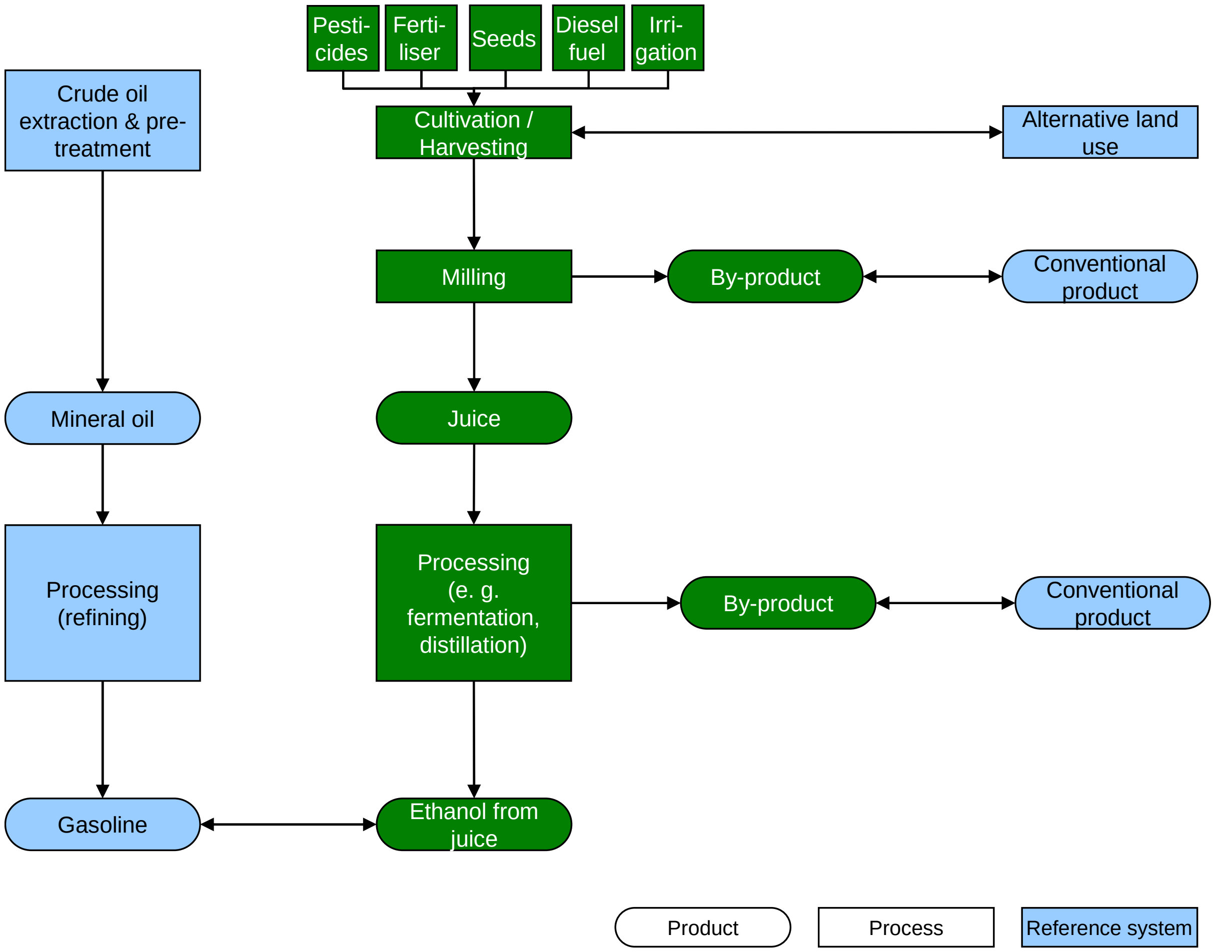

Fig. 3-1 Basic principle of life cycle comparison between sweet sorghum ethanol and gasoline

3.1.3.2 Semi-arid climate

The scenarios for semi-arid tropical climate cover sweet sorghum breeding for semi-arid tropical and subtropical climates as well as for acid soils in tropical, moist savannahs – all associated with roundabout 700 mm rainfall per year. Since the target systems, i. e. the processing and use options for sweet sorghum products are similar for both environments, they are not differentiated in the following scenario descriptions. Differences in cultivation methods and yields are covered by sensitivity analyses (see chapter 3.1.3.2.1).

The target systems in the tropical climate are rural settings and small to large farms. The focus lies on the use of sweet sorghum as multi-purpose crop to limit feed / fuel trade offs. This means that the grains are used as feed or food whereas juice is used for energy production. The focus in energy production is first generation ethanol since second generation technologies will not be established there in the foreseeable future. In all scenarios, bagasse is used primarily for process energy generation. In case there is any surplus bagasse, other uses are assessed. Besides the centralized system, also decentralized production is assessed with part to all of the production being realized at village level. Since infrastructure for biomass transportation to large central processing facilities will in many cases be not well developed, partially local processing may be necessary.

3.1.3.2.1 Cultivation

The breeding objectives in the tropical climate target two environments: semi-arid, tropical or sub-tropical climate with summer rains and acid soils in tropical, moist savannahs. Whereas in semi-arid climates, rainfall and thus water availability is the limiting factor, in moist (albeit water limited) savannahs, soil acidity is the most important abiotic constraint. Besides water use efficiency and sensitivity to soil acidity, the sweet sorghum breeds differ regarding grain production, stalk juice and sugar content. The yield differences and related differences in cultivation practices (e. g. the amount of fertilizer as well as harvesting expenditures) are parameters that considerably influence the outcomes of the economic and ecological analyses. The influence of yield differences and thus cultivation practices on the overall results will be assessed via sensitivity analyses.

3.1.3.2.2 Centralized production

An overview on all centralized production scenarios is given in Fig. 3-2. After harvest, the sweet sorghum stalks are transported from the villages to centralized ethanol facilities. The leaves are either separated prior to the harvest or not. This depends on the production conditions, more exactly on the machinery available and the labour costs. Due to high labour costs, leaves are only separated if there is machinery available which does it directly during harvesting. If leaves are separated, they are left on the fields and serve as fertilizer replacing mineral fertilizer. Since also the use as animal feed is promoted and might be an option in some regions, also this use is assessed. In this case, cereals are replaced as feed. If the leaves are not separated, they are used together with the bagasse for energy production or as feed.

In the centralized system, the focus lies on gaining optimized juice content, thus no significant or usable amount of grain. Therefore, the use of grains as feed or food is only analyzed in a sensitivity analysis.

In the central ethanol production units, the sweet sorghum stalks are crushed and separated into juice and bagasse. The juice is fermented into ethanol which is used in two different ways. The first use option is the dehydration and use as transport fuel replacing conventional gasoline. As a second option, the direct use of the ethanol for the production of cooking gel has been suggested. For doing so, ethanol is heated together with calcium acetate and water. The cooking gel is storable over a longer period of time and can be used in stoves replacing the use of wood, paraffin or LPG. Its use is especially promoted in Africa as more environmentally friendly and, more important, less harmful to health than wood or paraffin.

However, there is evidence that cooking gel might only be of limited use for household application due to following reasons (/Elizabeth Bates, 2010/):

- Firstly, cooking gel burns a lot cooler than liquid ethanol. Therefore, food that requires a hot flame for cooking cannot be prepared. All other food preparation consumes much more time, as less heat is getting into the pot.
- Second – because there is the additional process of turning it into a gel – it is more expensive. It is very unlikely that people on low incomes want to use gelfuel as a heating fuel – this seems more to be a product for the more affluent societies. People may find it expensive even as a cooking fuel.

- Finally, it gives out more pollutants – and this is because of its gelling nature – so although people say it is safer as it is a gel – the pollutant levels are higher and we’re all trying to get fuel as clean as possible to reduce levels of respiratory illness. It is said, that if you get hot burning gelfuel on your hands, it is very dangerous indeed. Without the gelling agent, ethanol is intrinsically very clean – when it burns efficiently, there are minute amounts of pollutant – it goes all to water vapour and carbon dioxide. By adding a gelling agent, not enough air gets into the mix and it gives off substantially more pollutant – and at the same time, the carbon in the pollutant that should have been creating heat is left unburnt. This is nowhere near the levels for wood fuel – but it is not ‘fixable’.

Therefore, gel pathways are not further investigated. Instead, there have been promising trials with the direct use of ethanol in cooking stoves which we included into the SWEETFUEL pathways.

From part of the bagasse process energy is generated which is used internally in the ethanol production process. If there is any surplus bagasse, it is used for generating green power that is fed into the power grid replacing conventionally produced electricity. Since in many areas, there is no connection to the electricity grid the use of the bagasse as animal feed is regarded as second scenario. In certain regions, bagasse is a very popular animal feed. For example in India, feed traders travel up to 100 km in order to buy the bagasse.

Other by-products derived during ethanol production are vinasse, fusel oils, and carbonation lime. Vinasse and carbonation lime are used as fertilizer, replacing mineral fertilizer and lime fertilizer, respectively. Fusel oils are used internally for process energy production. For fusel oils, the use in aroma industry has been indicated as one use option. However, the extraction of fusel oils for a use in industry requires a lot of energy. Up to now, there is no evidence that this is realizable at acceptable efforts and costs. However, this option will be analysed in a sensitivity analysis, conventional aroma production is substituted.

Also the capture and use of CO_2 in the beverage industry has been suggested. However, CO_2 is a by-product in many different processes and is already produced at large scale. Since the market is not big enough at the moment to absorb additional amounts of CO_2 and since there is no evidence that this market will considerably grow in future, this option is not assessed.

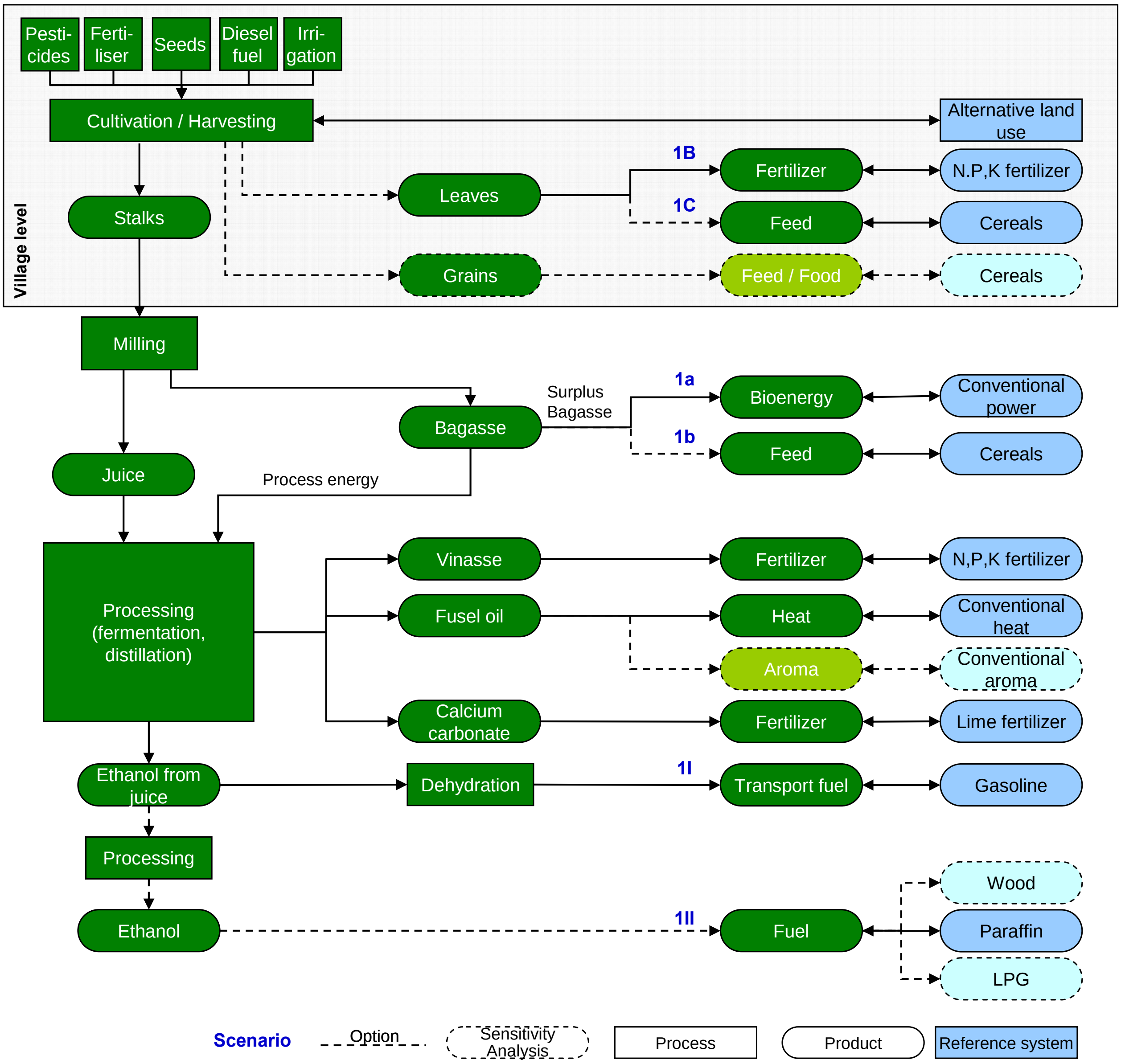

Fig. 3-2 Schematic overview on the SWEETFUEL scenarios for centralized production in the semi-arid and in tropical climate (scenario 1); numbers indicate scenario numbers (for a summary, see Table 3-1)

3.1.3.2.3 Decentralized production

In some cases, infrastructure for biomass transportation to large centralized production units may be insufficient or not existent. Therefore, partially decentralized processing might be necessary. Additionally, central ethanol producers often face the difficulty of a rather narrow production window where large amounts of sweet sorghum need to be processed. Here, the syrup production from sweet sorghum juice might be an advantage. Since the syrup can be stored slightly longer than the sweet sorghum juice, the ethanol production facility can ease production and expand the production window.

The realization of the whole production chain at village level also is an opportunity for many rural areas to gain access to energy and produce a more sustainable and healthier energy

source than wood or paraffin. Here, sweet sorghum could considerably contribute to rural development.

Therefore, two levels of decentralization are assessed: first, the sweet sorghum juice is processed at village level into syrup which is transported to centralized ethanol production facilities (“Syrup production at village level”). Second, the whole production chain until the production of ethanol is realized at small-scale village level (“Ethanol production at village level”).

Syrup production at village level

The sweet sorghum stalks are milled at village level and the juice is further processed into syrup which is transported to central ethanol units. The grains are again separated before harvest and used as feed or food replacing cereals.

Also here, the leaves are either separated or not – depending on the machinery used and the economic situation. The possible uses of the leaves are the same as for the decentralized level: if they are not separated they are used together with the bagasse; if they are separated, they are used as fertilizer replacing mineral fertilizer or as feed replacing cereals. The exact type of cereal that is used in certain regions as feed and food and which is replaced by sweet sorghum grains needs to be clarified.

A small part of the bagasse which is obtained during stalk milling is used at village level for heat production that is needed to concentrate the juice into syrup. The leftover bagasse is either used as animal feed, as raw material for cooking, for electricity production or it is put back on the fields as fertilizer. In the first case, cereals are replaced. In the second case, wood, petroleum or LPG as common cooking fuels in developing countries are replaced. Another possibility is the small-scale production of electricity. The electricity is not fed into the grid but used locally in the village. The bagasse needs to be pelletized and the pellets are combusted for energy generation. If bagasse is neither needed as feed nor for cooking and if electricity generation is not possible, it can be put back on the fields as fertilizer. It then replaces mineral fertilizer.

The syrup is transported to a centralized ethanol production unit and it is treated just as the juice in the centralized scenario: ethanol is produced and either used as transport fuel or for cooking.

For the description of the reference systems and the use of the by-products vinasse, fusel oils and carbonation lime, see chapter 3.1.3.2.1. For the central ethanol unit, external energy carriers need to be used since the bagasse from syrup production is left in the villages. These can be either fossil energy carriers such as coal or oil or bagasse that is left over from joined processes. In some regions the ethanol units may process syrup from decentralized stalk processing along with sweet sorghum stalks from fully centralized systems. The bagasse obtained from stalk milling might be enough to fuel both processes. Furthermore, in some regions the joined processing of sweet sorghum and sugarcane is planned and there might be enough bagasse from sugarcane processing. In these cases, leftover bagasse is used for process energy generation. Since it is a residue, there are not expenditures for bagasse production but the loss of its use for electricity production or for feed (if there is no connection to the electricity grid) is calculated as expenditure.

The syrup that is produced in the villages could also be used as food. However, this is not within the objective of this study since it aims at optimizing sweet sorghum breeds for energy production (see chapter 1). Therefore, this option is not assessed.

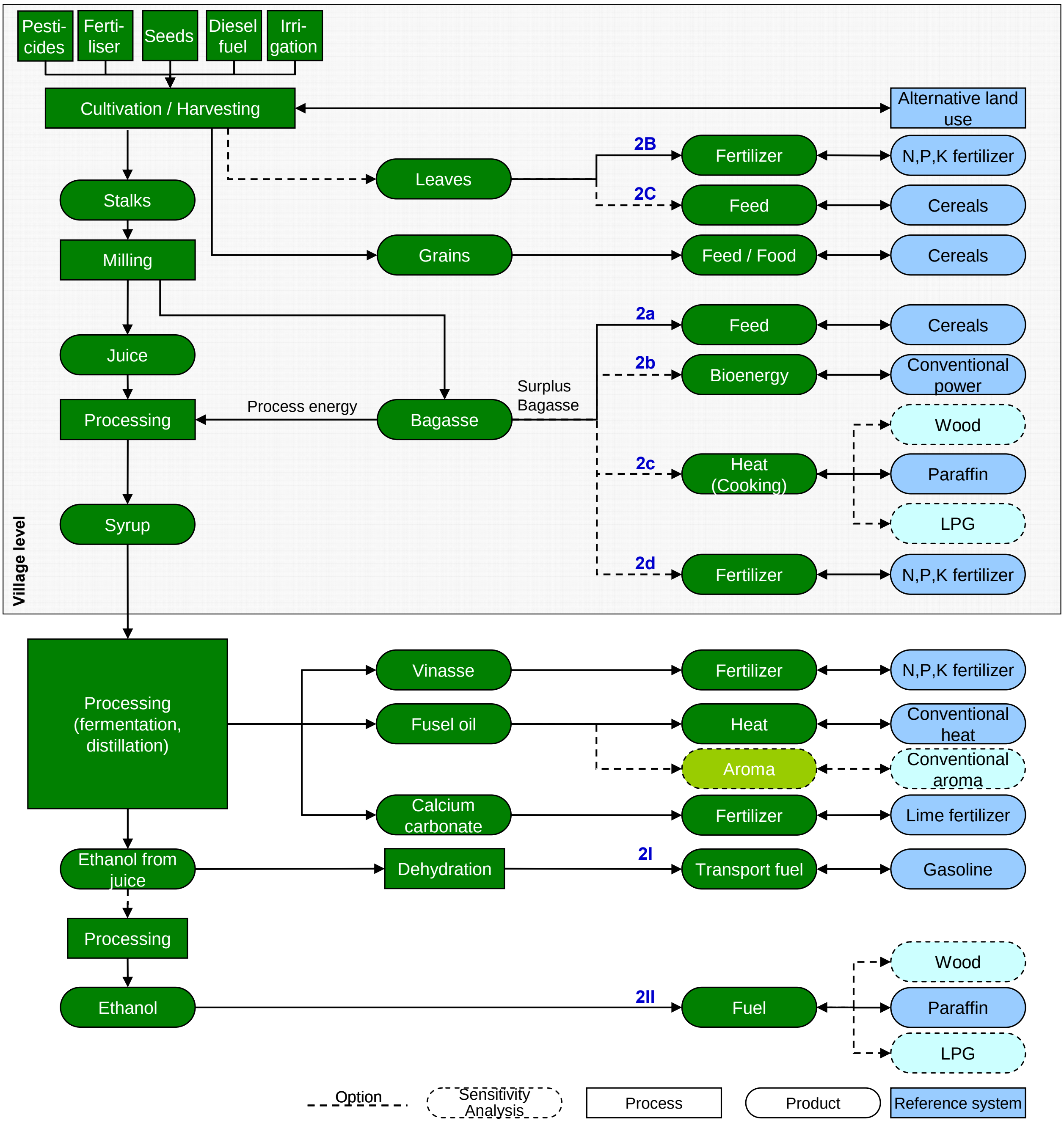

Fig. 3-3 Schematic overview on the SWEETFUEL scenarios for decentralized production in the semi-arid and in tropical climate (scenario 2); numbers indicate scenario numbers (for a summary, see Table 3-2)

Ethanol production at village level

In this scenario, the whole production chain is realized at village level, i. e. the milling of stalks and the processing of the juice into ethanol.

Again, the grains are separated prior to harvesting and used as feed or food. Also leaves are either used together with bagasse or they are cut off prior to harvesting and used as fertilizer or feed.

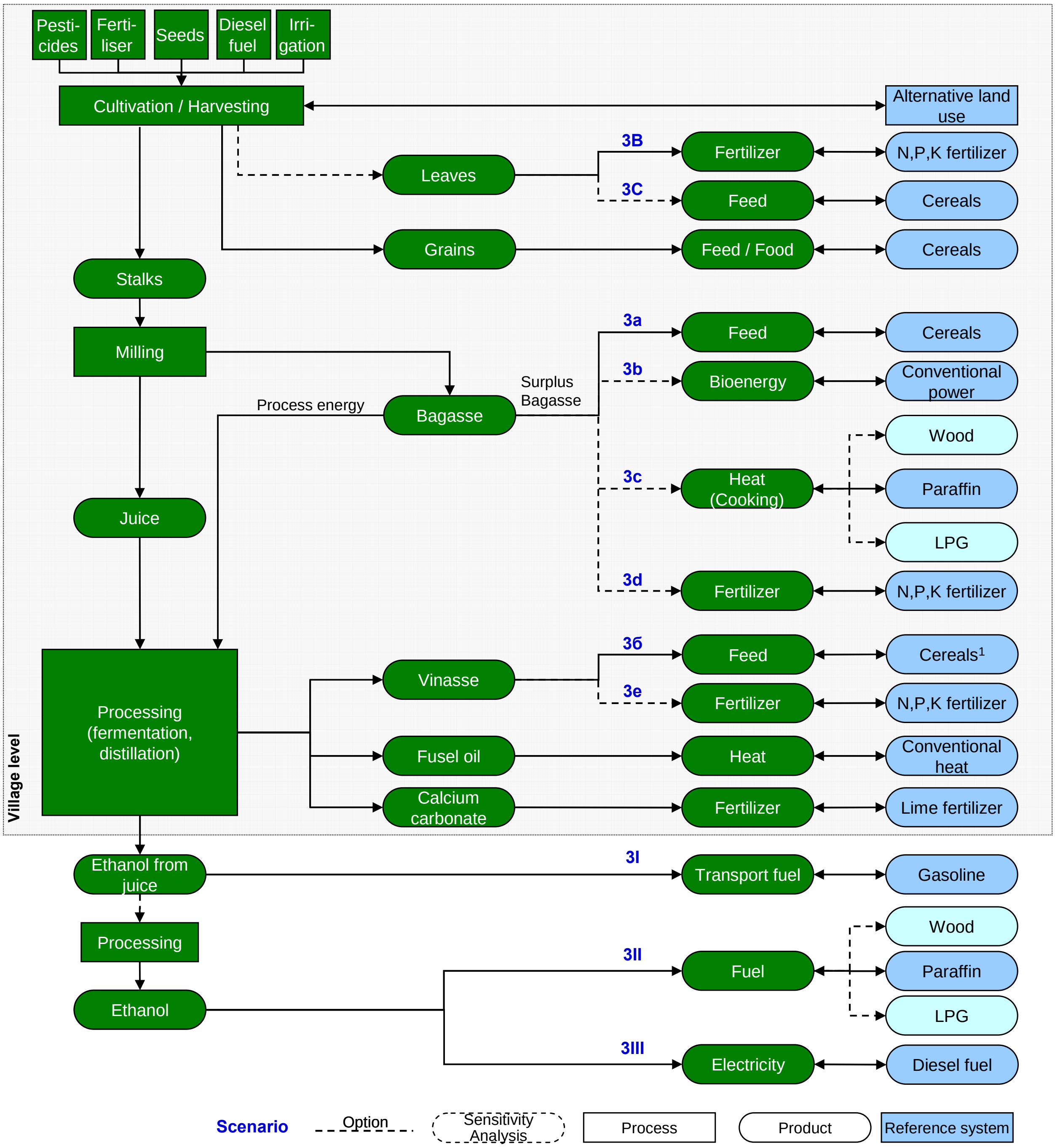

Fig. 3-4 Schematic overview on the SWEETFUEL scenarios for decentralized production in the semi-arid and in tropical climate (scenario 3); numbers indicate scenario numbers (for a summary, see Table 3-3)

The juice is processed into ethanol which is not dehydrated but used directly as transport fuel in agricultural machinery replacing conventional gasoline. For doing so, slight adaptations are necessary at the motor. Another use option is the using ethanol directly for cooking. A third option is to use the ethanol in small generators to produce electricity or for pumping water substituting generators operated by ordinary diesel oil.

A small part of the bagasse is used for heat production which is needed for juice distillation and the production of cooking gel. Analogous to the previous scenario (“Syrup production at village level”), the surplus bagasse is either used as animal feed (replacing cereals), as energy source for cooking (replacing wood, petroleum or LPG), for small scale electricity production (replacing conventional electricity production) or it is put back on the fields as fertilizer (replacing mineral fertilizer).

During juice processing into ethanol, only small amounts of vinasse are obtained as by-product. It can be used as feed replacing cereals if enough animals are there for an immediate consumption of the vinasse. Due to its fast degradation, the vinasse cannot be stored over a long period of time nor transported. The vinasse which cannot be used immediately is put on the fields and serves as fertilizer replacing mineral fertilizer.

3.1.3.3 Tropical climate

The scenarios for tropical climate cover sweet sorghum breeding for tropical climates associated with roundabout 1,200 mm rainfall per year. Since the target systems, i. e. the processing and use options for sweet sorghum products are similar for those as already listed for the semi-arid climate conditions, we refer to the respective chapter (see chapter 3.2). Differences in cultivation methods and yields are covered by sensitivity analyses (see chapter 3.1.3.2.1).

3.1.3.4 Temperate climate

The target systems are centralized, mechanized systems in industrialized settings. The focus lies on high biomass yields for 2nd generation technologies, whereas sugar content and grain yields are of less importance. Accordingly, the crop is used as a whole. Several options of energy production from sweet sorghum are assessed in order to give a bandwidth on different use options in temperate zones and to include both first and second generation technologies. First generation energy production pathways are biogas production and the combustion of the biomass. Analogous to the tropical climate, also fuel production is analyzed, however, here the focus is on second generation technologies. Two options are assessed: first, second generation ethanol produced from lignocellulose and second, biomass gasification with the synthesis of the gas into biofuel.

The scenarios are divided into a “wet biomass pathway” that uses the crop as it is harvested and a “dry biomass pathway” that requires dry biomass for further processing.

3.1.3.4.1 Wet biomass pathway

The use of wet biomass for 2nd generation technologies, i.e. ethanol production from lignocellulose is the main breeding focus of the project in the temperate climate. In order to also

present a first generation energy production option, the biomass fermentation with biogas or biomethane production is included as scenario.

Biogas production

For the biogas production, the sweet sorghum biomass is crushed after harvest. The biogas is used for heat and power production replacing conventionally produced heat and power.

Alternatively, the biogas can be further processed into biomethane and used for

1. heat and power production which replaces conventional heat and power,
2. or as a transport fuel replacing conventional gasoline and natural gas, respectively.

In all processes, digestate is produced as by-product. It is used as fertilizer replacing mineral fertilizer.

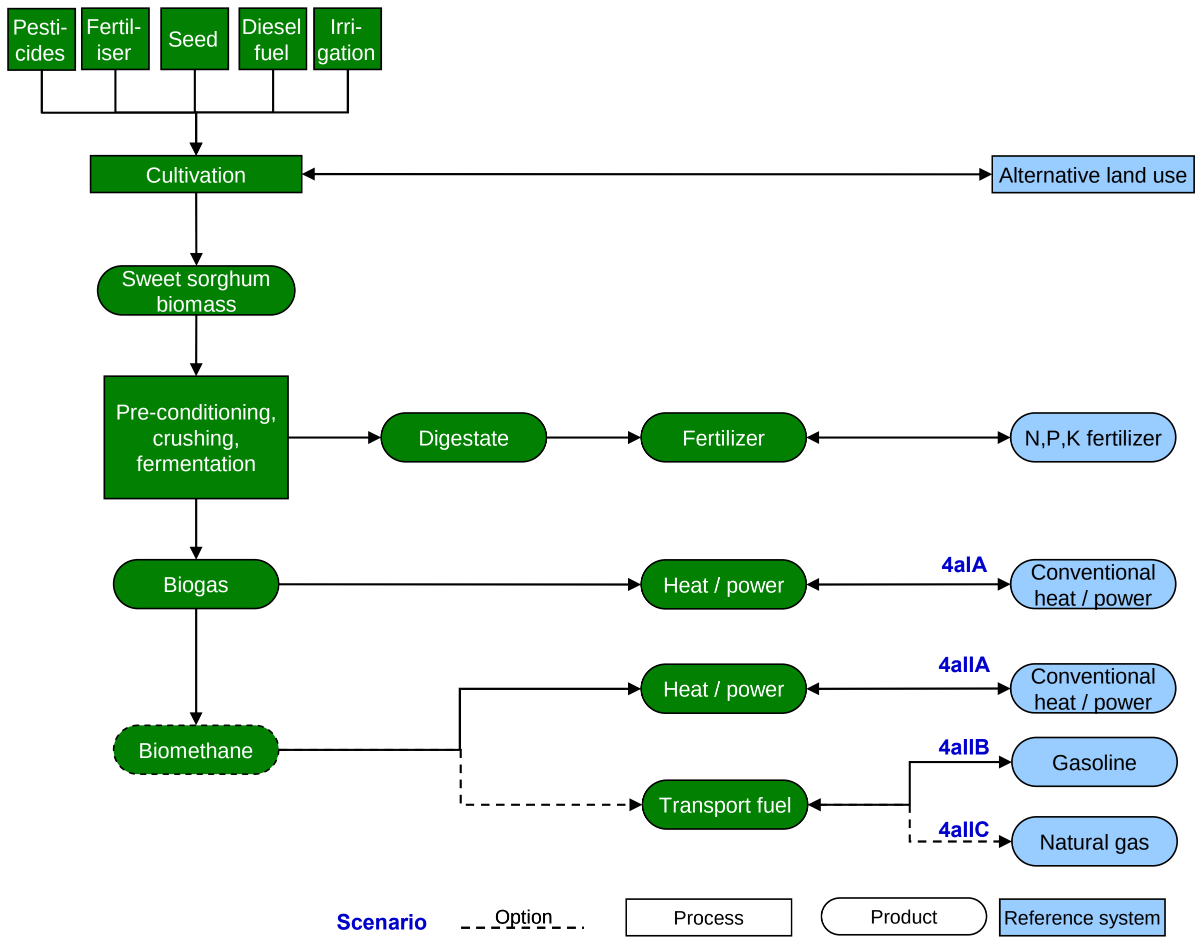

Fig. 3-5 Schematic overview on biogas production from sweet sorghum for the temperate climate (scenario 4); numbers indicate scenario numbers (for a summary, see Table 3-4)

Sweet sorghum biomass can be fermented together with co-substrates such as manure or corn. However, the main objective is to optimize the output from 1 hectare of sweet sorghum. Therefore, sweet sorghum digestion will be assessed without any co-substrate.

2nd generation ethanol from lignocellulose

The sweet sorghum biomass is used for producing second generation ethanol from lignocellulose. The biomass is crushed and pre-treated in order to render the cellulose accessible for a subsequent hydrolysis step. After the hydrolysis of the cellulose for braking down the long chains into sugars, the substrate is fermented. The ethanol is used as transport fuel replacing conventional gasoline.

Vinasse is obtained as by-product and either used as feed replacing soy meal or as fertilizer replacing mineral fertilizer. If there is surplus bioenergy from the process, it is fed into the grid and replaces conventional power production.

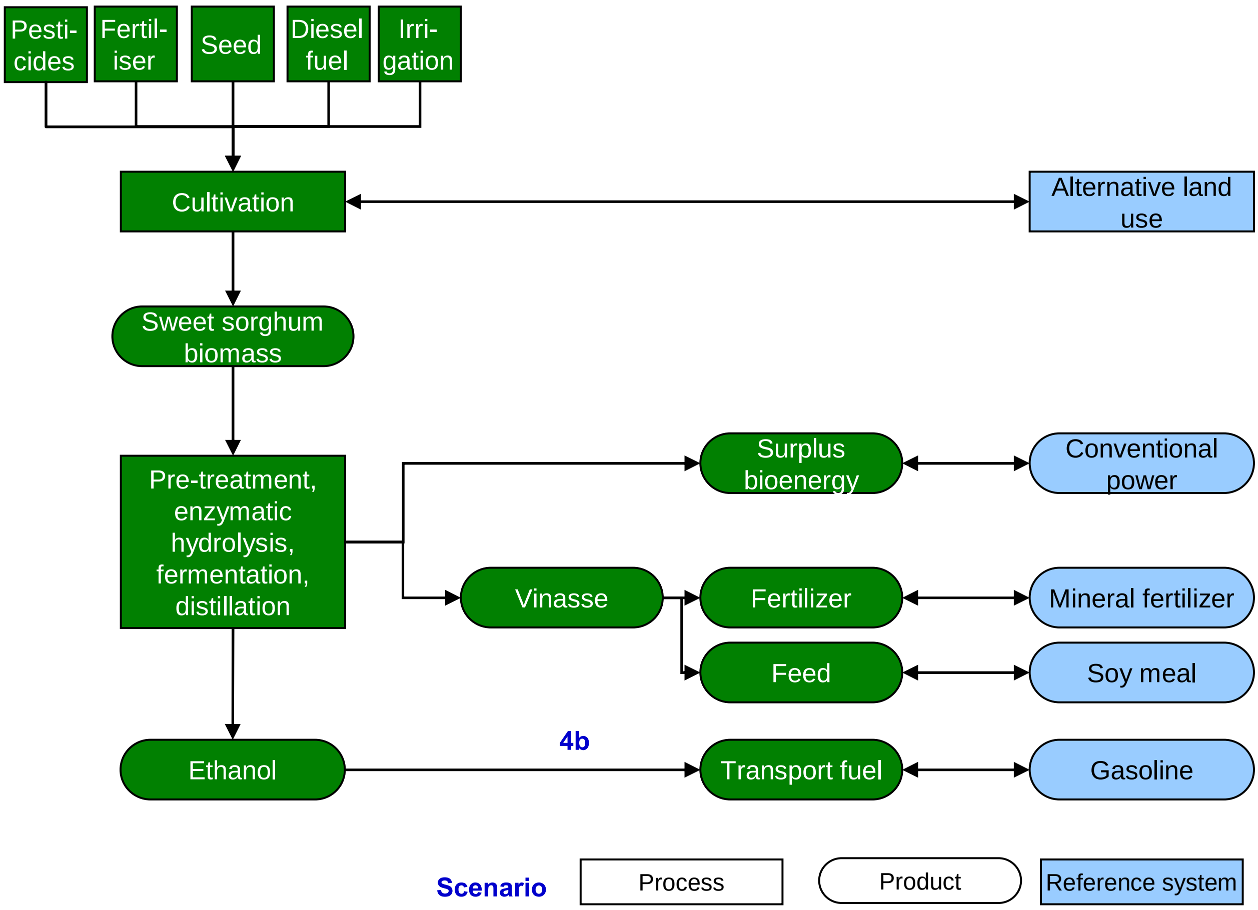

Fig. 3-6 Schematic overview on second generation ethanol production from sweet sorghum lignocellulose for the temperate climate (scenario 4); numbers indicate scenario numbers (for a summary, see Table 3-4)

3.1.3.4.2 Dry biomass pathway

The dry biomass pathways require dry biomass. Within the temperate zones this is only feasible in the southern regions such as the southern part of Spain. Here, the stalks remain on the field after harvest for drying during several days due to the high water content of the crop. After collection, they can be further processed with first or second generation technolo-

gies. Two pathways are assessed: the direct combustion of the crop (first generation technology) as well as its gasification (second generation technology).

Direct combustion

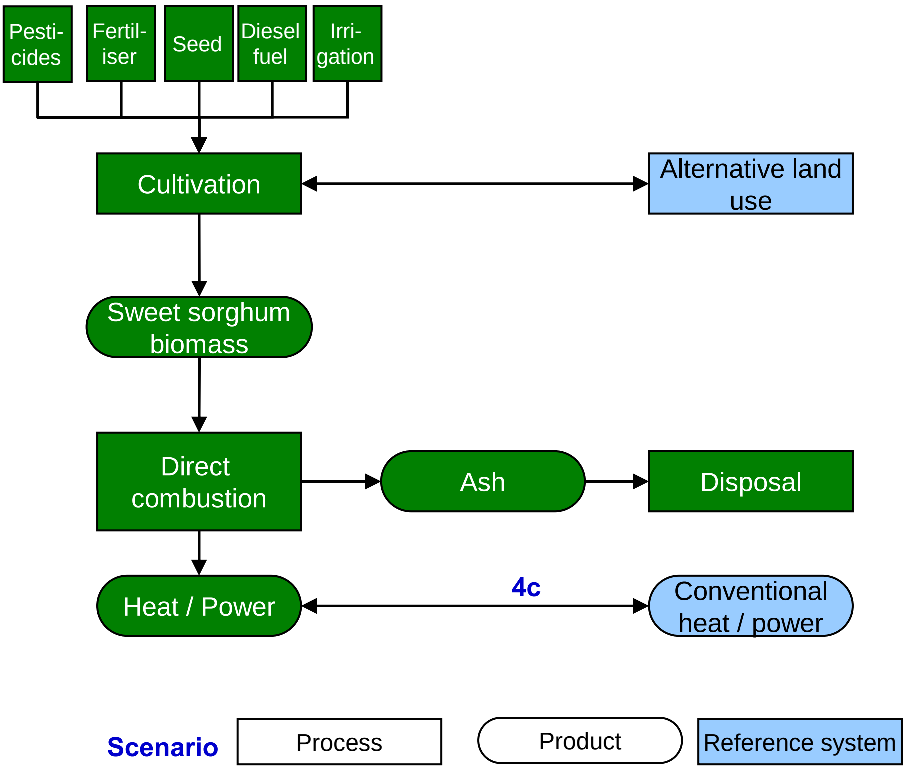

Fig. 3-7 Schematic overview on direct combustion of from sweet sorghum for the temperate climate (scenario 4); numbers indicate scenario numbers (for a summary, see Table 3-4)

Through combustion, heat and power are produced that replace conventionally produced heat and power. The only by-product is ash which has to be disposed in landfills.

Gasification

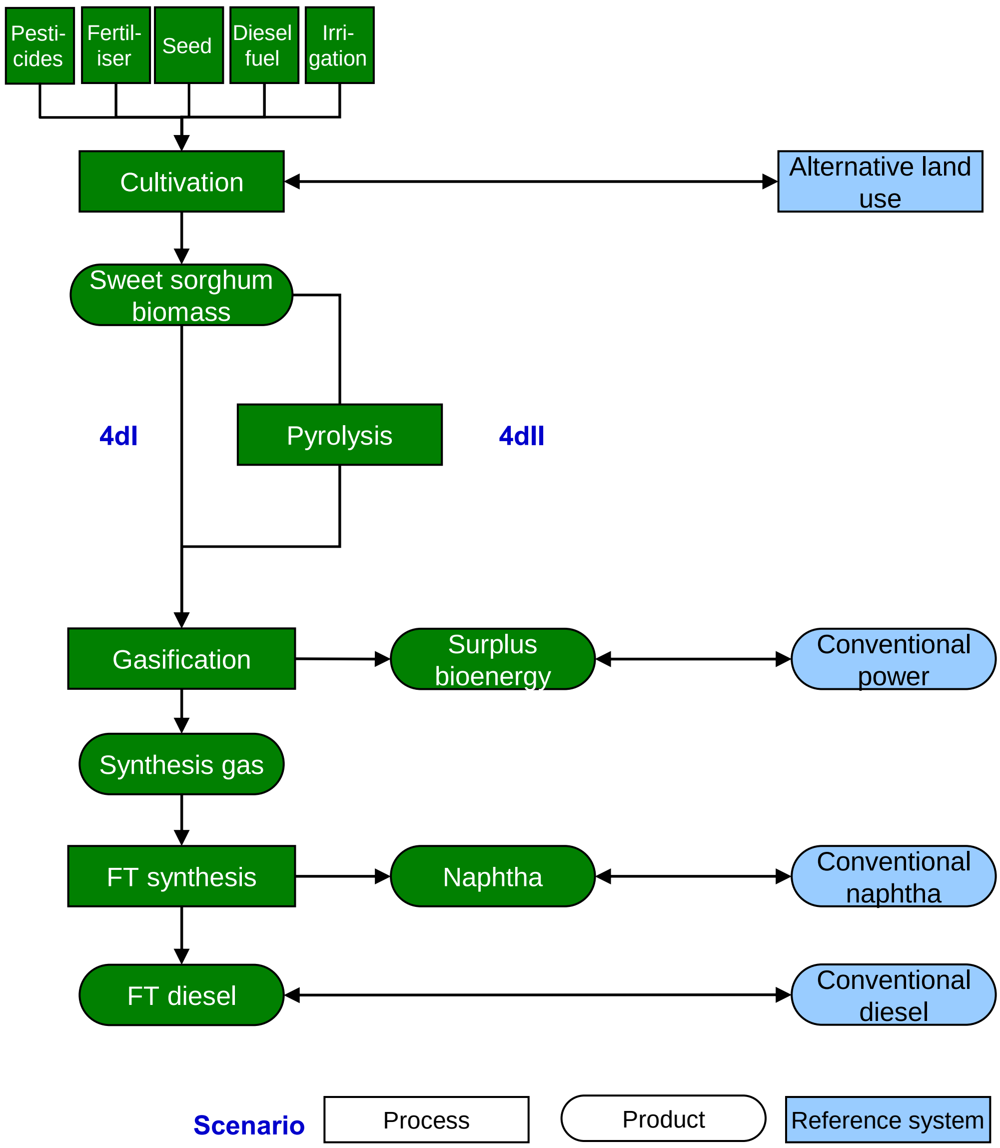

Fig. 3-8 Schematic overview on biodiesel production from sweet sorghum gasification for the temperate climate (scenario 4); numbers indicate scenario numbers (for a summary, see Table 3-4)

For biomass gasification, two options are analyzed: first the direct gasification, second the gasification with a prior torrefaction or pyrolysis of the biomass.

For both options, the biomass needs to be dried as a pre-treatment. Direct biomass gasification can only be realized in large scale centralized units. Here, waste heat can be used for biomass drying. Torrefaction or pyrolysis of biomass is often used in decentralized systems for making biomass transportable. In this case, external energy would be necessary for biomass drying. However, both options could also be applied in centralized systems in order to get standardized biomass characteristics. Thus, the reactors do not have to be adapted to different biomass types.

As a next step, the biomass, the pyrolysis oil or the torrefied biomass are gasified into a synthesis gas. It is a mixture of hydrogen and carbon monoxide. After cleaning the gas, it is synthesized into the so-called BtL (biomass-to-liquid) fuels. The standard synthesis is the Fischer-Tropsch synthesis where biodiesel is produced as main product. Naphtha is obtained as by-product which replaces fossil naphtha. If there is surplus bioenergy from the process, it is fed into the grid and replaces conventional energy.

Torrefaction and pyrolysis are both rather new technologies with specific advantages and disadvantages. For certain circumstances it was agreed between the project partners to cover the pyrolysis technology in the SWEETFUEL project.

3.1.3.5 SWEETFUEL scenarios: summary

Table 3-1 to Table 3-4 summarize all SWEETFUEL scenarios. The numbers are also displayed in the flow charts depicted in the previous chapters.

Table 3-1 Summary of all SWEETFUEL scenarios for centralized production in semi-arid and in tropical climate

1	**Semi-arid and tropical climate, centralized**						
	Division of production	**Option**	**Use of surplus Bagasse**	**Option**	**Use of Ethanol**	**Option**	**Use of leaves**
1		**1 a**	Bioenergy	**1 a I**	Dehydrated as transport fuel	**1 a I A**	No use (together with bagasse)
						1 a I B	Fertilizer (left on fields)
						1 a I C	Feed
				1 a II	Cooking	**1 a II A**	No use (together with bagasse)
						1 a II B	Fertilizer (left on fields)
						1 a II C	Feed
		1 b	Feed	**1 b I**	Dehydrated as transport fuel	**1 b I A**	No use (together with bagasse)
						1 b I B	Fertilizer (left on fields)
						1 b I C	Feed
				1 b II	Cooking	**1 b II A**	No use (together with bagasse)
						1 b II B	Fertilizer (left on fields)
						1 b II C	Feed

Table 3-2 Summary of all SWEETFUEL scenarios for decentralized production (syrup production at village) in semi-arid and in tropical climate

2	**Semi-arid and tropical climate, decentralized, syrup production at village**						
	Division of production	**Option**	**Use of surplus Bagasse**	**Op-tion**	**Use of Ethanol**	**Option**	**Use of leaves**
2	Syrup produced at village level, further process centralized	2 a	Feed	2 a I	Dehy-drated as trans-port fuel	2 a I A	No use (together with bagasse)
						2 a I B	Fertilizer (left on fields)
						2 a I C	Feed
				2 a II	Cooking	2 a II A	No use (together with bagasse)
						2 a II B	Fertilizer (left on fields)
						2 a II C	Feed
		2 b	Electricity production from pellets	2 b I	Dehy-drated as trans-port fuel	2 b I A	No use (together with bagasse)
						2 b I B	Fertilizer (left on fields)
						2 b I C	Feed
				2 b II	Cooking	2 b II A	No use (together with bagasse)
						2 b II B	Fertilizer (left on fields)
						2 b II C	Feed
		2 c	Heat production (cooking)	2 c I	Dehy-drated as trans-port fuel	2 c I A	No use (together with bagasse)
						2 c I B	Fertilizer (left on fields)
						2 c I C	Feed
				2 c II	Cooking	2 c II A	No use (together with bagasse)
						2 c II B	Fertilizer (left on fields)
						2 c II C	Feed
		2 d	Fertilizer	2 d I	Dehy-drated as trans-port fuel	2 d I A	No use (together with bagasse)
						2 d I B	Fertilizer (left on fields)
						2 d I C	Feed
				2 d II	Cooking	2 d II A	No use (together with bagasse)
						2 d II B	Fertilizer (left on fields)
						2 d II C	Feed

Table 3-3 Summary of all SWEETFUEL scenarios for decentralized production (ethanol at village level) in semi-arid and in tropical climate

3	**Semi-arid and tropical climate, decentralized, ethanol production at village**								
	Produc-tion place	**Option**	**Use of surplus Bagasse**	**Option**	**Use of Ethanol**	**Option**	**Use of leaves**	**Option**	**Use of vinasse**
3	Ethanol produc-tion at village level	3 a	Feed	3 a I	Raw as trans-port fuel	3 a I A	No use (together with bagasse)	3 a I A б	Feed
								3 a I A e	Fertilizer
						3 a I B	Fertilizer (left on fields)	3 a I B б	Feed
								3 a I B e	Fertilizer
						3 a I C	Feed	3 a I C б	Feed
								3 a I C e	Fertilizer
				3 a II	Cooking	3 a II A	No use (together with bagasse)	3 a II A б	Feed
								3 a II A e	Fertilizer
						3 a II B	Fertilizer (left on fields)	3 a II B б	Feed
								3 a II B e	Fertilizer
						3 a II C	Feed	3 a II C б	Feed
								3 a II C e	Fertilizer
				3 a III	In genera-tors	3 a III A	No use (together with bagasse)	3 a III A б	Feed
								3 a III A e	Fertilizer
						3 a III B	Fertilizer (left on fields)	3 a III B б	Feed
								3 a III B e	Fertilizer
						3 a III C	Feed	3 a III C б	Feed
								3 a III C e	Fertilizer
		3 b	Electricity produc-tion from pellets	3 b I	Raw as trans-port fuel	3 b I A	No use (together with bagasse)	3 b I A б	Feed
								3 b I A e	Fertilizer
						3 b I B	Fertilizer (left on fields)	3 b I B б	Feed
								3 b I B e	Fertilizer
						3 b I C	Feed	3 b I C б	Feed
								3 b I C e	Fertilizer
				3 b II	Cooking	3 b II A	No use (together with bagasse)	3 b II A б	Feed
								3 b II A e	Fertilizer
						3 b II B	Fertilizer (left on fields)	3 b II B б	Feed
								3 b II B e	Fertilizer
						3 b II C	Feed	3 b II C б	Feed
								3 b II C e	Fertilizer
				3 b III	In genera-tors	3 b III A	No use (together with bagasse)	3 b III A б	Feed
								3 b III A e	Fertilizer
						3 b III B	Fertilizer (left on	3 b III B б	Feed

							fields)	3 b III B e	Fertilizer
						3 b III C	Feed	3 b III C б	Feed
								3 b III C e	Fertilizer
		3 c	Heat produc-tion (cooking)	3 c I	Raw as trans-port fuel	3 c I A	No use (together with bagasse)	3 c I A б	Feed
								3 c I A e	Fertilizer
						3 c I B	Fertilizer (left on fields)	3 c I B б	Feed
								3 c I B e	Fertilizer
						3 c I C	Feed	3 c I C б	Feed
								3 c I C e	Fertilizer
				3 c II	Cooking	3 c II A	No use (together with bagasse)	3 c II A б	Feed
								3 c II A e	Fertilizer
						3 c II B	Fertilizer (left on fields)	3 c II B б	Feed
								3 c II B e	Fertilizer
						3 c II C	Feed	3 c II C б	Feed
								3 c II C e	Fertilizer
				3 c III	In genera-tors	3 c III A	No use (together with bagasse)	3 c III A б	Feed
								3 c III A e	Fertilizer
						3 c III B	Fertilizer (left on fields)	3 c III B б	Feed
								3 c III B e	Fertilizer
						3 c III C	Feed	3 c III C б	Feed
								3 c III C e	Fertilizer
		3 d	Fertilizer	3 d I	Raw as trans-port fuel	3 d I A	No use (together with bagasse)	3 d I A б	Feed
								3 d I A e	Fertilizer
						3 d I B	Fertilizer (left on fields)	3 d I B б	Feed
								3 d I B e	Fertilizer
						3 d I C	Feed	3 d I C б	Feed
								3 d I C e	Fertilizer
				3 d II	Cooking	3 d II A	No use (together with bagasse)	3 d II A б	Feed
								3 d II A e	Fertilizer
						3 d II B	Fertilizer (left on fields)	3 d II B б	Feed
								3 d II B e	Fertilizer
						3 d II C	Feed	3 d II C б	Feed
								3 d II C e	Fertilizer
				3 d III	In genera-tors	3 d III A	No use (together with bagasse)	3 d III A б	Feed
								3 d III A e	Fertilizer
								3 d III B б	Feed

						3 d III B	Fertilizer (left on fields)	**3 d III B e**	Fertilizer
						3 d III C	Feed	**3 d III C б**	Feed
								3 d III C e	Fertilizer

Table 3-4 Summary of all SWEETFUEL scenarios for temperate climate

4	**Temperate climate**				
	Conversion process	**Option**	**Main product / method**	**Option**	**Use of main product**
4 a	Biogas production	**4 a I**	Biogas	**4 a I A**	Heat and power
		4 a II	Biomethane	**4 a II A**	Heat and power
				4 a II B	Transport fuel replacing gasoline
				4 a II C	Transport fuel replacing natural gas
4 b	LCF-Ethanol production	**4 b**	Ethanol		Transport fuel
4 c	Direct combustion	**4 c**	Heat & Power		Heat and power
4 d	Gasification	**4 d I**	Direct gasification		FT diesel
		4 d II	Gasification with prior pyrolysis		FT diesel

3.2 Interlinkages between WP 5 and WP 6

3.2.1 Introduction

Bioethanol is one part in the increasing use of biofuels. Worldwide, sugar cane is the main source of bioethanol. However, the cultivation of this crop cannot be realized in water-limited or temperate regions. On this background, sweet sorghum has several advantages due to its high water use and nutrient efficiency. Furthermore, the production of food, feed and fuel can be combined in one crop. This is an important asset on the background of the currently increasing discussion on fuel production and food security.

As the more widespread use of sweet sorghum for bio-ethanol production is primarily limited by the lack of varieties specifically bred for this purpose, the SWEETFUEL project aims at developing sweet sorghum breeds for improved cultivars and hybrids for temperate, tropical semi-arid and tropical acid soil environments. The focus lies on tolerance to cold, drought and acid soil as well as on a high production of stalk sugars, easily digestible biomass and grains – depending on the environmental region the crop shall be cultivated in and the purpose it shall be used for.

Accompanying the development of new sweet sorghum breeds, WP 6 “Integrated assessment” of the European Commission funded project “SWEETFUEL: Sweet Sorghum: an alternative energy crop” provides a multi-criteria evaluation of the sweet sorghum production and use pathways taking into account technological, environmental, economic and social aspects. The outcome of the integrated assessment will be a set of optimized, sustainable sweet sorghum production and use systems.

Importance of common settings and definitions

The sustainability assessment for the SWEETFUEL systems is mainly carried out by WP 6 (integrated assessment), but to some extent also in WP 5. WP 5 will develop a crop model for sorghum that will be delivered to WP 6 and integrated into the overall assessment. Due to this SWEETFUEL-specific division of sustainability assessment between WP 6 and WP 5, common settings and definitions are essential to ensure consistency of results between WP 6 and WP 5. And with this, also all interlinkages between these two work packages have to be defined to guarantee an unequivocal definition of responsibilities for the work to be done by each partner and its contributions concerning WP 6.

Next to the consistency of the above mentioned results, common settings and definitions are needed to ensure consistency of all assessments within WP 6, as most of the tasks will be using life cycle assessment (LCA) methodology (environmental LCA in task 6.2, life cycle costing in task 6.3, and SWOT analysis in task 6.4). Even though internationally standardised assessment techniques such as life cycle assessment (LCA) will be applied in all three tasks, the degree of freedom they offer in terms of methodological or data choices might lead to incomparable evaluations. As the findings of tasks 6.2 to 6.4 are used by task 6.5 to identify and depict the most sustainable pathways and the most promising optimization potentials, the use of common settings and definitions by tasks 6.2 to 6.4 are an indispensable prerequisite.

The common settings and definitions are also relevant for the whole consortium as the partners responsible for breeding and optimization of productivity traits (WP 1-4) have to deliver mass and energy flow data in compliance with these common settings and definitions. Therefore, the common settings and definitions need the agreement of all partners. Another reason for defining the settings within the whole consortium is the fact that the general settings will affect the outcomes of the sustainability assessment and hence are of high importance for the whole project.

After having defined these definitions and settings (see interim report on technological assessment “Definitions and settings” from August, 8, 2011) all interlinkages between WP 5 and WP 6 have to be defined and agreed upon.

Goal and scope of this report

This report is a first draft concerning the interlinkages being a part of Task 6.1: Technological assessment of the SWEETFUEL project. It provides a first description of the interlinkages between the work packages WP 5 and WP 6, the responsibility of the partners involved and the data and information, the respective partners have to deliver, contribute or review in the course of the project.

The contents of this report will be updated frequently in the course of the next few months and, finally, this report will serve as a handout for the envisaged “Workshop on interlinkages between WP 5 and WP 6” being milestone M 6.2 of the SWEETFUEL project.

For this, several internal meetings have been arranged to prepare the workshop (/Rettenmaier 2011/):

- Internal meeting IFEU / UNIBO at IFEU (26 August 2011)
- Internal meeting IFEU / WIP at IFEU (20 September 2011)
- Internal meeting IFEU / ICRISAT / CIRAD at ICRISAT (17 October 2011)

3.2.2 Interlinkages between WP 5 and WP 6

In this chapter, an overview of all interlinkages between the work packages WP 5 “Package production and crop modelling” and WP 6 “Integrated assessment” are presented. This includes both, the general interlinkages as well as the specific ones which will be discussed further in chapter 3.2.3.

3.2.2.1 General interlinkages between WP 5 and WP 6

WP 5 “Package production and crop modelling” is dedicated to investigate the agricultural and agronomic data, of sweet sorghum whereas in WP 6 “Integrated assessment” an overall assessment on the sustainability of sweet sorghum production and use pathways are investigated.

Table 3-5 lists the tasks of WP 5 “Package production and crop modelling” and Fig. 3-9 gives an overview of the structure of WP 6 “Integrated assessment”.

Table 3-5 Tasks of work package 5 “Package production and crop modelling”

Task number	Task description (leadership)
Task 5.1	Evaluation of integrated stress responses in field conditions (Task leader: UNIBO)
Task 5.2	Evaluation of stress responses in controlled environment (UNIBO)
Task 5.3	Optimization of harvesting techniques and logistics (Task leaders: UNIBO and ARC-GCI)
Task 5.4	Development of a crop model for sorghum (Task leaders: CIRAD and UCSC)

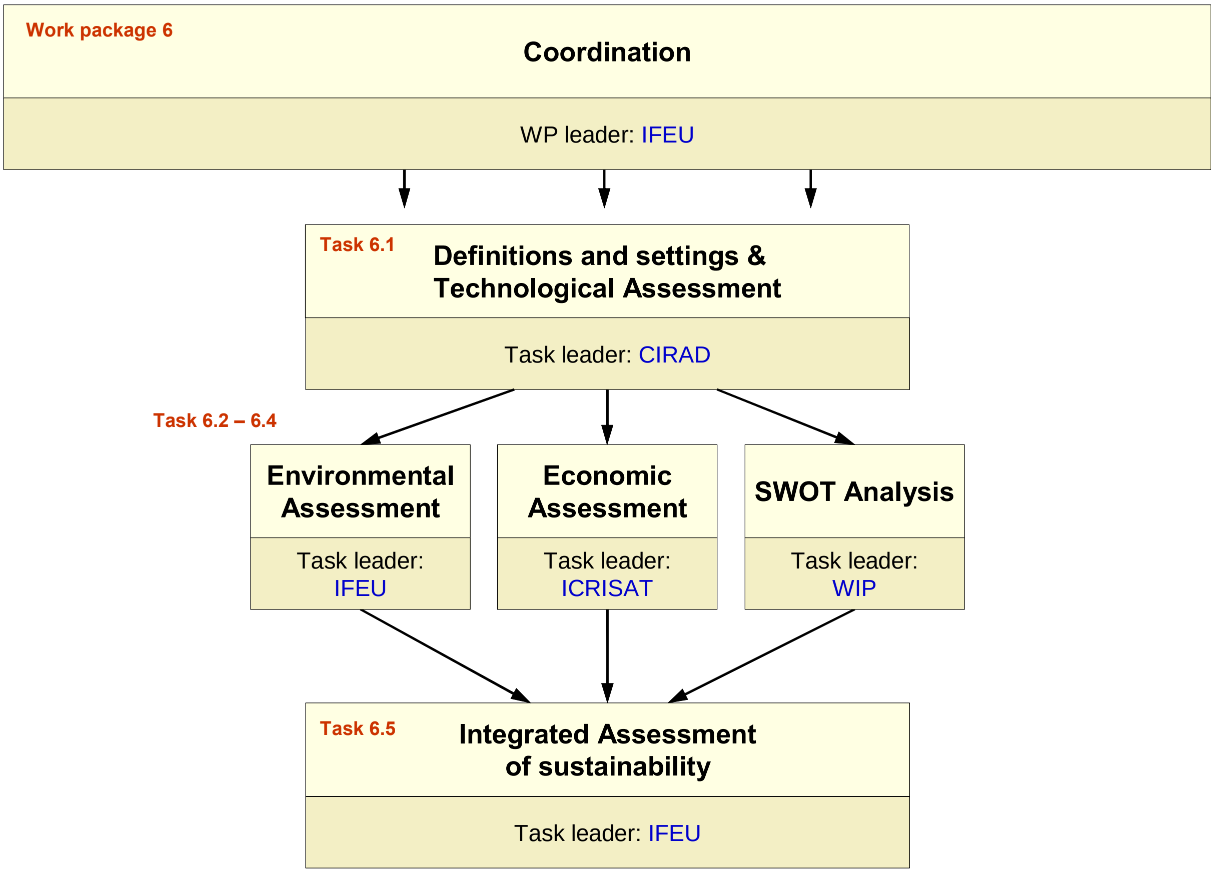

Fig. 3-9 Structure of work package 6 “Integrated assessment” of SWEETFUEL project

3.2.2.2 Specific interlinkages between WP 5 and WP 6

The specific interlinkages between the two work packages WP 5 “Package production and crop modelling” and WP 6 “Integrated assessment” cover both, interlinkages from WP 5 towards WP 6 and vice versa:

From WP 5 for WP 6:

WP 5 “Package production and crop modelling” investigates especially on the agricultural production of sweet sorghum. Therefore, most of the interlinkages towards WP 6 “Integrated assessment” will cover this field of expertise. This includes all four tasks of WP 6: tasks 6.1 to 6.4 (see Fig. 3-9). Concerning task 6.5, no direct input in terms of results from WP 5 is foreseen.

Special note: Whether for the SWOT analysis also some information is required concerning the downstream processes “conversion” and “use” from WP 5 (see next chapter) has to be clarified, as in WP 5 these issues are not covered according to the DoW.

From WP 6 for WP 5:

For the work to be done in WP 5 “Package production and crop modelling” some data and information are needed from WP 6 “Integrated assessment” which includes especially general definitions and settings. This was finalized in the interim report on technological

assessment “Definitions and settings” /Braconnier & Reinhardt et al 2011/). In this, the description of system boundaries and settings, the definition and description of sweet sorghum scenarios as well as the definition and description of respective reference systems are described in detail.

For further work in task 6.1 especially on the analysis of potentials and technological constraints further interlinkages have to be defined. This will be done at a later stage of the project.

3.2.3 Data requests from WP 5 for WP 6

3.2.3.1 Data request from WP 5 for task 6.1

Concerning task 6.1 “Technological assessment” general definitions and settings as a basis for the whole work package have been defined in the interim report on technological assessment “Definitions and settings” /Braconnier & Reinhardt et al 2011/). In this the description of system boundaries and settings, the definition and description of sweet sorghum scenarios as well as the definition and description of respective reference systems are described in detail.

For further work in task 6.1 especially on the analysis of potentials and technological constraints further interlinkages have to be defined. This will be done at a later stage of the project.

3.2.3.2 Data request from WP 5 for task 6.2

For the work in task 6.2 “Environmental assessment” quite a number of data and information is needed with respect to the agricultural production of sweet sorghum. Taking into consideration the interim report on technological assessment “Definitions and settings” /Braconnier & Reinhardt et al 2011/) the requested data are related to following subcategories:

- Agricultural sweet sorghum production – an overview
- Climate & geographical coverage
- Geographical differentiations
- Reference systems

3.2.3.2.1 Agricultural sweet sorghum production – an overview

Concerning the agricultural production of sweet sorghum the whole production life cycle from preparation of the field up to harvest and storage must be covered. This also includes all production activities such as sowing, fertilizing, spraying etc. Table 3-6 lists all single processes which require data collection for the sweet sorghum scenarios in the SWEETFUEL project.

Table 3-6 List of processes addressed by data collection from WP 5 for WP 6 (for details see text and /Rettenmaier 2011/)

Inputs	**Unit**	**Yields**	**Unit**
Seeds	kg / (ha*year)	Grains	Mg / (ha*year)
N	kg / (ha*year)	Water content grains	%
P_2O_5	kg / (ha*year)	Stalks (extractable)	Mg / (ha*year)
K_2O	kg / (ha*year)	Juice content total	% of stalks
CaO[1]	kg / (ha*year)	Glucose content of juice	%
Pesticides[2]	kg / (ha*year)	Fructose content of juice	%
Herbicides	kg / (ha*year)	Sucrose content of juice	%
		Total sugar content of juice	%
***Tractor diesel for*[4]**		Leaves	Mg / (ha*year)
field preparation	L / (ha*year)	N-content of leaves	kg / Mg
mechanical weed control	L / (ha*year)	P-content of leaves	kg / Mg
sowing	L / (ha*year)	K-content of leaves	kg / Mg
fertilizing	L / (ha*year)		
spraying[3]	L / (ha*year)		
harvesting	L / (ha*year)		

1: For temperate climate only
2: Includes insecticides, molluscicides and fungicides
3: Only for maximum scenario (spraying: all climates)
4: Field work only, travel to and from the field is not included

It is obvious, that there is not just one single number for each of the processes but as a rule a bandwidth or uncertainty. Therefore in the data collection template the whole range of the bandwidth will be collected by minimum / maximum values which should not reflect the absolute minimum and maximum extremes, but some sort of average minimum and maximum numbers. Additional, a mean value is required, which should not be in all cases an arithmetical average of a given set of numbers but an average based on an educated expertise interpretation mean of the numbers given.

More details on the selection of the processes and its reasons are listed in /Rettenmaier 2011/. After having had all internal meetings (see chapter 3.2.1) a full overview of the details will be given in this chapter.

3.2.3.2.2 Climate & geographical coverage

As the project aims at developing optimized sweet sorghum genotypes for specific climates, the scenarios are oriented at these specific climatic regions. Three scenarios have been defined covering the tropical as well as the temperate climates, respectively (see /Braconnier & Reinhardt 2011/):

- One scenario examines a temperate climate,

- a second scenario covers a subtropical / semi-arid climate with around 700 mm rainfall
- and a third scenario refers to a tropical climate with around 1,200 mm rainfall per year.

All data required as described in the subchapter above have to be differentiated for these three climates.

3.2.3.2.3 Geographical differentiations

With respect to the three climate scenarios as described above, there might be great differences within these regions due to differences in environmental conditions as well as due to varying production practices and conditions in different countries. These differences are captured by sub-scenarios and sensitivity analyses taking into account different yields, uses of the (by-)products or production costs, etc. It is outside the scope of the project to analyze every single country where sweet sorghum could be produced. However, if it becomes evident that country specific conditions have a significant influence on the results, for the geographical coverage single countries may be chosen to show these dependencies. This might be the case for labour costs or emissions from electricity generation. For those cases, additional settings have to be agreed upon between the task partners in WP 6, namely task 6.2 (environmental assessment), task 6.3 (economic assessment) and task 6.4 (SWOT analysis). For further information see /Braconnier & Reinhardt 2011/.

For these cases, the data requirements are the same as listed in the subchapter 3.2.3.2.1.

3.2.3.2.4 Reference systems

Several so-called reference systems have been defined in the interim report on technological assessment “Definitions and settings” /Braconnier & Reinhardt et al 2011/) to be assessed in the work package “Integrated assessment”. These reference systems are cover scenarios for an alternative land use which defines how the land would be used if sweet sorghum was not cultivated. It also comprises any change in land cover induced by the cultivation of sweet sorghum or an alternative land use needs to be taken into account if sweet sorghum is cultivated on areas that become free due to the intensification of existing land use (for details see above quoted literature).

The following land uses are regarded as reference systems in the SWEETFUEL project (according to /Braconnier & Reinhardt et al 2011/):

- Dense thickets / sparse forests (carbon storage around 60 t carbon / hectare)
- Wooded grassland / planted pastures / (carbon storage around 15 t carbon / hectare)
- Degraded soils (carbon storage close to zero)
- Replacing grain sorghum
- Replacing other food crops such as soy, peanuts, maize and cotton.

Concerning the interlinkages between WP 5 and WP 6 the first three reference systems mentioned don’t require any data exchange. With respect to the last scenario (replacing other food crops), the methodological approach of this study leads to an assessment to produce the replaced food at another part of the world. This ends up finally in a land use change as listed above in the first three reference systems (or others). In case the production

intensity, yields and all other agronomic production data of the food crop under consideration are the same at both production places no differences can be found and this scenario leads to results being zero in total. In case production intensities are different, differences may occur. But as the SWEETFUEL project aims towards the introduction of sweet fuel crops and not to different food crop scenarios, no differences in food crop production is considered to guarantee that the final results are related solely to sweet sorghum production and use and not to differences in food production.

In conclusion: concerning the reference systems with respect to the interlinkages between WP 5 and WP 6 only the grain sorghum scenario has to be covered. As this scenario is not relevant for the temperate climate there will be only two different climate scenarios (subtropical / tropical semi-arid and tropical).

3.2.3.2.5 Summary and data transfer templates

Considering the above mentioned needs for data collection from WP 5 for the work in WP 6, three main sweet sorghum scenario differentiations are to be covered. For each of them a separate data collection template was established (see Fig. 3-7). Note: all of these templates cover all three, minimum (“min”), mean and maximum (“max”) bandwidth data according to the description in chapter 3.2.3.2.1:

Table 3-7 Data collection templates for data transfer from WP 5 for WP 6

Description of scenario	Data collection template
Sweet sorghum production 2014: - 3 climate scenarios	Sweet-Sorghum-main-2014.xls
Sweet sorghum production 2020: - 3 climate scenarios	Sweet-Sorghum-main-2020.xls
Grain sorghum production 2014: - 2 climate scenarios	Grain-Sorghum-main-2014.xls
Grain sorghum production 2020: - 2 climate scenarios	Grain-Sorghum-main-2020.xls
Sweet sorghum production 2014 - additional differentiations*	Sweet-Sorghum-optional-2014.xls
Sweet sorghum production 2020 - additional differentiations*	Sweet-Sorghum-optional-2020.xls

* additional differentiations are optional subscenarios to be defined in the course of the project by ICRISAT, IFEU or WIP

3.2.3.3 Data request from WP 5 for task 6.3

Concerning task 6.3 “Economic assessment” some interlinkages between the subtasks in task 6.3 have been identified (/Basavaraj & Rao 2011/).

Next to these, most likely all data needs of task 6.2 "environmental assessment" from WP 5 may be necessary to fulfil the economic assessment as in both, task 6.2 and task 6.3, the same scenarios have to be investigated. Details on this as well as on additional specific interlinkages of task 6.3 and WP 5, if any, will follow later.

3.2.3.4 Data request from WP 5 for task 6.4

Concerning task 6.4 "SWOT analysis" some data and information is required by WIP from WP 5 "Packages and crop modelling". As of August 17, 2011, the requirements are as follows (/Jansen et al 2011/):

a) Cultivation, harvesting, transport
   This thematic field will include breeding results of different sweet sorghum varieties, GMO aspects, as well as cultural and harvesting practices. Furthermore, issues of land use, land use change, and land use conflicts will be addressed.
   Contributions of partners involved in WP 5 (lead: UNIBO) are foreseen.

b) Conversion (technologies)
   This thematic field will assess conversion processes of sweet sorghum raw material involving different scales of production, different maturity level of technologies, as well as a variety of different by-products.
   Contributions of partners involved in WP 5 (lead: UNIBO) according to their expertise are foreseen.

c) End use, market deployment
   This thematic field will assess the distribution and end use of ethanol as transport fuel, ethanol gel as cooking fuel, and different by-products (bagasse, vinasse, etc.). Aspects of competition between uses for food, feed, fibres, and biofuels, as well as market deployment for products and by-products will be investigated.
   Contributions of partners involved in WP 5 (lead: UNIBO) are foreseen.

Special note: According to UNIBO at the IFEU/UNIBO meeting: "End uses, market development goes beyond the WP 5 expertise". Conclusion: has to be clarified in the course of the upcoming meeting IFEU/WIP.

Specific details on data requests from WP 5 concerning the SWOT analysis will follow later.

3.2.3.5 Data request from WP 5 for task 6.5

No data or information is foreseen to be delivered to task 6.5 "Integrated assessment" from WP 5 "Packages and crop modelling".

3.2.4 Data requests from WP 6 for WP 5

Data request for the work in work package WP 5 "Package production and crop modelling" from WP 6 "Integrated assessment" has still to be identified.

3.2.5 Interlinkages within WP 6

According to the structure of WP 6 “Integrated assessment” (see Fig. 2 1) quite a number of data and information on the scenarios are used in both, task 6.2 “Environmental assessment” and task 6.3 “Economic assessment”. Most likely all data listed in the data collection templates summarized in chapter 3.2.5 will be used in both tasks. Additional data and details of its uses will follow later by the needs addressed by ICRISAT, IFEU and WIP.

3.2.6 References

/Basavaraj & Rao 2011/: Basavaraj G. and Parthasarathy Rao P.: SWEETFUEL: Sweet Sorghum – an alternative energy crop. WP 6, Task 6.3, Methodology for economic assessment – Draft

/Braconnier & Reinhardt et al. 2011/: Braconnier S., Reinhardt G., Köppen S., Rettenmaier N., Detzel A., Amaducci S., Avelino J., Basavaraj G., Bursztyn M., Garcia-Zambrano E.A., Gutierrez-Diez A., Janssen R., Magalhaes J., Monti A., Parrella R., Parthasarathy Rao P., Purcino A.A.C., Reddy B.V.S., Rodrigues J.A., Rutz D., Schaffert R., Simeone M.L.F., Srinivasa Rao P., Trevino-Ramirez J.E., Zacharias A., Zavala-Garcia F., Zegada-Lizarazu W. (2011): SWEETFUEL: Sweet Sorghum – an alternative energy crop. WP 6, Task 6.1, Interim report on technological assessment: “Definitions and settings”, 8 August 2011

/Janssen 2011/: Janssen R: Sweet Sorghum as Energy Crop. SWOT Analysis, 17 August 2011

/Rettenmaier 2011/: Rettenmaier, N.: Minutes of the “Internal meeting on interlinkages“ between IFEU and UNIBO on August 26, 2011 in Heidelberg, Germany

4 Interim results task 6.2: Methodology for environmental assessment

Authors:

Reinhardt, Guido (IFEU); Rettenmaier, Nils (IFEU); Detzel, Andreas (IFEU); Köppen, Susanne (IFEU);

This chapter summarises the work done in the Task 6.2 “Environmental assessment” – status: November 30, 2011. A detailed task 6.2 description can be found in chapter 1.2.

The work done in this task so far consists mainly of two components:

- Life cycle assessment (LCA) methodology
- Environmental assessment (EIA) methodology

Details are listed in the following chapters 4.1 “Background and objective”, 4.2 “Life cycle assessment” and 4.3 “Environmental assessment”. Both are in the status of “preliminary results” and will be decided upon in April 2012 in Bologna, Italy, on the occasion of the next assembly meeting.

4.1 Background and objective

The SWEETFUEL project

Increasing world market prices for fossil fuels, driven by limited reserves, growing demand and instability in producing regions, now render renewable fuels economical. Such fuels are also a pathway to reducing greenhouse gas emissions and mitigating climate change. Bio-ethanol from crop plants is a promising, partial solution to sustainability satisfying the energy demand for road transport. The success of bio-ethanol from sugarcane in Brazil demonstrates proof of concept but cannot be transferred to water-limited or temperate environments. Sweet sorghum, as a source of either fermentable free sugars or lignocellulosics, has many potential advantages, including: high water, nitrogen and radiation use efficiency; broad agro-ecological adaptation; rich genetic diversity for useful traits; and the potential to produce fuel feedstock, food and feed in various combinations. Fuel-food crops can thereby help reconciling energy and food security issues.

The SWEETFUEL project will breed for improved cultivars and hybrids of sorghum for temperate, tropical semi-arid and tropical acid-soil environments by pyramiding in various combinations, depending on region and ideotype, tolerance to cold, drought and acid soils, and high production of stalk sugars, easily digestible biomass and grain. Agro-ecological

adaptation and sustainable practices are developed and a full integrated assessment on sustainability will be undertaken.

Sustainability assessment within SWEETFUEL

In the last couple of years a controversial discussion on the net benefit of bioenergy has been ongoing, showing that the replacement of fossil resources by biomass is not environmentally friendly per se, simply because biomass is renewable. But it is accepted, that that biofuels can positively affect environmental and social aspects under certain specifications. However, they can also have negative effects on the environmental, social or economic sustainability especially with relation to the agricultural production of the biomass, such as sweet sorghum for bioethanol. E. g. potentially higher risks for biodiversity loss or higher acidification and eutrophication of natural ecosystems have to be taken into account. Also, the discussion gained momentum in the light of increasing competition for agricultural land between the production of food, feed, fibre and fuel which might even aggravate in the decades to come and jeopardise food security. Most likely, agricultural land will be expanded at the cost of (semi-)natural ecosystems, which are converted into cropland. Several studies have pointed out the negative effects of such direct and indirect land-use changes, among others in terms of biodiversity loss and greenhouse gas emissions.

Therefore it is obvious that in order to validate the benefits on sustainable development and identify the related bottlenecks of any given sweet sorghum production and use scenario and, ultimately, to provide a basis for the development of incentive policies, it is essential to apply a strict and sufficiently overarching sustainability assessment to evaluate the SWEETFUEL processes. This integrated assessment of sustainability is performed in work package (WP) 6.

Environmental assessment

Within WP 6, task 6.2 will assess all environmental implications associated with the SWEETFUEL systems and conclude on their optimisation potentials. The entire life cycles of the SWEETFUEL systems will be under investigation including all alternative reference systems and all scenarios defined in task 6.1.

The environmental assessment in task 6.2 consists of two parts: Life cycle assessment and environmental impact assessment.

Life cycle assessment is a standardised methodology addressing product related, global environmental impacts of a specific product or process. It takes into account the entire production chain (“cradle to grave” approach) including all inputs and outputs and reference products. For life cycle assessment, two international standards are worth it to be considered, the requirements of the International Reference Data System (ILCD) Handbook as well as the international ISO 14040 & 14044 standards on life cycle assessments. Details about life cycle assessment methodology applied in the SWEETFUEL project are given in chapter 4.2.

Environmental impact assessment are also standardised methodologies, but with focus on local, site specific environmental impacts. For SWEETFUEL, the analysis of local environ-

mental effects will be oriented at EIA methodology. Details about environmental impact assessment methodology as applied in WP 6 are given in chapter 4.3 of this report.

4.2 Life cycle assessment (LCA)

4.2.1 Introduction to LCA methodology

Life cycle assessment (LCA) addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of emissions) throughout a product's 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 (biofuels) or farm-to-fork (food).

LCA methodology is laid down in important regulatory frameworks: two ISO standards (chapter 4.2.1.1) and the ILCD Handbook (chapter 4.2.1.2). The last chapter (4.2.2) outlines the general approach which the SWEETFUEL project will take.

4.2.1.1 The ISO standards 14040 and 14044

Life cycle assessment (LCA) is structured, comprehensive and internationally standardised through ISO standards 14040:2006 and 14044:2006 /ISO 2006/ 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).

The life cycle analyses (LCA) in this study are carried out largely following the above mentioned ISO standards on product life cycle assessment /ISO 2006/.

There are four iterative phases in an LCA study (Fig. 4-1):

1) the goal and scope definition phase,

2) the inventory analysis phase,

3) the impact assessment phase, and

4) the interpretation phase.

All phases are iterative as depicted in Fig. 4-1. Therefore, interpretation has to be seen as a continuous process.

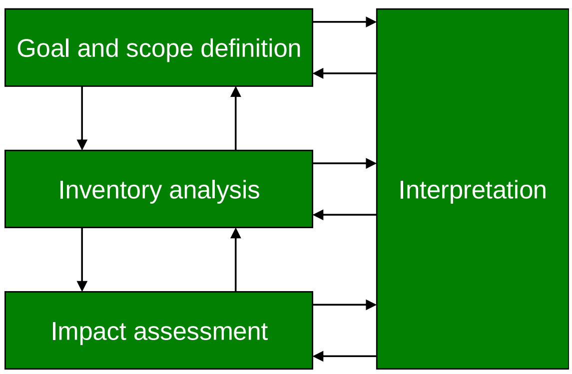

Fig. 4-1 Phases of an LCA /ISO 2006/

4.2.1.2 The ILCD Handbook

The ISO 14040 and 14044 standards provide the indispensable framework for life cycle assessment (LCA). This framework, however, leaves the individual practitioner with a range of choices, which can affect the legitimacy of the results of an LCA study. While flexibility is essential in responding to the large variety of questions addressed, further guidance is needed to support consistency and quality assurance. The International Reference Life Cycle Data System (ILCD) has therefore been developed by the Institute for Environment and Sustainability in the European Commission Joint Research Centre (JRC), in co-operation with Directorate General for the Environment of the European Commission (DG Envi) to provide guidance for consistent and quality assured life cycle assessment data and studies /JRC-IES 2010/.

The ILCD Handbook is a series of technical documents (depicted in Fig. 4-2) that provide detailed guidance on all the steps required to conduct a life cycle assessment (LCA). In the Communication on Integrated Product Policy, the European Commission committed to produce a handbook on best practice in LCA. The Sustainable Consumption and Production Action Plan confirmed that "(…) consistent and reliable data and methods are required to assess the overall environmental performance of products (…)". The Handbook's main goal is to ensure quality and consistency of life cycle data, methods and assessments. Its main target audience is LCA practitioners, data providers, and reviewers.

While the ISO standards on life cycle assessment are in place since the mid 1990ies, the ILCD Handbook is still under development. The first volumes were launched in March 2010, but important volumes such as the one on life cycle impact assessment are still pending. Moreover, the ILCD Handbook's practicability has not been tested yet. It remains to be seen whether the majority of LCA practitioners will adopt the ILCD Handbook and whether commissioners of LCA studies are willing to cover additional costs associated with an ILCD-compliant study.

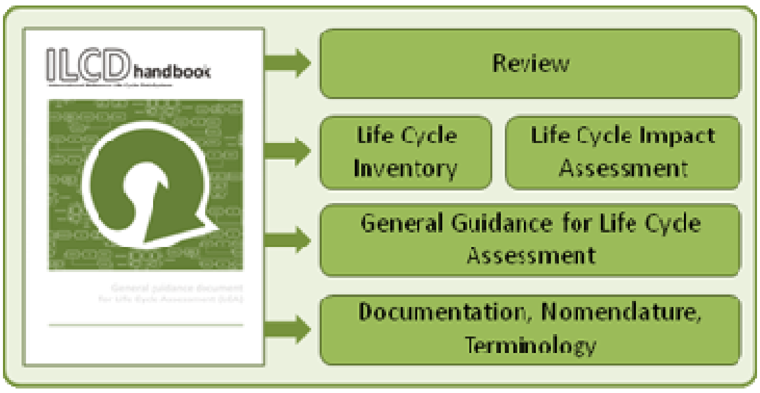

Fig. 4-2 The ILCD Handbook: a series of technical documents providing guidance for good practice in life cycle assessment /JRC-IES 2010/

4.2.2 The LCA approach for SWEETFUEL

Life cycle assessment (LCA) is a relevant part of the sustainability assessment for the SWEETFUEL concept. The objective of carrying out an LCA in SWEETFUEL is to identify the most promising SWEETFUEL pathways, to identify optimisation potentials and to compare the SWEETFUEL concept to conventional production chains (for details on goal and scope see chapter 3.1 “Definitions and settings”.

As the international ISO LCA norm is running since quite some time and was applied successfully, it will be considered within the SWEETFUEL project. In contrast, as the ILCD Handbook was developed, when the SWEETFUEL project was already running, and, second, even as of November 30, 2011, the handbook is not yet completed, its requirements cannot be taken into account at a full scale. Still, some of its requirements will be addressed, but especially those regarding documentation, review and reporting cannot be considered.

For the life cycle assessment, a two-step approach is applied:

Screening life cycle assessment

For the selection of additional value chains, so-called screening life cycle balances will be performed. These screening life cycle balances will largely follow the above mentioned ISO standards except for a) the level of detail of documentation, b) the quantity of sensitivity analyses and c) the mandatory critical review. Nevertheless, the results of these screening LCAs are quite reliable due to the close conformity with the ISO standards.

Sensitivity analyses to identify optimisation potentials

Based on the interpretation of the screening assessments, several sensitivity analyses will be calculated to identify the optimisation potentials.

4.2.3 Goal definition, general specifications and settings

For the analysis of the SWEETFUEL scenarios, general definitions and settings are necessary. They are used in the subsequent task analyses to assess environmental, economic and social implications and guarantee their consistency. There are general definitions and settings which have to be applied by all assessments, namely for the environmental, economic and social assessment, and specific ones which will be applied only in the environmental assessment. Below, the actual status of the methodologies, specifications and settings chosen for the environmental assessment is listed. There will be a continuous update up to the next assembly meeting in Bologna, Italy, in April 2012 to discuss and conclude on all methodology items.

4.2.3.1 Time frame

In this project the use of sweet sorghum for both, 1st generation as well as 2nd generation, fuel technologies is assessed. The former, i. e. the production of bioethanol is already well-established. In contrast, second generation technologies such as the production of ethanol

from lignocellulose or the biomass gasification for so-called BtL[3] fuels are not yet existent and still in their pilot phase. For analyzing and comparing mature technologies, 2014 is set as reference year because this is the time at the end of the project. An outlook shall be given for 2020.

4.2.3.2 Geographical coverage

As the project aims at developing optimized sweet sorghum genotypes for specific climates, the scenarios are oriented at these specific climatic regions. Three scenarios are defined covering the tropical as well as the temperate climates, respectively:

- One scenario examines a temperate climate,
- a second scenario covers a subtropical / semi-arid climate with around 700 mm rainfall,
- and a third scenario refers to a tropical climate with around 1,200 mm rainfall per year.

However, within these regions there might be great differences due to differences in environmental conditions as well as due to varying production practices and conditions in different countries. These differences are captured by sub-scenarios and sensitivity analyses taking into account different yields, uses of the (by-)products or production costs, etc. It is outside the scope of the project to analyze every single country where sweet sorghum could be produced. However, if it becomes evident that country specific conditions have a significant influence on the results, for the geographical coverage single countries may be chosen to show these dependencies. This might be the case for labour costs or emissions from electricity generation. For those cases, additional settings have to be agreed upon between the task partners in WP 6, namely task 6.2 (environmental assessment), task 6.3 (economic assessment) and task 6.4 (SWOT analysis).

4.2.3.3 Functional unit

The functional unit has to be chosen depending on the questions to be answered. As the project aims at increasing the output of the crop by developing improved varieties and since land usually is the limiting factor, the use of sweet sorghum from 1 hectare of land is assessed.

4.2.3.4 Alternative land use

The alternative land use defines how the land would be used if sweet sorghum was not cultivated. It also comprises any change in land cover induced by the cultivation of sweet sorghum. As agricultural land is becoming increasingly scarce, more and more natural land (e. g. forests or grass land) is transformed into arable land. Such land use and land cover changes may have considerable influences on the outcomes of the ecological assessment since e. g. the area’s carbon stock or biodiversity are influenced. For example, a decline in above-ground and below-ground carbon stock leads to greenhouse gas emissions, which have to be included in the greenhouse gas balance. Beside direct land use changes also indirect changes can occur. This is the case if for example the cultivation of sweet sorghum

[3] BtL: Biomass-to-Liquid; synthetic biofuels produced via biomass gasification

displaces the production of a food crop to other areas. Depending on use and/or land cover of that area, the displacement can cause different environmental effects.

The alternative land use also needs to be taken into account if sweet sorghum is cultivated on areas that become free due to the intensification of existing land use. Since on these areas, natural ecosystem could emerge if sweet sorghum was not cultivated, these potential ecosystems need to be taken into account as reference systems.

The following land uses are regarded as reference systems:

- Tropical / subtropical climate:
    - In the tropical /subtropical climate the objective is to grow sweet sorghum in wet to dry savannah. In order to derive a bandwidth of different vegetation types and thus amounts of carbon stored, three reference systems are identified:
        - Dense thickets / sparse forests (carbon storage around 60 t carbon / hectare)
        - Wooded grassland / planted pastures / (carbon storage around 15 t carbon / hectare)
        - Degraded soils (carbon storage close to zero)

      This classification is mainly oriented at the carbon content of the vegetation but it refers to some extent also to the vegetation type. The carbon contents given here serve the purpose to characterize the reference systems. They don’t reflect real carbon contents but serve as an indicative differentiation between the reference systems defined.

    - Additionally to the reference systems listed above sweet sorghum may be grown on fields already used for agricultural purposes and, therefore, replacing food crops. This is the case e.g. in South Africa (grain sorghum), Mexico (grain sorghum and corn), Brazil (soy or peanuts, which are suitable crops as well to interact as a intermediate food crop after a 5 year sugar cane cycle) and India (cotton or soy). With this given, two additional reference systems will be considered:
        - Replacing grain sorghum
        - Replacing other food crops such as soy, peanuts, and cotton.
- Temperate climate
    - Fallow land is regarded as reference scenario.

      Forest conversion is forbidden in all countries within Europe. Also, a large scale conversion of grassland is undesired from a nature protection point of view and forbidden throughout Europe. Therefore, forest and grassland will not be assessed as agricultural reference systems.

Concerning the indirect land use change, no general definition is done at the present state of the project as the international debate on how to integrate the indirect land use change into

life cycle assessments is still running. This issue will be taken into account at a latter stage of the project. Concerning specific indirect land use changes they may occur in the reference system no. 5 listed above: replacement of food production. For this, one or two indirect land use change scenarios will be considered such as clearing of virgin land, e.g. containing 15 t of carbon per hectare. This has to be agreed upon at a latter stage of the project.

4.2.3.5 Technical reference

The technical reference describes the technology to be assessed in terms of plant capacity and development status / maturity. As the SWEETFUEL scenarios cover both, “central” and “decentralized production on village level” two main technical references have to be defined. It is suggested to assess following capacities[4]:

- 25,000 – 120,000 t ethanol per year in the case of centralized production
- 1 t ethanol per day in the case of decentralized production.
- 3 t syrup per day in the case of decentralized production.

For all plant capacities, mature, full industrial plant will be assessed.

4.2.3.6 Settings for Life Cycle Impact Assessment (LCIA)

Impact categories: Midpoint vs. endpoint level

An LCA generally covers all environmental impacts related to a specific product. Impact categories can be divided into “midpoint-level” and “endpoint-level”. Three main endpoints “damage to human health”, “damage to ecosystem diversity” and “resource scarcity” can be defined according to the ILCD handbook (Fig. 4-3). Midpoint indicators represent processes, which are known to have an impact on endpoints indicators. For example “acidification” (midpoint) causes damage to ecosystem diversity (endpoint). Midpoint indicators are no damage themselves but cause damage to endpoint indicators. Therefore, they can be understood as “potential” or “risk” for damage.

[4] The exact capacity numbers have still to be agreed upon between the partners

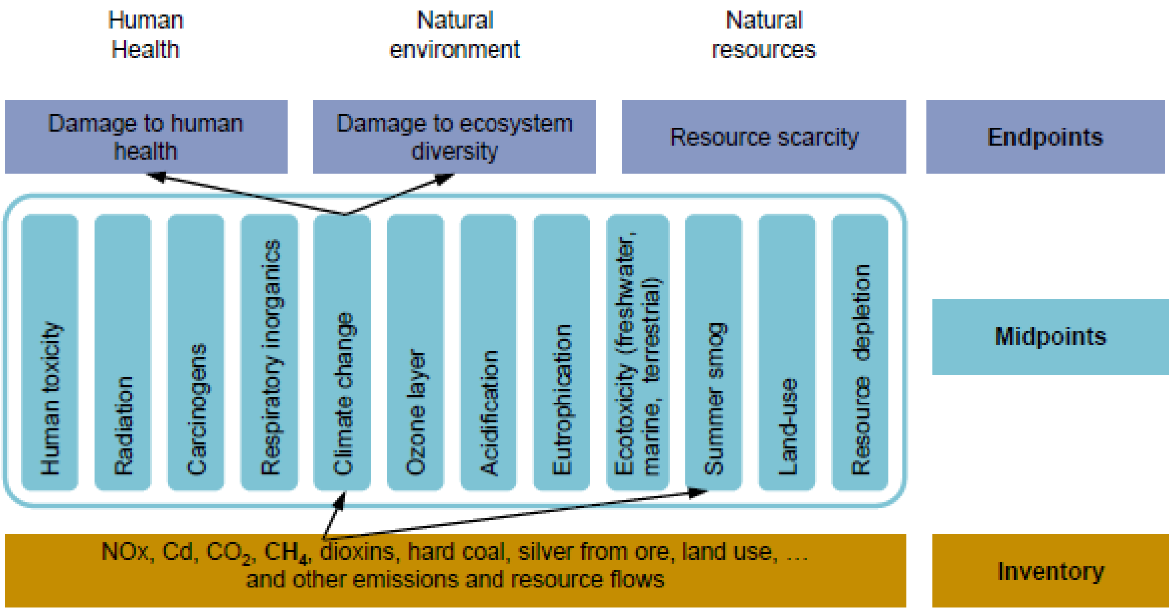

Fig. 4-3 Life cycle impact assessment. Overview on endpoint and midpoint categories /IFEU 2011/ on the basis of /JRC-IES 2010/ (p. 108)

Life cycle impact assessment (LCIA) methods exist for midpoint and for endpoint level. There are advantages and disadvantages associated with both levels. In general, on midpoint level a higher number of impact categories are differentiated and the results are more accurate and precise compared to the three Areas of Protection at endpoint level that are commonly used for endpoint assessments. Within the SWEETFUEL project, the impacts will be assessed at midpoint level only. Moreover, the LCAs will not cover all of the default impact categories at midpoint level that are mentioned in the ILCD Handbook. It was decided that impact categories such as human and ecotoxicity which are classified as level III or II/III in the ILCD Handbook will be excluded from the assessment. Thus, it would not make sense to calculate results at endpoint level (e.g. damage to Human Health) if one of the main contributing impact categories at midpoint level (e.g. human toxicity) is excluded.

Selection of relevant midpoint-level impact categories

This project will assess the midpoint indicators listed in Table 4-1. The effect on these indicators is linked to given environmental parameters as shown in Table 4-2. All impact categories are standard categories in life cycle assessments /JRC-IES 2010/.

Some impact categories, which are not listed in these tables, are excluded because they are i) irrelevant for the SWEETFUEL systems (e.g. ionising radiation) or ii) still under methodological development (e.g. human and ecotoxicity, water depletion and land use; classified as level III or II/III in the ILCD Handbook). Moreover, LCI data accuracy regarding 2025 will be an issue - even for some of the established impact categories at midpoint level. This issue is particularly relevant for human toxicity and ecotoxicity, which cover dozens of substances. It is already foreseeable today that the LCI data will be at least questionable (if not uncertain), which will entail large uncertainty margins. As these uncertainty margins add up, the range of result might become extreme, which would clearly hamper interpretation. If the same

approach was used for the aggregated Areas of Protection (AoP) at endpoint level, uncertainty would be even higher, resulting in a very low informative value.

Table 4-1 Environmental impact categories and their description

Impact category	Description
Depletion of non-renewable energy resources	Depletion of non-renewable energy resources, i.e. fossil fuels such as mineral oil, natural gas and different types of coal as well as uranium ore. The procedures and general data for the calculation are documented in detail in /Borken et al. 1999/
Climate change	Global warming as a consequence of the anthropogenic release of green-house gases. Besides carbon dioxide (CO_2) originating from the combustion of fossil energy carriers, a number of other trace gases – among them methane (CH_4) and nitrous oxide (N_2O) – are included. The latter two are converted into carbon dioxide equivalents (CO_2 equiv.) using GWP100 factors /IPCC 2007/. Further details can be found in /Borken et al. 1999/.
Acidification	Shift of the acid/base equilibrium in soils and water bodies by acidifying gases (keyword ‘acid rain’). Emissions of sulphur dioxide, nitrogen oxides, ammonia, and hydrogen chloride are playing a major role.
Terrestrial eutrophication	Input of nutrients into soils and by gaseous emissions. Excessive nutrient intake into natural ecosystems harm endangered and rare species as well as fragile ecosystems like forests, calcareous grasslands etc.. Among others, nitrogen oxides and ammonia are responsible for this.
Photochemical ozone formation	Formation of specific reactive substances, e.g. ozone, in presence of nitrogen oxides, volatile hydrocarbons and solar radiation in the lower atmosphere (keyword ‘ozone alert’, ‘summer smog’ or ‘Los Angeles smog’).
(Stratospheric) Ozone depletion	Loss of the protective ozone layer in the stratosphere by certain gases such as CFCs or nitrous oxide (keyword ‘ozone hole’). All ozone-depleting gases are converted into CFC-11 equivalents. For N_2O, Ravishankara’s value / Ravishankara et al. 2009/ is used.
Respiratory inorganics (particlulate matter emissions)	Damage to human beings due to air pollutants such as fine, primary particles and secondary particles (mainly from NO_X, NH_3 and SO_2). Heavy industries, electricity and heat production from liquid and solid fuels, as well as road traffic and agriculture are important sources of these pollutants (keyword ‘winter smog’ or ‘London smog’)

Table 4-2 Indicators, LCI parameters and characterisation factors for the respective impact categories (/CML 2004/, /IPCC 2007/, /Klöpffer & Renner 1995/, /Leeuw 2002/, /Ravishankara et al. 2009/, /IFEU 2011/ on the basis of /IPCC 2007/)

Impact category	Category indicator	Life cycle inventory (LCI) parameter	Formula	Character. factor
Depletion of non renewable energy resources	Cumulative primary energy use from non-renewable sources	Crude oil Natural gas Hard coal Lignite Uranium ore	—	—
Climate change	CO_2 equivalent (carbon dioxide equivalent)	Carbon dioxide fossil Nitrous oxide Methane biogene* Methane fossil**	CO_2 N_2O CH_4 CH_4	1 298 25 27.75
Acidification	SO_2 equivalents (sulphur dioxide equivalent)	Sulphur dioxide Nitrogen oxides Ammonia Hydrochloric acid	SO_2 NO_X NH_3 HCl	1 0.7 1.88 0.88
Terrestrial eutrophication	PO_4 equivalents (phosphate equivalent)	Nitrogen oxides Ammonia	NO_X NH_3	0.13 0.346
Photochemical ozone formation	C_2H_4 equivalents (ethylene equivalents)*	Non-methane hydrocarbons Methane	NMHC CH_4	0.5 0.007
(Stratospheric) Ozone depletion	CFC-11 equivalents	Nitrous oxide (Dinitrogen oxide)	N_2O	0.017
Respiratory inorganics (particulate matter emissions)	PM_{10} equivalents	Particulate matter Sulphur dioxide Nitrogen oxides Non-methane hydrocarbons Ammonia	- SO_2 NO_X NMHC NH_3	1 0.54 0.88 0.012 0.64

*without CO_2 effect; **with CO_2 effect

Regarding ozone depletion, an ODP factor for nitrous oxide from a study by /Ravishankara et al. 2009/ is used although it is not yet commonly accepted because it is the only one available.

Normalisation

Normalisation helps to better understand the relative magnitude of the results for the different environmental impact categories. It is optional for LCAs. To this end, the category indicator results are set into relation with reference information. Normalisation transforms an indicator

result by dividing it by a selected reference value, e.g. a certain emission caused by the system is divided by this emission per capita in a selected area.

In the SWEETFUEL LCA study, the environmental advantages and disadvantages for the European scenarios can be related to the environmental situation in the EU27. The reference information is the yearly average energy demand and the average emissions of various substances per inhabitant in Europe, the so-called inhabitant equivalent (IE). The reference values are presented in Table 4-3 for all environmental impact categories.

For example, each EU27 inhabitant causes yearly average GHG emissions of 11 tons (=1 IE). The production and use of rapeseed biodiesel (FAME) from 100 ha of agricultural land in central Europe leads to emission savings of 19.1 IE or 21.4 t CO2 eq. / (ha*yr).

Table 4-3 Emissions in the environmental impact categories and the resulting inhabitant equivalent related to inhabitant and year (base year: 2005) (/IFEU 2011/ on the basis of /Eurostat 2007/ and /CML 2009/). Inhabitants EU27 2005: 491,153,644 /Eurostat 2010/.

Impact category	Unit	EU27 inhabitant equivalent
Cumulative primary energy demand	GJ / yr	82
Climate Change	t CO_2 equivalent / yr	11
Acidification	kg SO_2 equivalent / yr	49
Terrestrial Eutrophication	kg PO_4 equivalent / yr	6
Photochemical ozone formation	kg C_2H_4 equivalent / yr	20
(Stratospheric) Ozone depletion	kg CFC-11 equivalent / yr	0.069
Respiratory inorganics (particulate matter)	kg PM_{10} equivalent / yr	40

Due to the insecurity related to future emissions of various substances, the inhabitant equivalents will be calculated based on 2010 emissions. These values are subsequently used to normalise data which are calculated for 2015 and 2025 (time frame for SWEETFUEL systems). The resulting bias for 2015 will probably be less pronounced than for 2025.

To ensure comparability, results for the non European scenarios may are also normalised using the EU inhabitant equivalents for EU27. Results expressed in inhabitant equivalents for these regions, if available, are calculated as sensitivity analyses.

Weighting

Weighting will not be applied. Weighting uses numerical factors based on value-choices to compare and sometimes also aggregate indicator results, which are not comparable on a physical basis.

4.2.3.7 System boundaries

System boundaries define which unit processes are part of the product system and thus included into the assessment. The LCA for SWEETFUEL will cover the entire value chain (life cycle) from the feedstock production to the distribution and usage of the final products including land use change effects and associated changes in carbon stocks (see Fig. 4-4)

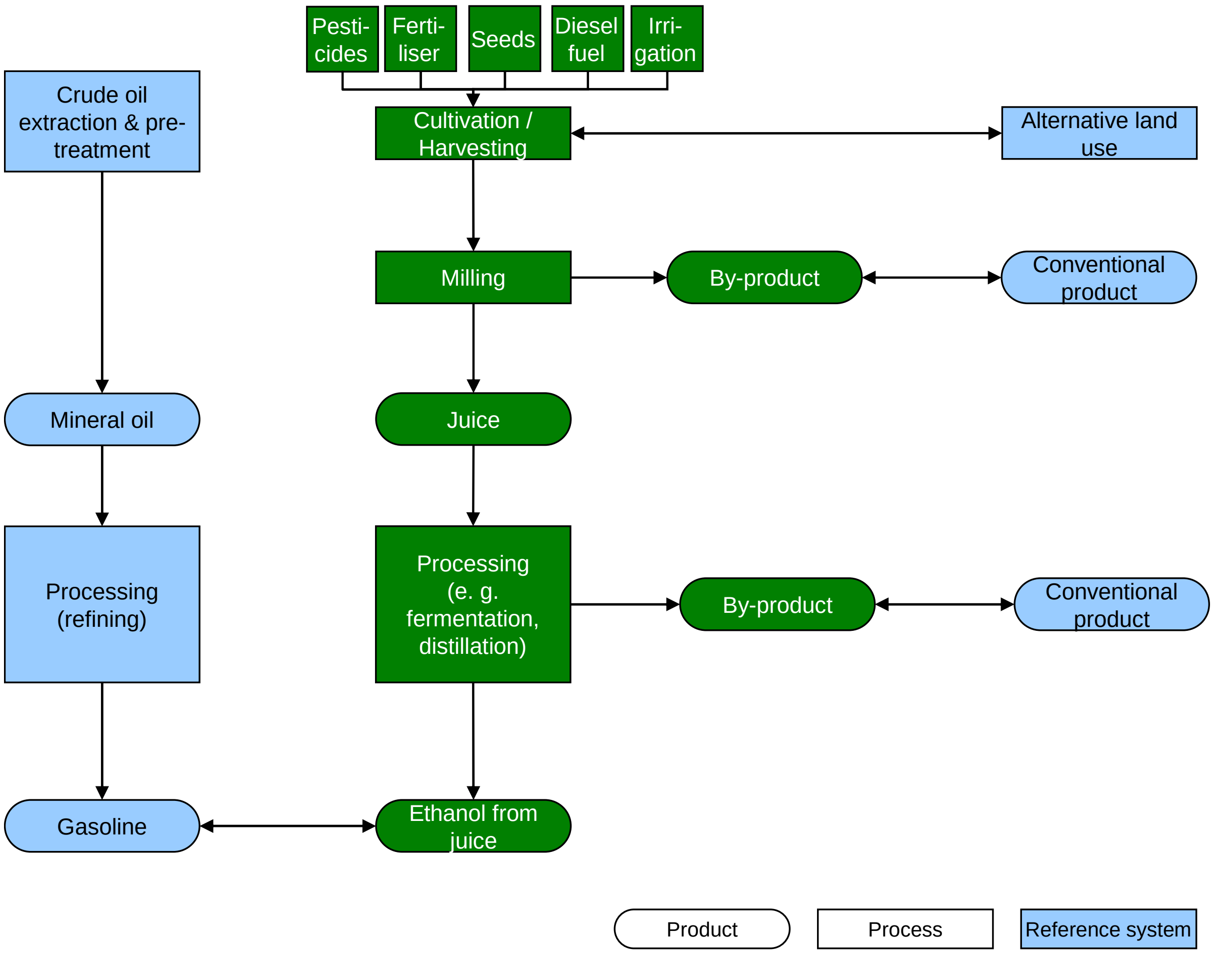

Fig. 4-4 System boundaries applied in the case of SWEETFUEL

Systematic exclusion of activity types

Infrastructure is excluded from the system. This applies to production and processing equipment, vehicles such as tractors, buildings and streets connected with the crop’s production and use. In many LCAs assessing bioenergy systems it was shown that infra-structure accounts for less than 10 % of the overall results (see /Nitsch et al. 2004/, /Fritsche et al. 2004/ and /Gärtner 2008/). However, this only applies for the environmental impacts. In contrast, investment and capital costs for process equipment or buildings are an important part of the economic assessment.

4.2.3.8 Further methodological issues

Biogenic carbon

There are two possible sources for carbon dioxide (CO_2) emissions: (recent) biogenic or fossil carbon stocks. For biofuels, the amount of CO_2 released into the atmosphere from direct biofuel combustion equals the amount of CO_2 that has been taken up by the plants recently (short carbon cycle). This release of biogenic CO_2 is considered carbon neutral, i.e. it does not promote climate change. Therefore, only fossil carbon is taken into account for calculating greenhouse gas balances in SWEETFUEL, which is the standard approach among LCA practitioners.

Direct land use change and changes in organic carbon stocks

Changes in direct land use and related changes in organic carbon stocks of above- and below-ground biomass, soil organic carbon, litter and dead wood will be covered by SWEETFUEL LCA /IPCC 2006/. Changes in organic carbon stocks may result from extraction of woody biomass or straw for bio-refining, which formerly remained on the field/in the forest. The carbon stock changes and resulting release of greenhouse gases (mainly in the form of CO_2) are integrated into the GHG balances by using the above mentioned methodologies if alternative land use options lead to different carbon stocks. The methodologies described by the IPCC guidelines for national greenhouse gas inventories /IPCC 2006/ and the guidelines for the calculation of land carbon stocks for the purpose of Annex V to EU RED /EC 2010/ will be used.

Carbon sequestration, which could also result from a land use change, will not be taken into account. This is because the potential to sequester carbon in soil is very site-specific and highly dependent on former and current agronomic practices, climate and soil properties /Larson 2005/. Moreover, it is impossible to assure that the carbon is sequestered permanently. As there is no scientific consensus about this issue, carbon sequestration in agricultural soils will not be accounted for.

Indirect effects

New systems using biomass can indirectly affect environmental indicators by withdrawing resources from other (former) uses. One of the most common indirect effects is indirect land use change: Biomass formerly used for other purposes (e.g. as food or feed) has to be produced elsewhere if it is now used for biorefineries. This can cause a clearing of (semi-)natural ecosystems (=indirect land use change) and hence changes in organic carbon stocks and damages to biodiversity.

Withdrawing biomass from other uses may affect not only land use patterns but also other goods and services. For example, if a SWEETFUEL bioethanol plant is less efficient compared to an other energetic biomass use option (e.g. CHP plants) in terms of replacement of crude oil equivalents but more efficient from an economic point of view and hence withdraw biomass from direct energetic use pathways, the crude oil production may even increase.

Indirect effects of SWEETFUEL systems on the environment will be assessed by sensitivity analyses.

4.3 Elements of environmental impact assessment (EIA)

In Task 6.2 of the SWEETFUEL-project, local environmental effects are assessed using the elements of environmental impact assessment (EIA). These elements are meant to supplement the life cycle assessments (LCA) which are known to be less suitable for addressing local / site-specific environmental impacts.

4.3.1 Introduction to EIA methodology

Environmental impact assessment (EIA) is a standardised methodology for analysing proposed projects regarding their potential to affect the environment. It is based on the identification, description and estimation of the project’s environmental impacts and is usually applied at an early planning stage, i.e. before the project is carried out. EIA primarily serves as a decision support for project management and authorities which have to decide on approval. Moreover, it helps decision makers to identify more environmentally friendly alternatives as well as mitigation and compensation measures.

The environmental impacts of a planned project depend on both the nature / specifications of the project (e.g. a biorefinery plant housing a specific production process and requiring specific raw materials which have to be transported there) and on the specific quality of the environment at a certain geographic location (e.g. occurrence of rare or endangered species, air and water quality etc.). Thus, the same project probably entails different environmental impacts at two different locations. EIA is therefore usually conducted at a site-specific / local level. These environmental impacts are compared to a situation without the project being implemented (“no-action alternative”).

4.3.1.1 Regulatory frameworks related to EIA

As the SWEETFUEL project covers all regions in the world, ideally all regions should be considered.

Within the European Union, it is mandatory to carry out an environmental impact assessment (EIA) for projects according to the following Council Directive 85/337 EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment /CEC 1985/. This Directive has been amended three times:

- Council Directive 97/11/EC of 3 March 1997 /CEU 1997/
- Directive 2003/35/EC of 26 May 2003 /EP & CEU 2003/
- Directive 2009/31/EC of 23 April 2009 /EP & CEU 2009/

Another example listed here is India. The concept of environmental protection and resource management has traditionally been given strong emphasis and has been woven in all facets of life. EIA was introduced in 1994 by the Ministry of Environment and Forest (MOEF) by the

- Environment Impact Assessment Notification S. O. 60 (E) /MOEF 1994/, amended by the

- Environment (Protection) Act Notification (2004) – regarding new towns and industrial estates S. O. 801 (E) /MOEF 2004/ and the
- Environment Impact Assessment Notification (2006) S. O. 1533 /MOEF 2006/

With this, it becomes obvious, that there exist al together hundreds of regulations worldwide related to environmental impact assessment differing from country to country or region to region. Taking this in mind, for the SWEETFUEL project it is most appropriate to follow a generic approach taking the existing regulations into account. Details will be given later in this chapter.

Basically, an EIA covers direct and indirect effects of a project on the following factors (/CEC 1985/):

- human beings, fauna and flora; biodiversity
- soil, water, air, climate and the landscape;
- material assets and the cultural heritage;
- the interaction between these factors

4.3.1.2 Steps of an EIA

An EIA generally includes the following steps:

- Screening
- Scoping
- EIA report
    - Project description an consideration of alternatives
    - Description of environmental factors
    - Prediction and evaluation of impacts
    - Mitigation measures
- Monitoring and auditing measures

Screening

Usually an EIA starts with a screening process to find out whether a project requires an EIA or not. According to article 4 (1) and annex 1 (6) of the EIA Directive, an EIA is mandatory for “Integrated chemical installations, i.e. those installations for the manufacture on an industrial scale of substances using chemical conversion processes, in which several units are juxtaposed and functionally linked to one another and which are (i) “for the production of basic organic chemicals”. Referring to annex 1 (6) of the EIA Directive, an EIA would be required if a SWEETFUEL bioethanol plant would be implemented.

Scoping

Scoping is to determine what should be the coverage or scope of the EIA study for a project as having potentially significant environmental impacts. It helps in developing and selecting

alternatives to the proposed action and in identifying the issues to be considered in an EIA. The main objectives of the scoping are:

- Identify concerns and issues for consideration in an EIA
- Identify the environmental impacts that are relevant for decision-makers
- Enable those responsible for an EIA study to properly brief the study team on the alternatives and on impacts to be considered at different levels of analysis
- Determine the assessment methods to be used
- Provide an opportunity for public involvement in determining the factors to be assessed, and facilitate early agreement on contentious issues.

EIA report

An EIA report consists of a project description, a description of the status and trends of relevant environmental factors and a consideration of alternatives including against which predicted changes can be compared and evaluated in terms of importance.

1. Impact prediction: a description of the likely significant effects of the proposed project on the environment resulting from:
    - The construction / installation of the project; temporary impacts expected, e.g. by noise from construction sites.
    - The existence of the project, i.e. project-related installations and buildings; durable impacts expected e.g. by loss of soil on the plant site.
    - The operation phase of the project; durable impacts expected, e.g. by emission of gases.

Prediction should be based on the available environmental project data. Such predictions are described in quantitative or qualitative terms considering e.g.:

- Quality of impact
- Magnitude of impact
- Extent of impact
- Duration of impact.

2. Mitigation measures are recommended actions to reduce, avoid or offset the potential adverse environmental consequences of development activities. The objective of mitigation measures is to maximise project benefits and minimise undesirable impacts.

Monitoring and auditing measures

Monitoring and auditing measures are post-EIA procedures that can contribute to an improvement of the EIA procedure.

Monitoring is used to compare the predicted and actual impacts of a project, so that action can be taken to minimise environmental impacts. Usually, monitoring is constrained to either

potentially very harmful impacts or to impacts, that cannot be predicted very accurately due to lack of baseline data or methodological problems.

Auditing is aimed at the improvement of EIA in general. It involves the analysis of the quality and adequacy of baseline studies and EIA methodology, the quality and precision of predictions as well as the implementation and efficiency of proposed mitigation measures. Furthermore, the audit may involve an analysis of public participation during the EIA process or the implementation of EIA recommendations in the planning process.

4.3.2 The EIA approach for SWEETFUEL

4.3.2.1 Objectives and approach

Within the SWEETFUEL project, a set of different technologies for sweet sorghum use is analysed. Each concept is defined by its inputs, the conversion, the downstream processes and the final products. This is also reflected in the objectives of the sustainability assessment in WP 7: the aim is to qualitatively assess the impacts associated with each of the (hypothetical) SWEETFUEL concepts (in the sense of technological concepts) at a generic level. The assessment is not meant to be performed for a specific SWEETFUEL biorefinery plant at a certain geographic location.

Environmental impact assessment (EIA), however, is usually conducted at a site-specific / local level (see chapter 4.3.1) for a planned (actual) project. For the purpose of the SWEETFUEL project which neither does encompass the actual site specific production of sweet sorghum nor the construction of a plant, it is therefore not appropriate to perform a full-scale EIA according to the regulatory frameworks mentioned in chapter 4.3.1. Monitoring and auditing measures, for example, become redundant if a project is not implemented, as they are post-project procedures. Consequently, monitoring and auditing measures will be omitted within SWEETFUEL. Nevertheless, elements of environmental impact assessment (EIA) are used to characterise the environmental impacts associated with the SWEETFUEL concepts at a generic level.

The elements of EIA used in SWEETFUEL are shown in Fig. 4-5.

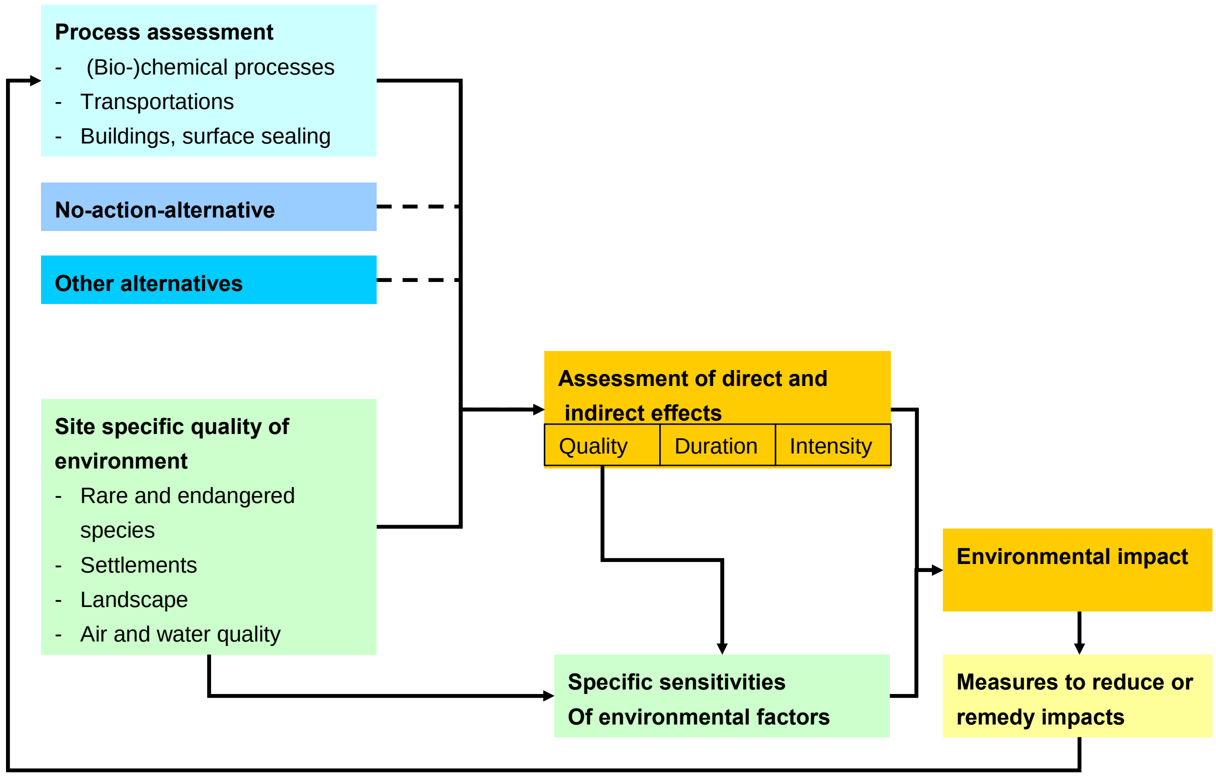

Fig. 4-5 Structure of an EIA in the SWEETFUEL project

4.3.2.2 Reference systems

Generally, an EIA compares a planned project to a so-called no-action alternative (a situation without the project being implemented) in terms of environmental impacts. This assessment is restricted to one specific project or site such as a biorefinery. Biomass production sites and / or the impacts associated with the end use of the manufactured products are usually not considered.

For SWEETFUEL, the scope, and therefore also the reference system, of the EIA was chosen to encompass all life cycle stages from biomass production through biomass conversion up to the use of the manufactured products. This corresponds to a life-cycle perspective and goes beyond the regulatory frameworks for EIA.

Covering the impacts of biomass production is crucial for the environmental assessment because the land-use impact (including indirect impacts on fauna and flora, biodiversity, soil and water) of biomass production exceeds the land-use impact of biomass conversion by far. Therefore, the reference systems are divided into 1) reference systems for biomass production and 2) reference systems for biomass conversion and use.

4.3.2.2.1 Reference systems for biomass production

Biomass in the SWEETFUEL project is related only to Sweet sorghum. The reference system for biomass production specifies the alternative land use, i.e. what the land would be used for if the crops under investigation were not produced /Jungk et al. 2002/. In the case of

the SWEETFUEL project the reference systems have been defined in the milestone M6.1 (see Table 4-4).

Table 4-4 Reference systems for biomass production

Biomass	Type of land used	Reference system
Sweet Sorghum	Europe, arable land	Fallow land
	Tropics / Subtropics arable land	Dense thickets / sparse forests
		Wooded grassland / planted pastures
		Marginal land
		Grain sorghum
		Other food crops (such as soy and peanuts)
		Cotton

4.3.2.2.2 Reference systems for biomass conversion and use

The reference system for biomass conversion and use specifies what the biomass would be used for if the bioenergy carriers and bio-based products under investigation were not produced (alternative biomass use). Here, quite a number of reference systems will be investigated as first and second generation bioethanol as well as biogas production is investigated. For the conventional (fossil) systems we refer to milestone 6.1 of the SWEETFUEL-project.

4.3.2.3 Impact assessment

The assessment of environmental impacts of biomass production, conversion and use is carried out as a benefit and risk assessment. This is useful if no certainty exists regarding the possible future location of biomass cultivation sites and conversion facilities.

4.3.2.3.1 Impact assessment for biomass production

In the case of biomass production the following factors have been identified to assess the possible benefits and risks of biomass production (see also Fig. 4-6).

- Soil
    - Soil erosion
    - Soil compaction
    - Soil chemistry
    - Soil organic matter
- Water
    - Nutrient leaching / eutrophication (water quality)
    - Use of water resources
- Flora, fauna & landscape:
    - Weed control / pesticides
    - Species diversity / habitat quality.

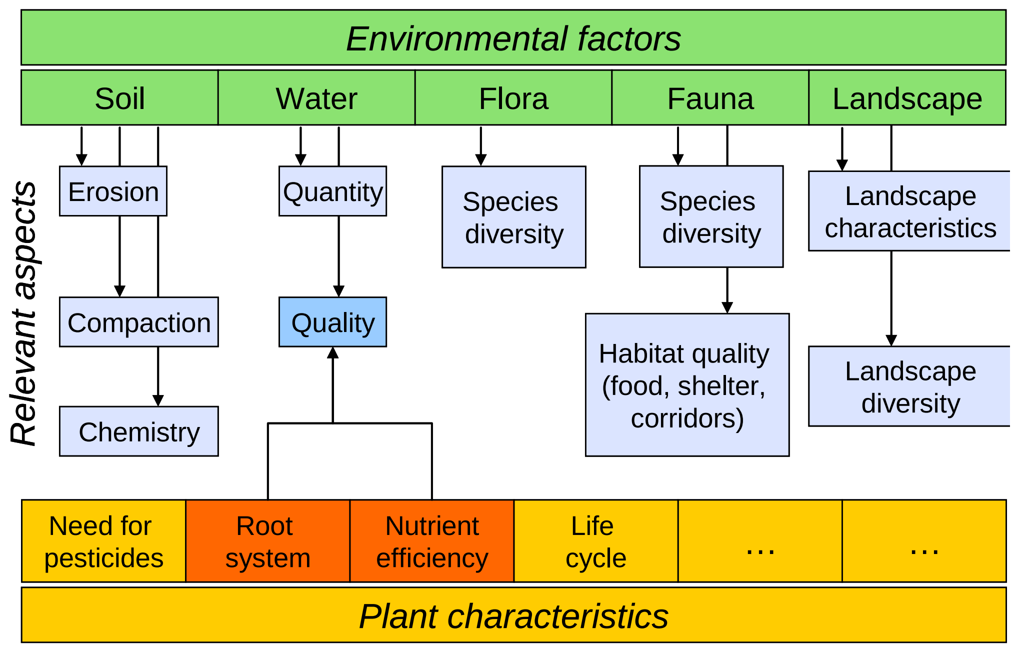

Fig. 4-6 Identification of factors for the EIA of biomass production

Based on these factors, a biomass-specific assessment of the environmental impact is done in this study. After that, an evaluation of different biomass feedstock relative to the respective reference systems is done by qualitative-descriptive classification in different classes. Moreover, geographic differences are evaluated.

4.3.2.3.2 Impact assessment for biomass conversion and use

A separate benefit and risk assessment is performed for biomass conversion and use. This assessment covers the impacts caused by a conversion plant, by the use of bio-based energy carriers and products as well as by transportation of biomass feedstock and interme-

diates. The benefits and risks assessment for conversion, use and transportation investigates potential effects of conversion and use units on the local environment. The aspects human health, soil, flora, fauna and landscape are studied. Effects beyond the local environment (e.g. climate change) are derived from results of LCA.

The potential environmental benefits and risks of the different conversion technologies are derived from the following factors:

1. emissions of noise and odour
2. waste water and waste water treatment
3. amount of traffic caused by potentially different logistics
4. size and height of conversion plants related to the different technologies.

The environmental issues potentially affected by these factors are shown in Table 4-5.

Table 4-5 Technology-related factors, environmental issues and potential environmental impacts of biomass conversion and use

Technology-related factor	Environmental issue	Potential environmental impact
Emission of noise and odours	Human health	Annoyance by an increase of environmental noise or gaseous emissions
Waste water and waste water treatment	Water	Depletion of water resources Nutrient input into water bodies causing eutrophication
Amount of traffic (noise and gaseous emissions)	Human health	Annoyance by an increase of environmental noise or gaseous emissions
Size and height of conversion plants	Soil Flora Fauna Landscape	Soil compaction or soil sealing Loss of vegetation Loss of habitat Landscape disturbance

4.3.2.4 Development of conflict matrices

Aggregated conflict matrices will be created based on the biomass-specific benefits and risks, which summarize the impacts of biomass production, conversion and use on the selected environmental factors.

The following qualitative indicators are used in the conflict matrices to compare the environmental impacts of biomass production, conversion and use to the respective reference systems (relative evaluation):

- “positive”: compared to the reference systems, biomass production, conversion and use is more favourable
- “neutral”: biomass production, conversion and use show approximately the same impacts as the reference system
- “negative”: compared to the reference systems, biomass production, conversion and use is less favourable.

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5 Interim results task 6.3: Methodology for Economic Assessment

Authors:

Basavaraj, G. (ICRISAT); Parthasarathy Rao, P. (ICRISAT); Reddy, Belum V.S. (ICRISAT); Srinivasa Rao, P. (ICRISAT)

This chapter summarises the work done in the Task 6.3 “Economic assessment” – status: November 30, 2011. A detailed task 6.3 description can be found in chapter 1.2.

The work done in this task so far consists mainly of the description of the methodology to be used in the economic assessment as well as its coverage. Both are in the status of “preliminary results” and will be decided upon in April 2012 in Bologna, Italy, on the occasion of the next assembly meeting. Details are listed in the following chapters.

5.1 Introduction

Bioethanol is one part in the increasing use of biofuels. Worldwide, sugar cane is the main source of bioethanol. However, the cultivation of this crop cannot be realized in water-limited or temperate regions. On this background, sweet sorghum has several advantages due to its high water use and nutrient efficiency. Furthermore, the production of food, feed and fuel can be combined in one crop. This is an important asset on the background of the currently increasing discussion on fuel production and food security.

As the more widespread use of sweet sorghum for bio-ethanol production is primarily limited by the lack of varieties specifically bred for this purpose, the SWEETFUEL project aims at developing sweet sorghum breeds for improved varieties and hybrids for temperate, tropical semi-arid and tropical acid soil environments. The focus lies on tolerance to cold, drought and acid soil as well as high production of stalk sugars, easily digestible biomass and grains - depending on the environmental region the crop shall be cultivated in, and the purpose it shall be used for. Accompanying the development of new sweet sorghum breeds, WP 6 “Integrated assessment” of the European Commission funded project “SWEETFUEL: Sweet Sorghum: an alternative energy crop” provides a multi-criteria evaluation of the sweet sorghum production and use pathways taking into account technological, environmental, economic and social aspects. The outcome of the integrated assessment will be a set of optimized, sustainable sweet sorghum production and use systems.

Accompanying the development of new sweet sorghum breeds, the sub-activity “Economic Assessment” under WP 6.3 will assess the life cycle costing of sweet sorghum for different energy pathways under the proposed reference systems in comparison to the conventional systems.

The outcome of the economic assessment will help in determining areas/regions with differing rainfall and soil moisture regimes where sweet sorghum production will have comparative advantage over other traditional systems.

Importance of common settings and definitions

The sustainability assessment for the SWEETFUEL systems is mainly carried out by WP 6(integrated assessment), but to some extent also in WP 5. WP 5 will develop a crop model for sorghum that will be delivered to WP 6 and integrated into the overall assessment. Due to this SWEETFUEL-specific division of sustainability assessment between WP 6 and WP 5, common settings and definitions are essential to ensure consistency of results between WP 6 and WP 5. Furthermore, common settings and definitions are needed to ensure consistency of all assessments within WP 6, as most of the tasks will be using life cycle assessment (LCA) methodology (environmental LCA in task 6.2, life cycle costing in task 6.3, and SWOT analysis in task 6.4). Even though internationally standardized assessment techniques such as life cycle assessment (LCA) will be applied in all three tasks, the degree of freedom they offer in terms of methodological or data choices might lead to incomparable evaluations. As the findings of tasks 6.2 to 6.4 are used by task 6.5 to identify and depict the most sustainable pathways and the most promising optimization potentials, the use of common settings and definitions by tasks 6.2 to 6.4 are an indispensable prerequisite.

The common settings and definitions are also relevant for the whole consortium as the partners responsible for breeding and optimization of productivity traits (WP 1-4) have to deliver mass and energy flow data in compliance with these common settings and definitions. Therefore, the common settings and definitions need the agreement of all partners. Another reason for discussing the settings with the whole consortium is the fact that the general settings will affect the outcomes of the sustainability assessment and hence are of high importance for the whole project.

5.2 Goal and scope questions

The economic assessment of ethanol production from sweet sorghum value chain will answer some of the key questions like:

- Assess the cost of sweet sorghum cultivation across different climatic scenarios (semi-arid, tropical and temperate climates)
- Assess the cost of production of competing crops of sweet sorghum across different climatic scenarios(semi-arid, tropical and temperate climates)
- Assess the comparative advantage of sweet sorghum cultivation for ethanol production by comparing results across semi-arid, tropical and temperate climates vis-a vis its competing crops
- Economic competitiveness of sweet sorghum as a feedstock for different energy pathways under different climatic scenarios in comparison to the reference system

- Assess break-even points to recover the costs incurred in sweet sorghum production and processing
- Influence of different usage pathways for the by-products on the overall economic assessment through sensitivity analysis

5.3 General definitions and Settings

The common definitions and settings as well as the definition and description of sweet sorghum scenarios and respective reference systems with flow charts have been defined in the interim report on technological assessment “Definitions and settings” /Braconnier & Reinhardt et al 2011/ to be assessed in the work package “Integrated assessment”.

These reference systems are cover scenarios for an alternative land use which defines how the land would be used if sweet sorghum was not cultivated. It also comprises any change in land cover induced by the cultivation of sweet sorghum or an alternative land use needs to be taken into account if sweet sorghum is cultivated in areas that become free due to the intensification of existing land use.

5.3.1 Geographical Coverage

As the project aims at developing optimized sweet sorghum genotypes for specific climates, the scenarios are also oriented to these specific climatic regions. The following land uses are regarded as reference systems and accordingly the scenarios are defined as;

- One scenario examines a temperate climate,
- a second scenario covers a subtropical / semi-arid climate with around 700 mm rainfall,
- and a third scenario refers to a tropical climate with around 1,200 mm rainfall per year.

5.3.2 Geographical differentiations

The project aims at developing sweet sorghum genotypes for specific climates viz; temperate, subtropical/semi-arid and tropical climates.

The cultivation practices and cost of production of sweet sorghum vary across specific locations selected to represent these climatic scenarios. However, it is outside the scope of the project to analyse every single location representing these climatic scenarios due to varying production practices, varying data needs, varying costs, limitations in data availability, high costs of data collection and time limitation for analyzing the data. Hence, the economic assessment of cultivation of sweet sorghum and ethanol production will be assessed only for the generic climatic scenarios as defined in the interim report on technological assessment 6.1 (Braconnier & Reinhardt et al 2011). The variations in parameters of cultivation and assessment will be captured through sensitivity analysis.

5.3.3 SWEETFUEL Scenarios

The SWEETFUEL scenarios are presented and described in detail along with the flow charts in the interim report on technological assessment 6.1 (Braconnier& Reinhardt et al 2011). The scenarios described follow the principle of life cycle comparisons. The whole life cycle of a product (e.g. of sweet sorghum ethanol) is assessed-starting from cultivation through production, use, end-of-life treatment, recycling and final disposal (“cradle to grave approach”). All the inputs into and outputs from the system along with their by-products derived are taken into account. At the end, the whole life cycle of the product is compared to the use (and thus to the life cycle) of a conventional product that is replaced. As an example, sweet sorghum ethanol replaces conventional gasoline, thus both life cycles are compared.

The main task of economic assessment (6.3) in WP6 is life cycle costing. The life cycle costing in economic assessment for the SWEETFUEL scenarios defined will be carried out at two different stages. In the first stage, the economic assessment in cultivation of sweet sorghum will be carried out for the SWEETFUEL scenarios across the reference systems defined in the interim report on technological assessment. Additionally, to assess the comparative advantage in cultivation of sweet sorghum and its profitability vis-a-vis its competing crops, assessment will also be carried out for crops (example soybean and cotton in semi-arid tropics) which compete with sweet sorghum for returns to land. In the second stage, economic feasibility assessment for different energy pathways (production of ethanol/biomethane/heat/power/FT diesel from sweet sorghum) will be carried for the defined SWEETFUEL scenarios.

The economic assessment in stage 1 and stage 2 will be integrated to assess the overall lifecycle costing (“cradle to grave approach”) for the SWEETFUEL scenarios and compared to the reference systems/conventional systems (gasoline/diesel/natural gas/heat/power).

5.4 Data and Methodology

5.4.1 Data on sweet sorghum & competing crops production

Concerning the cultivation of sweet sorghum across geographical reference systems, real time data available from farmers’ field on production of sweet sorghum to be compiled under WP 5 across reference systems will be used for analysis (wherever farmers field data are not available, data from experimental/demonstrations fields-will be used for analysis). The data on cultivation aspects of sweet sorghum will include all the production activities starting from land preparation till harvest and transportation of the crop for further processing. Since the cultivations/production practices vary across reference systems, a generic template developed as in case of Interim report on “Interlinkages” (Guido Reinhardt et al 2011) is developed and provided for data compilation across the reference systems both for sweet sorghum and its competing crops. The data sheet can be modified by addition of parameters/variables

based on differences in activities performed, conditions prevailing on wage rates, input prices and differences in values of the indicators/variables across reference systems.

Table 5-1 Data requirement for various activities in sweet sorghum cultivation

Inputs	Activity	Parameter	Quantity & Unit	Price & Wages
Land		Rent paid		$ / ha
Seed	Sowing		Kg / (ha*season)	$ / kg
Fertilizer N	Application		Kg / (ha*season)	$ / kg
Fertilizer P_2O_5	Application		Kg / (ha*season)	$ / kg
Fertilizer K	Application		Kg / (ha*season)	$ / kg
Fertilizer CaO	Application		Kg / (ha*season)	$ / kg
Pesticides[1]	Application		Litres / (ha*season)	$ / litre
Farm yard manure/compost[2]	Application		Quintals / (ha*season)	$ / quintal
Poultry manure[2]	Application		Quintals / (ha*season)	$ / quintal
Tank silt[2]	Application		Quintals / (ha*season)	$ / quintal
Animal penning[2]	Application		Quintals / (ha*season)	$ / quintal
Tractor diesel for	Field preparation		Litres / (ha*season)	$ / litre
	Mechanical weed control		Litres / (ha*season)	$ / litre
	Sowing		Litres / (ha*season)	$ / litre
	Fertilizing		Litres / (ha*season)	$ / litre
	Spraying		Litres / (ha*season)	$ / litre
	Harvesting		Litres / (ha*season)	$ / litre
Tractor hours for	Field preparation		Hours / (ha)	$ / hour
	Mechanical weed control		Hours / (ha)	$ / hour
	Sowing		Hours / (ha)	$ / hour

	Fertilizing		Hours / (ha)	$ / hour
	Spraying		Hours / (ha)	$ / hour
	Harvesting		Hours / (ha)	$ / hour
Irrigation[3]				$ / ha
Bullock labour for[4]	Field preparation		Days/ (ha)	$ / day
	Sowing		Days/ (ha)	$ / day
Human labour for	Land Preparation	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Compost	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Planting & Sowing	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Seed Treatment	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Fertilizer & Micro Nutrient Application	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Interculture	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Weeding & Thinning	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Sprayer	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Watch& Ward	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Irrigation	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Harvesting	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
	Threshing	Male	Days/ha	$ / day
		Female	Days/ha	$ / day
Yield	Grain yield		Quintals / ha	$ / quintal
	Stalk yield		Quintals / ha	$ / quintal

1- Includes insecticides, herbicides, weedicide
2- Mostly applicable for semi-arid conditions where farm yard manure is commonly used.
3- Irrigation costs include diesel/electricity to pump & irrigate the fields with water
4- Mostly applicable for semi-arid where bullock is commonly used for ploughing& sowing

5- Mostly applicable for semi-arid where human labour (both men & women) are commonly used for all agricultural operations

Data for competing crops will be compiled using a similar template as described above for sweet sorghum. All the data computed will be for a specific period /year (this can vary across climatic scenarios depending on local conditions / data availability). In-case of non-availability of data for certain of the parameters, secondary data sources through literature review and discussion with experts in the field will be made use for data compilation.

5.4.2 Data on sweet sorghum processing to end products

The post-harvest data on processing of sweet sorghum for the SWEETFUEL scenarios described (chapter 3 Braconnier& Reinhardt et al 2011) will be complied for entire life cycle costing and economic feasibility assessment. The main objective of the economic feasibility assessment is to examine whether production of end products (ethanol, natural gas, diesel and heat/power) are profitable along the different segments of the entire supply chain of sweet sorghum described in the SWEETFUEL scenarios. There are not many field observations that are readily available for the entire life cycle assessments. This is specifically true for production of 2nd generation ethanol from lignocellulose in case of temperate climates. In the absence of real time data, a number of assumptions & estimates concerning the data and wherever possible data from literature will be made use to perform the life cycle costing assessments. The economic feasibility assessment will be carried out subject to availability of data both from secondary sources and available literature.

Table 5-2 Data requirement for post-harvest processing of sweet sorghum to end products of SWEETFUEL scenarios

Parameters	***Units***
Capital expenditure of processing unit	$
Capacity of the processing unit	kiloliter/to be defined for gas & power
Operating days of the processing unit	Days
Feedstock requirement for the processing unit	Tons/kiloliter/to be defined for gas & power
Landed cost of feedstock	$ / ton
Cost of Finance	
Debt component[2]	%
Term loan interest	%
Working capital interest	%
Depreciation rate	%
Tax rate	%

Repayment years	Years
Processing costs	
Cost of fuel	$/ Kilo liter
Cost of power	$/ Kilo liter
Cost of labor	$/Kilo liter
Cost of chemicals	$/Kilo liter
Operating costs	$/Kilo liter
Operation & maintenance cost	$
General costs	$
General inflation	%
Output	
Output of the end product/Recovery of endproduct	Kilo liter / % per ton
Price of end product	$/Kilo liter / ??
Escalation in sale price of end product	%
Recovery of by-products	
Recovery of Bagasse	Ton/Kilo liter
Co2	Ton/Kilo litre of ethanol
Price of Co2	$/Ton
Vinasse	Ton/Kilo liter
Price of Vinasse	$/Ton
Fusel Oil	Kilo liter
Price of Fusel Oil	$/Kilo liter
Calcium Carbonate	Ton
Surplus bioenergy	??
Price of bioenergy	??

1- The table in not exhaustive for parameters. Additions can be made to the existing fields
2- If the processing unit is financed through loan

5.4.3 Methodology

5.4.3.1 Cost and Returns to sweet sorghum cultivation across geographical references

5.4.3.1.1 Cost Analysis

The data compiled on sweet sorghum cultivation will be analyzed for the total cost of production per hectare per season of sweet sorghum across the geographical reference systems.

The data would include all the paid out costs (example seed costs, fertilizer costs, tractor diesel cost etc. as described in table 1) and imputed costs computed based on the prevailing market rates for labour for the reference period (example family labour in semi-arid tropics is imputed cost).The sum of all costs (labour and materials) per hectare of sweet sorghum cultivation and its competing crops will be computed for the reference system of sweet sorghum cultivation. For economic assessment of sweet sorghum cultivation, only the variable costs (cost A1) incurred in production will be considered for economic computations as these costs vary with the level of output produced. The fixed costs (include fixed capital on land) which are already a sunk cost and do not vary with the level of production will not be considered for economic assessments. This is particularly true in the semi-arid locations. The cost of production thus computed will help to calculate the net returns per hectare of sweet sorghum production. The total cost per hectare in production of sweet sorghum will be further disaggregated across different activities to understand high cost production activities vs. low cost activities in the total cost of production across geographical references.

5.4.3.1.2 Returns analysis

The data collected on yield of main product (sweet sorghum) and its by-products (example grain) will be used to calculate the gross returns to sweet sorghum cultivation per hectare per season at the prevailing prices.

Gross returns /hectare = $Q_s * P_s + Q_g * P_g$

Q_s is the average sweet sorghum stalk yield /hectare

Q_g is the average sweet sorghum grain yield /hectare

P_s is the prevailing price of sweet sorghum stalk ($/ton of stalk)

P_g is the prevailing price of sweet sorghum grain ($/quintal)

The net returns per hectare in cultivation of sweet sorghum will be calculated over variable cost of production.

Net returns per hectare over variable costs of production will be computed as:

Net Returns/hectare = Gross returns/hectare – Total costs/hectare

The net returns per hectare will help in comparing the economic costs and returns in cultivation of sweet sorghum and its profitability.

Similar calculations will be done for competing crops of sweet sorghum across the geographical reference systems. The computations and comparisons will help to assess the profitability of sweet sorghum versus its competing crops which will be a measure of their relative profitability.

5.4.3.1.3 Processing costs of end products

The processing cost and the returns from the end products are classified into different broad headings as capital costs, processing costs, operating costs, cost of financing and recovery of end-product and by-products.

The data compiled (table 2) on processing indicators of sweet sorghum for different end products will be used to calculate the total processing cost for an unit of end product across SWEETFUEL scenarios and the economics of different energy pathways. The total costs will be broken down component wise to understand variations in costing across cost components and SWEETFUEL scenarios.

5.4.3.1.4 Life Cycle costing

The cost of sweet sorghum production in stage 1 and cost of processing in stage 2 will be integrated to arrive at total cost of the entire life cycle for all the different SWEETFUEL scenarios. The economic analysis and the entire life cycle costing across different scenarios will help in determining areas and regions where sweet sorghum has comparative advantage in production of end products of sweet sorghum in comparison to the conventional systems.

5.5 Break-even and Sensitivity analysis

The cost and returns computed above will be used to assess the break-even points (yield, sales and price) to recover the fixed and variable costs of production of end products of sweet sorghum. The break-even analysis will help in determining what should be the minimum levels of yield, recovery and price of sweet sorghum to recover the costs of production and processing across different energy pathways and different geographical references.

5.5.1 Sensitivity analysis

The data collection templates will have actual average values for all indicators. Additionally, a full range of values for the indicators (average minimum and average maximum) would also be included. The range provided will help in performing sensitivity analysis by tweaking the parameters which have a significant role in life cycle costing assessments. Using the average values business as usual scenarios will be developed and sensitivity analysis will be carried out by tweaking the key parameters (with assumptions to be defined at the time of assessment) to develop alternate scenarios. The analysis will help in determining the most effective usage pathways and future opportunities for optimization. Further, sensitivity analysis also will help in determining the optimum level of production and processing parameters required to generate different revenue levels.

5.6 Interlinkages between subtasks

5.6.1 General interlinkages

The general interlinkages between WP5 and WP 6 have been described and presented in the interim report on “interlinkages between WP5 and WP6” /Guido Reinhardt et al 2011/.

5.6.2 Specific inter-linkages between WP 6.3 and WP 5 and data request

The scenarios that are to be investigated under "economic assessment" are described in /chapter 3 Braconnier & Reinhardt et al 2011/.

The specific data requirements of the task "economic assessment" from WP5 are mentioned under the chapter 5.4.1 (Table 5-1 and Table 5-2). Data would be collected for the variables mentioned in Table 1 for the crops such as soy, groundnut, maize and cotton for the reference systems under investigation. A data template in MS-Excel covering data needs of all the crops under different climatic scenarios will be provided for data collection. Apart from the average values to be provided for the variables under study/investigation for different scenarios, additionally a range (maximum, minimum) of values are also to be provided for the variables considered for "economic assessment" investigation. [5]

5.6.3 Interlinkages within WP 6

The data needs of the subtasks within WP6 has been detailed in the report "Interlinkages between WP and WP6" under chapter 5, figure 2-1. Accordingly, the information on the data required from the variables listed will be used wherever necessary.

5.6.4 Data request from WP 6.3 for WP 5

The interlinkages and the specific data request for the task WP 5 from 6.3 are to be identified and are to be requested for the specific data needs.

[5] Note: The details listed are a first draft version for further agreements. So far, no details of interlinkages between task 6.3 and WP 5 have been agreed upon. This will be done at the next assembly meeting in Bologna, 2012.

6 Interim results task 6.4: SWOT Analysis

Authors:

Janssen, Rainer (WIP); Rutz, Dominik (WIP)

This chapter summarises the work done in the Task 6.4 “SWOT analysis” – status: November 30, 2011. A detailed description of task 6.4 covering strengths, weaknesses, opportunities and threats (SWOT) can be found in chapter 1.2.

The work done in this task so far consists mainly of the description of the methodology to be used in the SWOT analysis and a concept for reporting. The latter is already integrated in the structure of the subchapters of this chapter. Both the methodology and the concept of reporting are in the status of “preliminary results” and will be decided upon in April 2012 in Bologna, Italy, on the occasion of the next assembly meeting. Details are listed in the following chapters.

6.1 Introduction

The energy crop sweet sorghum (Sorghum bicolor L. Moench) is raising considerable interest as a source of either fermentable free sugars or lignocellulosic feedstock with the potential to produce fuel, food, feed and a variety of other products. Sweet sorghum is a C4 plant with many potential advantages, including high water, nitrogen and radiation use efficiency, broad agro-ecological adaptation as well as a rich genetic diversity for useful traits. For developing countries sweet sorghum provides opportunities for the simultaneous production of food and bioenergy (e.g. bio-ethanol), thereby contributing to improved food security as well as increased access to affordable and renewable energy sources. In temperate regions (e.g. in Europe) sweet sorghum is seen as promising crop for the production of raw material for 2nd generation bio-ethanol.

The project SWEETFUEL (Sweet Sorghum: An alternative energy crop) is supported by the European Commission in the 7th Framework Programme to exploit the advantages of sweet sorghum as potential energy crop for bio-ethanol production. Thereby, the main objective of SWEETFUEL is to optimize yields in temperate and semi-arid regions by genetic enhancement and the improvement of cultural and harvest practices.

In order to get an overview of advantages and disadvantages of different sweet sorghum value chains a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted in the framework of the project. Thereby, the analysis investigated several sweet sorghum value chains under different framework conditions subtropical, tropical and temperate climate. The value chains include the cultivation of sweet sorghum, conversion to different products and end use of the products. More details on sweet sorghum value chains

and on scenarios for the sweet sorghum products are described in the report “Handout for the Workshop on Definitions and Settings” (Braconnier et al. 2011).

6.2 Method

6.2.1 The SWOT analysis

A SWOT analysis is a strategic planning tool used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or business venture. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favourable and unfavourable to achieving that objective.

In this report the SWOT analysis is applied to different value chain systems of sweet sorghum as an energy crop. Factors which are internal to the sweet sorghum pathways are classified as Strengths (S) or Weaknesses (W), and those external to the sweet sorghum pathways (in comparison to other crops, markets, fossil fuels) are classified as Opportunities (O) or Threats (T). The SWOT matrix is shown below.

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	**Strengths**	**Weaknesses**
External	**Opportunities**	**Threats**

6.2.2 Objective of the analysis

The objective of the SWEETFUEL sustainability analysis is to identify the best pathways to produce and use sweet sorghum as energy crop from an ecological, economic and social point of view.

The SWOT analysis is a tool to contribute to this objective. Results of the SWOT analysis shall help in decision making processes for improved sweet sorghum value chains in different climates and framework conditions in order to:

- ensure competitiveness/complementary with other energy (bioethanol) crops
- ensure competitiveness with fossil based energy/products
- guarantee environmental, social and economic sustainability

The SWOT analysis describes the state-of-the-art of sweet sorghum chains in order to formulate optimisation strategies for sweet sorghum production and use pathways. Also potential future developments are considered and integrated in the SWOT analysis. Thereby, the timeframe includes the years 2014 (the real situation at the end of the SWEETFUEL project) and 2020 (expected future based on conservative assumptions).

6.2.3 Structure of the SWOT analysis

Sweet sorghum is a promising energy crop for different climates able to provide a large variety of products and services, such as energy, food, fodder, and fibre. This is the result of the large genetic variability of the Sorghum family leading to a wealth of different genotypic and phenotypic traits of sweet sorghum varieties. Therefore, strengths, weaknesses, opportunities and threats are also very diverse among sweet sorghum varieties and different value chains in productions systems.

However, several characteristics are common to sweet sorghum as an energy crop and thus, in a first step (chapter 6.3), the SWEETFUEL SWOT analysis describes general strengths, weaknesses, opportunities and threats of sweet sorghum.

In a second step, SWOT analyses are elaborated for different production systems in subtropical/tropical (chapter 6.4) and temperate climate zones (chapter 6.5). These production systems include centralized ethanol, decentralized syrup and decentralized ethanol systems in subtropical/tropical climate as well as biogas, lignocellulose-ethanol, direct combustion and gasification systems in temperate climate. For each of these systems a two SWOT tables are shown: one for the sweet sorghum cultivation and one for sweet sorghum conversion to end products. Thereby, end products may include energy carriers (e.g. biogas), energy (e.g. electricity), fertilizer (e.g. digestate), food (e.g. grains), fodder (e.g. leaves) and other co-products. The use of energy carriers for different purposes is included in the SWOT table.

In summary, the following analyses are made and described in dedicated chapters:

- General SWOT for sweet sorghum
- Subtropical and tropical climate
    - Centralised production system (cultivation and conversion)
    - Decentralised syrup production system (cultivation and conversion)
    - Decentralised ethanol production system (cultivation and conversion)
- Temperate climate
    - Biogas production system (cultivation and conversion)
    - Lignocellulose-ethanol production system (cultivation and conversion)
    - Direct combustion system (cultivation and conversion)
    - Gasification system (cultivation and conversion)

The SWOT tables are providing brief statements (in bullet form) on the strengths, weaknesses, opportunities and threats of the production systems. These tables shall allow a quick overview about advantages and disadvantages of each production system. In addition to the tables, detailed descriptions of the statements are presented.

The SWOT statements address a large variety of environmental, social and economic sustainability aspects. Depending on the value chain, these statements may include the following sustainability aspects.

a) Land use

- Land use and land use change
- Competitive land use
- Land use conflicts

b) Social aspects

- Benefits for smallholders
- Income opportunities
- Employment opportunities
- Change in traditional use and knowledge
- Local/modern energy supply
- Gender aspects
- Working conditions
- Health
- Food security
- Food and feed prices

c) Environment

- GHG emissions
- Pollutant emissions
- Biodiversity
- Soil conservation and soil quality
- Water availability, use and efficiency
- Water quality
- Concentrated environmental disasters (oil spill)

d) Economics

- Productivity and processing efficiency
- Net energy balance
- National revenues, gross value added
- Energy security (security of supply)
- Infrastructure and logistics
- State of commercialization / competitiveness with reference products

Finally, a core focus is placed on the competition between the biomass uses for food, feed, fibres, and biofuels and on different scales of sweet sorghum production and use. Furthermore, **policy aspects** such as different policy framework conditions in target countries as well as issues of **social acceptance and public perception** will be taken into account.

6.3 Sweet sorghum as energy crop: general analysis

6.3.1 Description of the general sweet sorghum value chain

The general value chain of sweet sorghum production systems is similar to other bio-energy/biomass production systems. General value chain steps include:

- Crop cultivation
- Harvesting
- Transport
- Milling (1st process step)
- Processing (2nd process step)
- Transport
- End use

A schematic overview of general sweet sorghum production and use pathways is shown in Fig. 6-1. The life cycle of sweet sorghum includes cultivation, production, use, as well as end-of-life treatment, recycling and final disposal (“cradle-to-grave approach”). All inputs into and outputs from the system are taken into account including the several by-products obtained.

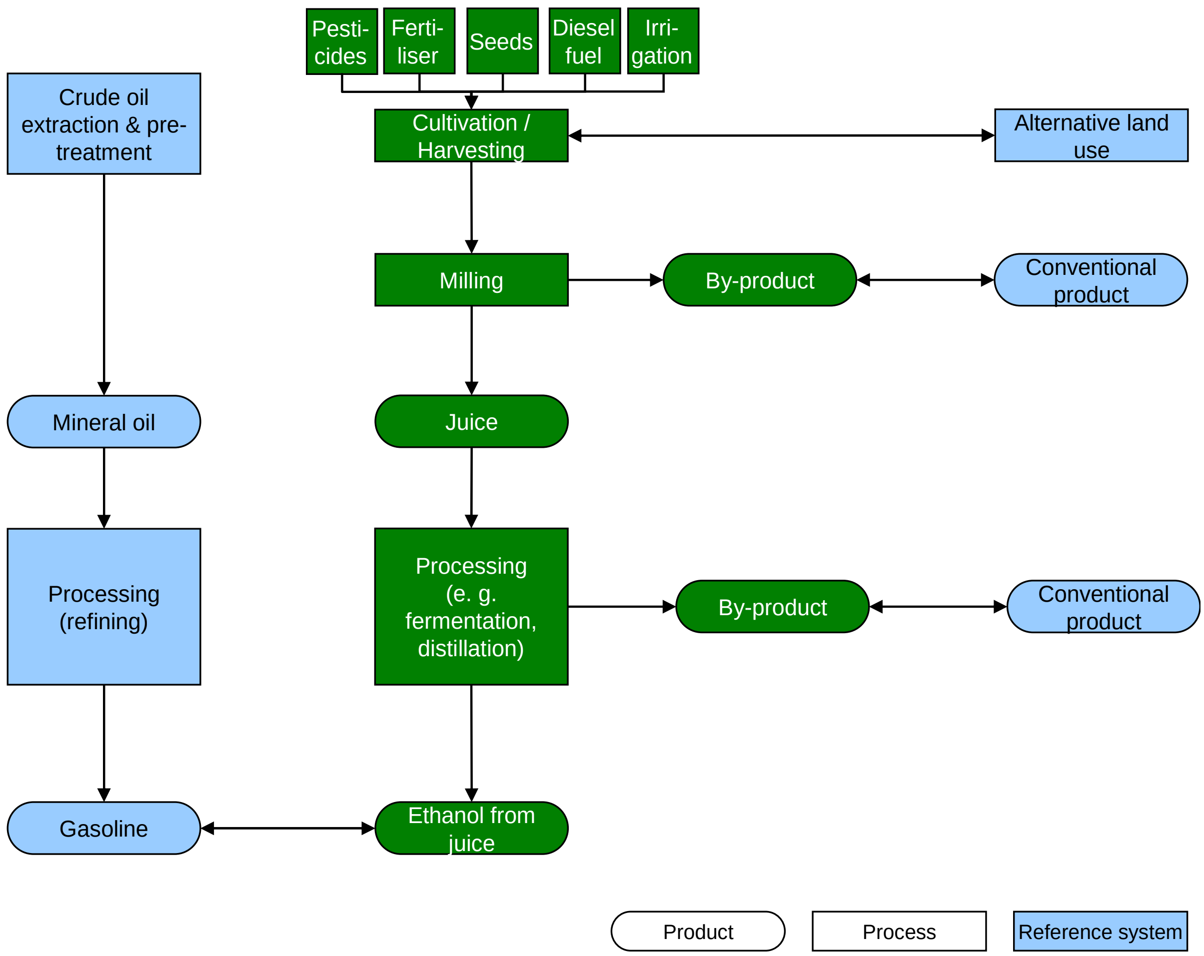

Fig. 6-1 Basic principle of life cycle comparison between sweet sorghum ethanol and gasoline (Braconnier et al. 2011)

6.3.2 SWOT for sweet sorghum as energy crop

This chapter presents a SWOT analysis for sweet sorghum as an energy crop describing general strengths, weaknesses, opportunities and threats of sweet sorghum. Thereby, specific reference is made to comparisons with other energy (bioethanol) crops as well as with fossil based energy/products.

	Helpful to achieve the objective	Harmful to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4 Sweet sorghum in subtropical and tropical climate

6.4.1 Centralized ethanol production system

This chapter presents a SWOT analysis for centralized ethanol (and cooking gelfuel) production from sweet sorghum for semi-arid tropical climates. Merely the cultivation and harvesting of sweet sorghum is performed at village level. After harvest, the sweet sorghum stalks are transported from the villages to centralized ethanol facilities. A schematic overview of the centralized production system is presented in Fig. 6-2.

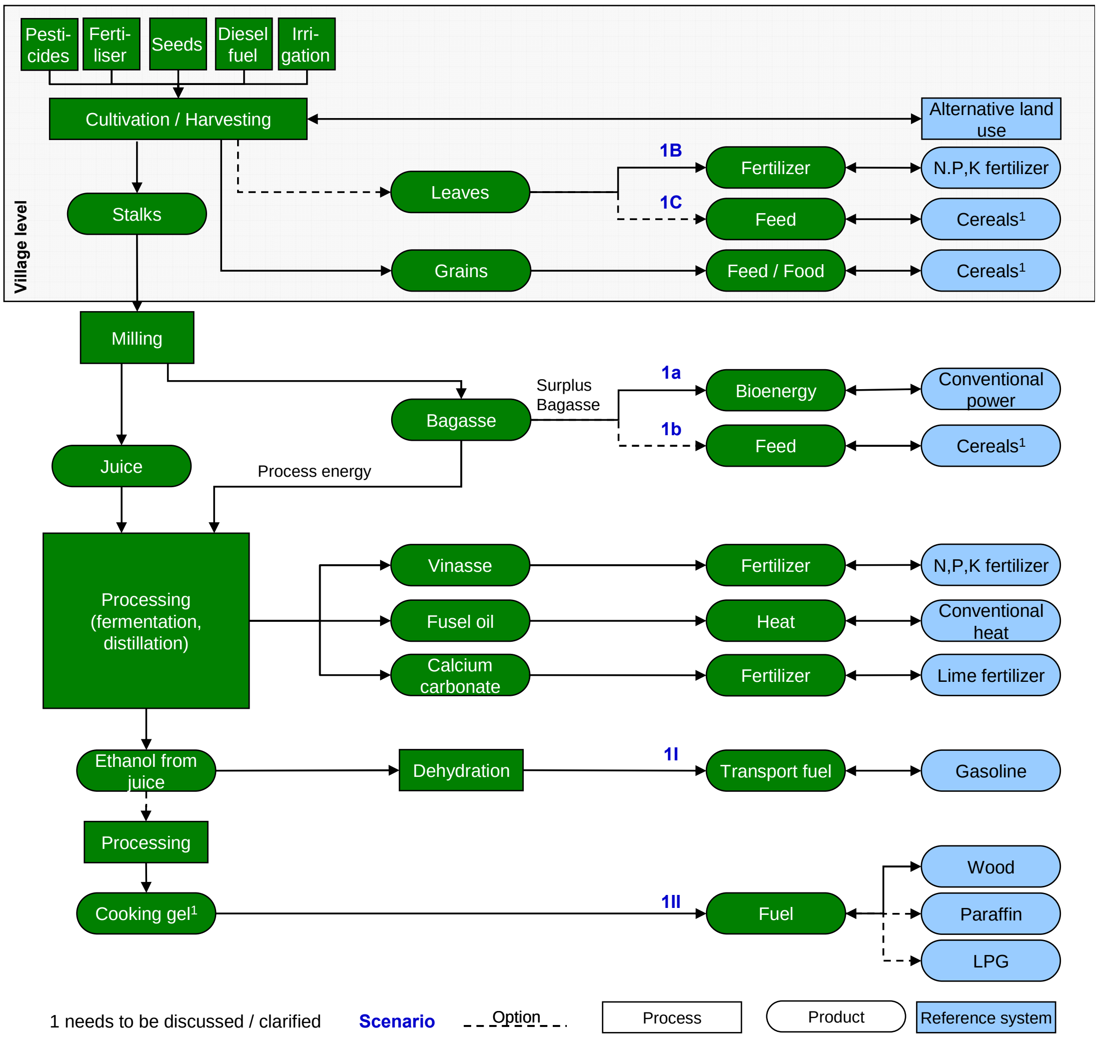

Fig. 6-2 Centralized ethanol production system (Braconnier et al. 2011)

6.4.1.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4.1.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4.2 Decentralized syrup production system

This chapter presents a SWOT analysis for a partially decentralized ethanol (and cooking gelfuel) production from sweet sorghum for tropical climates. In addition to the cultivation and harvesting of sweet sorghum, also the production of syrup from sweet sorghum juice is performed at village level. The syrup is then transported from the villages to centralized ethanol facilities. This system holds advantages if the infrastructure for biomass transportation to large centralized production units is insufficient or not existent and it provides enhanced value creation at village level. A schematic overview of the decentralized syrup production system is presented in Fig. 6-3.

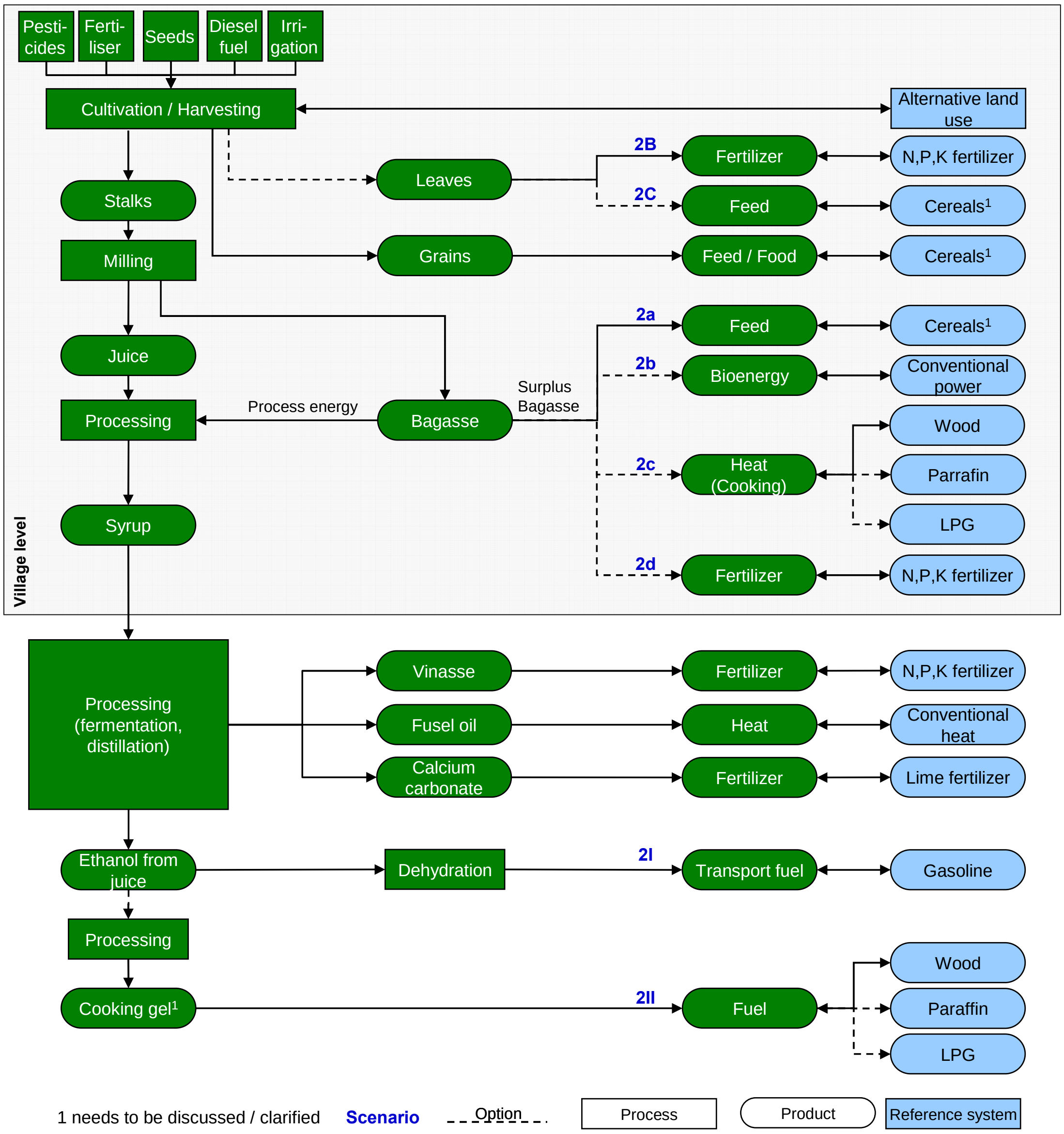

Fig. 6-3 Decentralized syrup productionsystem (Braconnier et al. 2011)

6.4.2.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4.2.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4.3 Decentralised ethanol production system

This chapter presents a SWOT analysis for decentralized ethanol production systems from sweet sorghum in subtropical/ tropical climates. In this system, the whole production chain is realized at village level, namely the cultivation and harvesting of sweet sorghum, the milling of the stalks to produce juice, and the processing of the juice into ethanol. Thereby, this system provides maximum value creation and benefit at village level. A schematic overview of the decentralised ethanol production system is presented in Fig. 6-4.

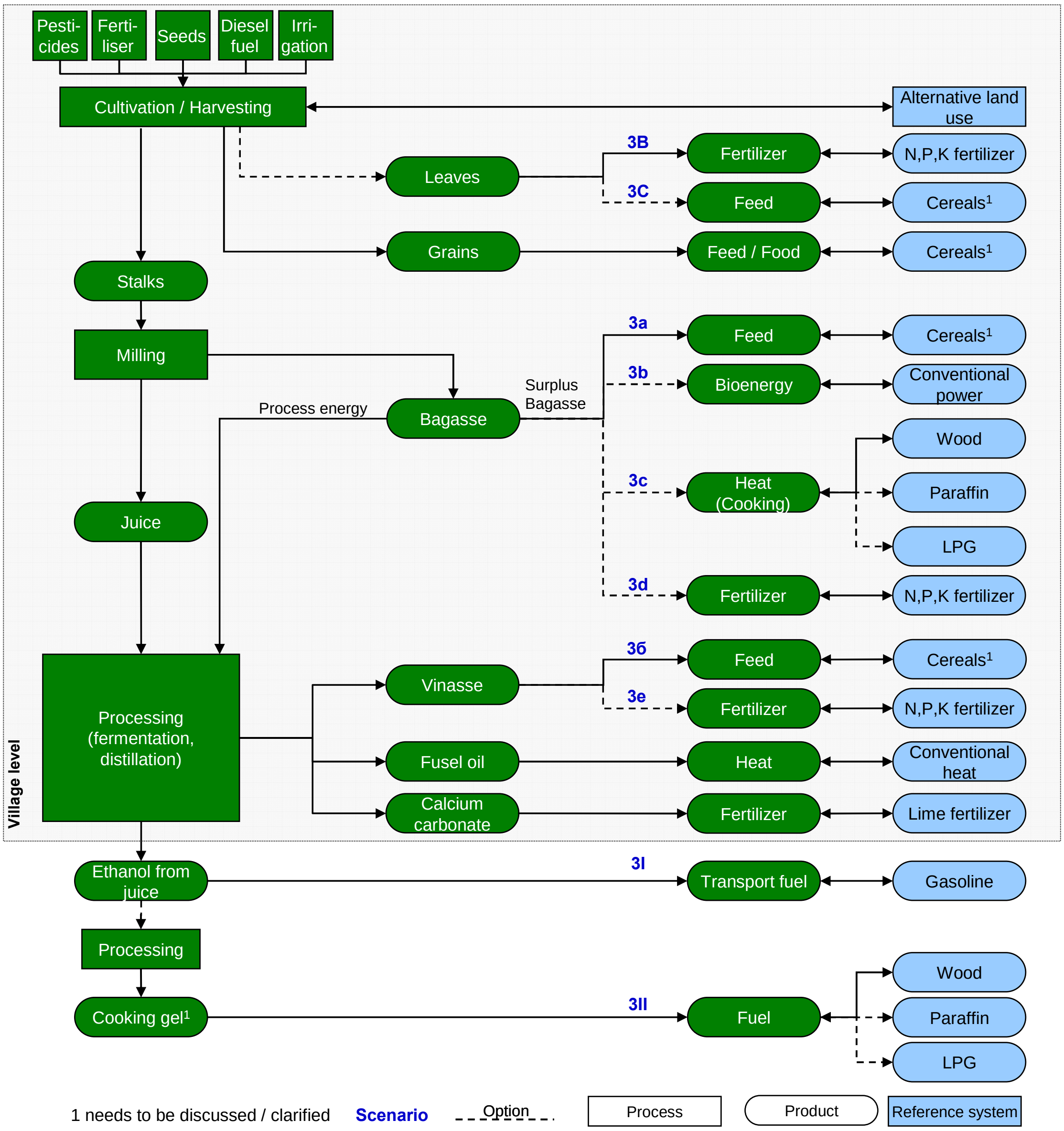

Fig. 6-4 Decentralized ethanol productionsystem (Braconnier et al. 2011)

6.4.3.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.4.3.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5 Sweet sorghum in temperate climate

6.5.1 Biogas production system

This chapter presents a SWOT analysis for the use of sweet sorghum for biogas production in temperate zones. For the biogas production, the sweet sorghum biomass is crushed after

harvest. The biogas is used for heat and power production replacing conventionally produced heat and power. Alternatively, the biogas can be further processed into biomethane and used for heat and power production (replacing conventional heat and power) or as transport fuel replacing conventional gasoline and natural gas. In all processes, digestate is produced as by-product. It is used as fertilizer replacing mineral fertilizer.

A schematic overview of the biogas production system is presented in Fig. 6-5.

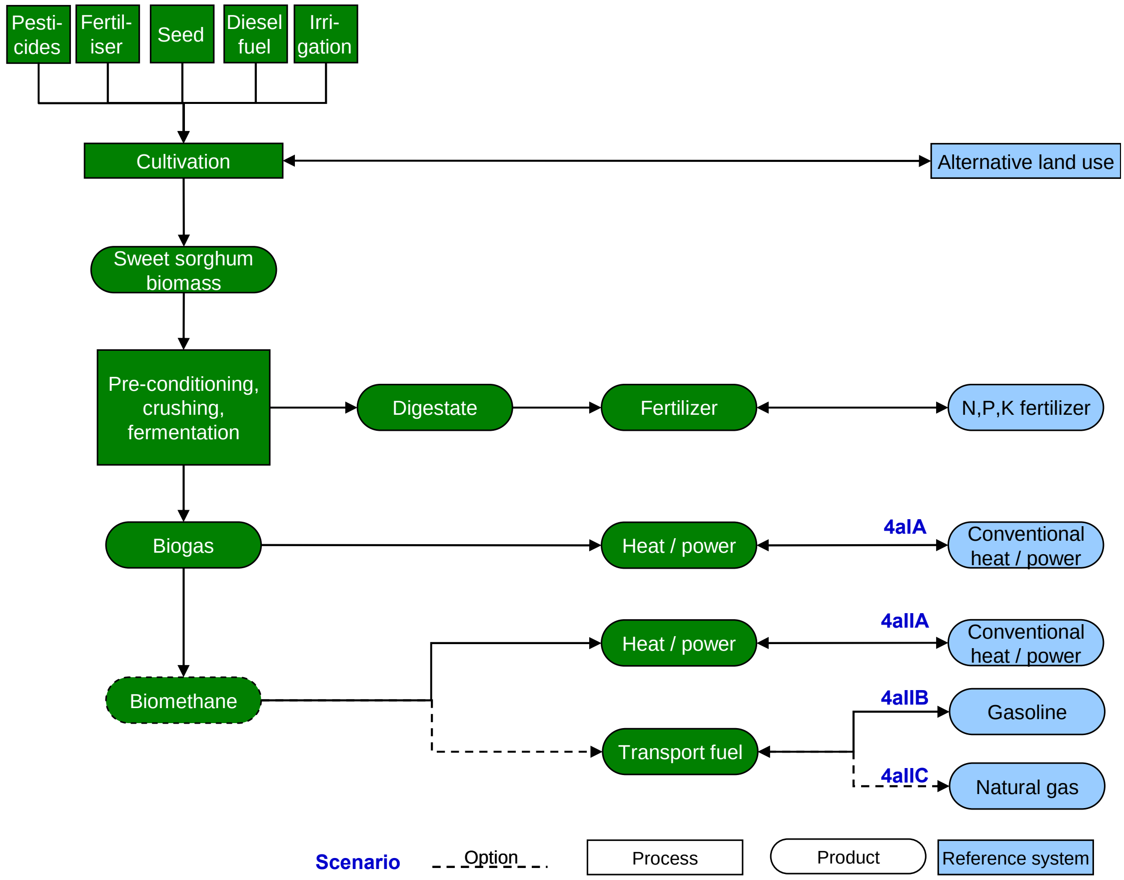

Fig. 6-5 Biogas production system(Braconnier et al. 2011)

6.5.1.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.1.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.2 Lignocellulose-ethanol production system

This chapter presents a SWOT analysis for the use of sweet sorghum for lignocellulose-ethanol production in temperate climates.

In this system the biomass is crushed and pre-treated in order to render the cellulose accessible for a subsequent hydrolysis step. After the hydrolysis of the cellulose for braking

down the long chains into sugars, the substrate is fermented. The ethanol is used as transport fuel replacing conventional gasoline.

Vinasse is obtained as by-product and either used as feed replacing soy meal or as fertilizer replacing mineral fertilizer. If there is surplus bioenergy from the process, it is fed into the grid and replaces conventional power production.

A schematic overview of the lignocellulose-ethanol production system is presented in Fig. 6-6.

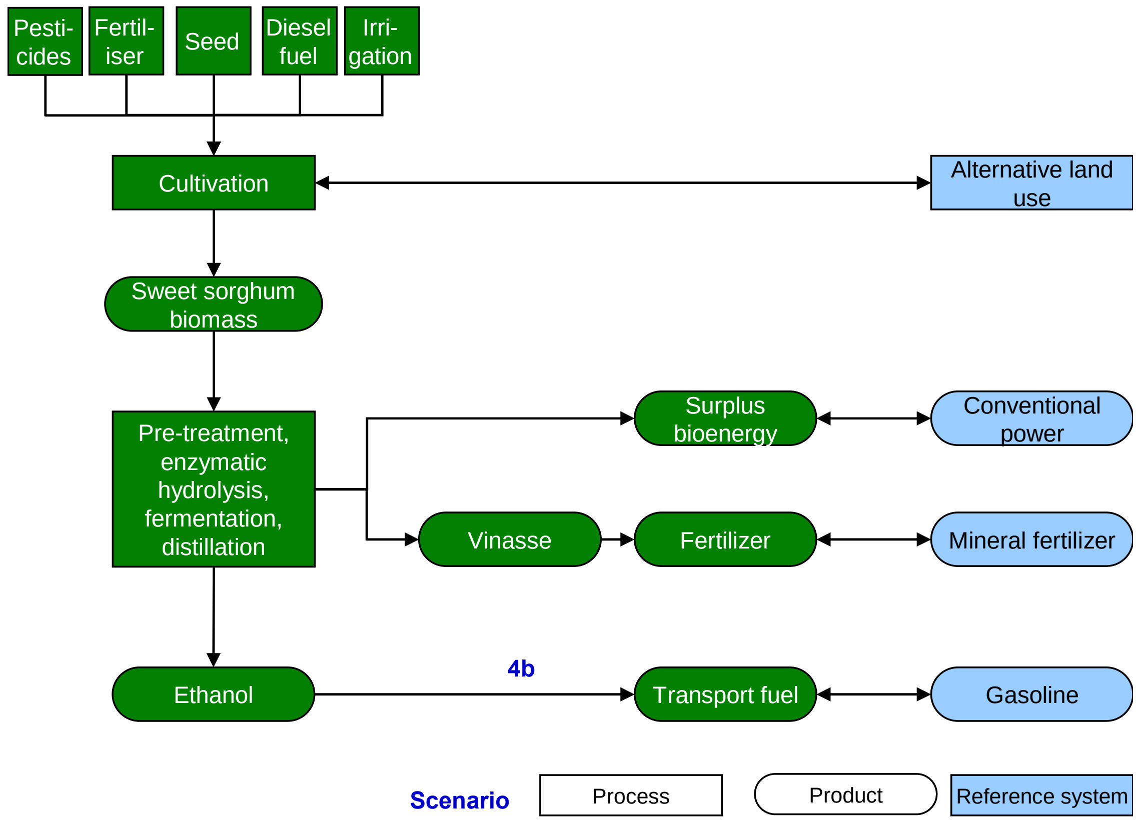

Fig. 6-6 Second generation ethanol production from sweet sorghum lignocellulose for temperate climates (Braconnier et al. 2011)

6.5.2.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.2.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.3 Direct combustion system

This chapter presents a SWOT analysis for the use of sweet sorghum for direct combustion in temperate climates.

Due to the high water content of the crop, before combustion the biomass has to remain on the fields for several days for drying. Through combustion, heat and power are produced that

replace conventionally produced heat and power. The only by-product is ash which has to be disposed in landfills.

A schematic overview of the direct combustion system is presented in Fig. 6-7.

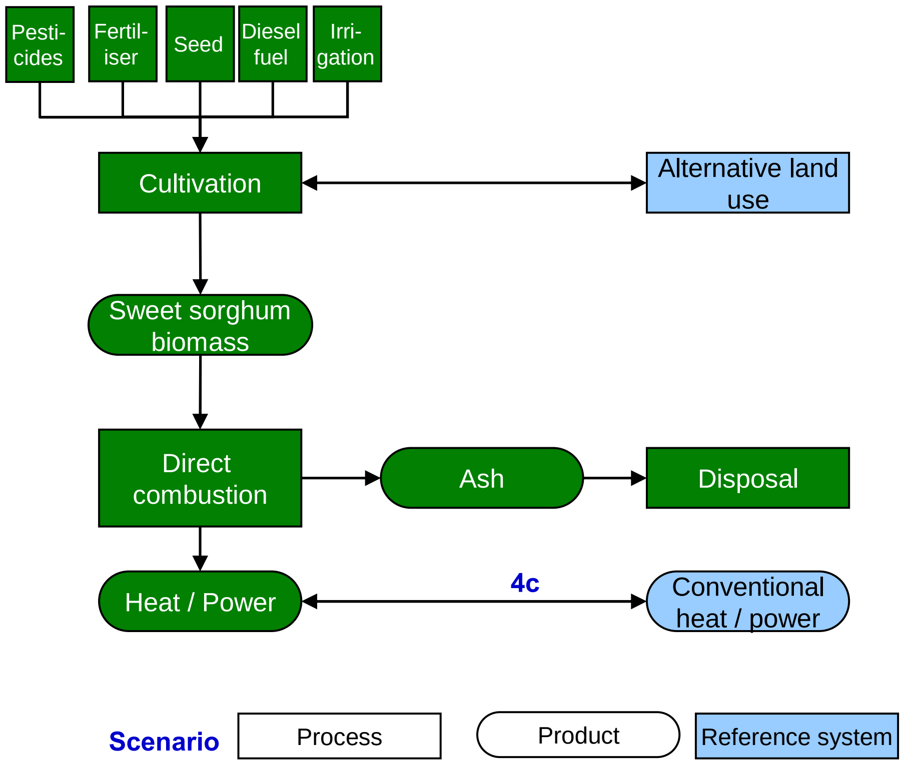

Fig. 6-7 Direct combustion system (Braconnier et al. 2011)

6.5.3.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.3.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.4 Gasification system

This chapter presents a SWOT analysis for the use of sweet sorghum for gasification in temperate climates. Thereby, two options exist namely direct gasification of the biomass feedstock and production of intermediate energy carriers (e.g. through pyrolysis and torrefaction) prior to gasification.

For both options, the biomass needs to be dried as a pre-treatment. Direct biomass gasification can only be realized in large scale centralized units. Here, waste heat can be used for biomass drying. Torrefaction or pyrolysis of biomass is often used in decentralized systems for making biomass transportable. In this case, external energy would be necessary for biomass drying.

As a next step, the biomass, the pyrolysis oil or the torrefied biomass are gasified into a synthesis gas (mixture of hydrogen and carbon monoxide). After cleaning the gas, it is synthesized into the so-called BtL (biomass-to-liquid) fuels. The standard synthesis is the

Fischer-Tropsch synthesis where biodiesel is produced as main product. Naphtha is obtained as by-product which replaces fossil naphtha. If there is surplus bioenergy from the process, it is fed into the grid and replaces conventional energy.

A schematic overview of the gasification system is presented in Fig. 6-8.

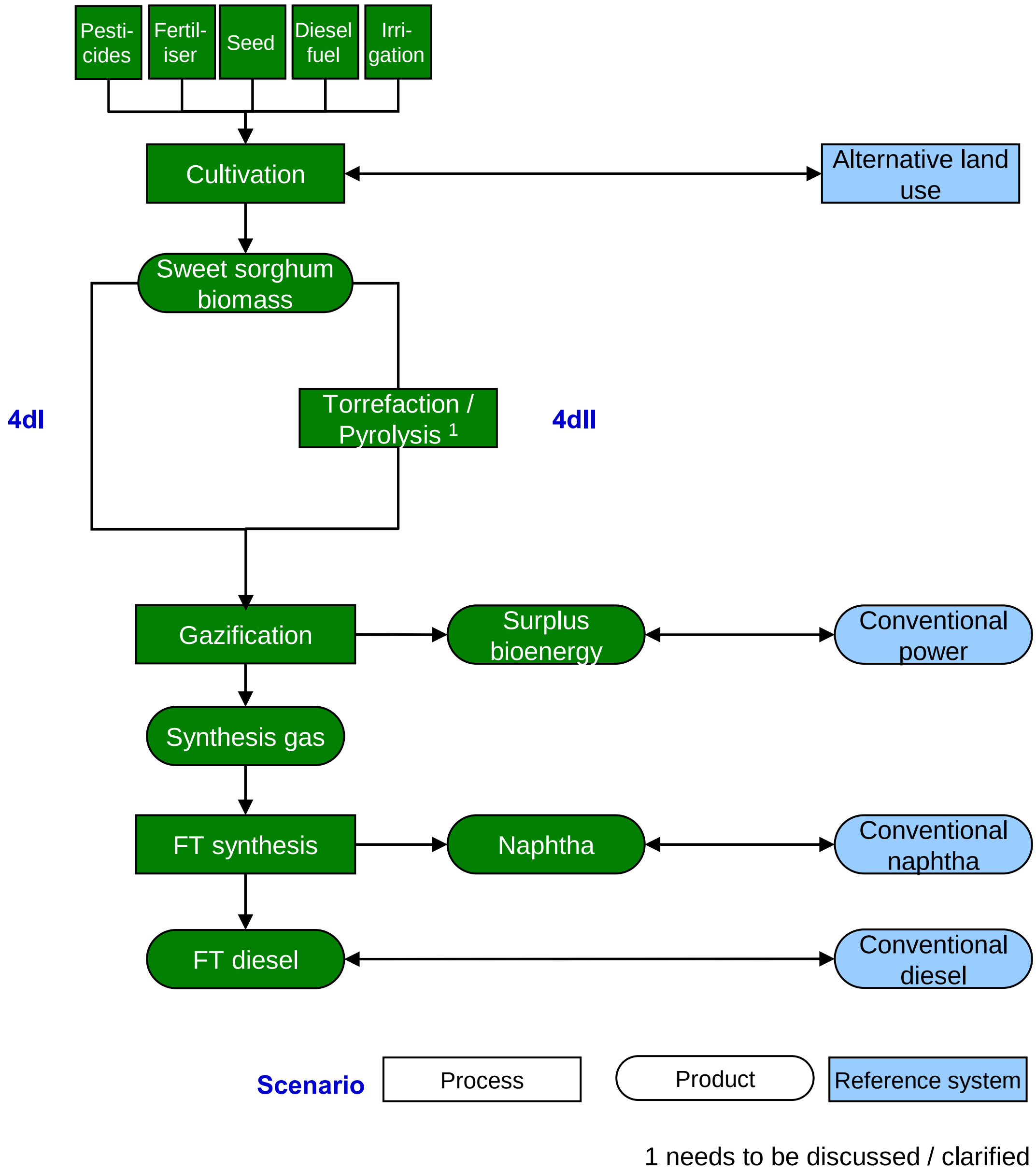

Fig. 6-8 Gasification system (Braconnier et al. 2011)

6.5.4.1 SWOT for sweet sorghum cultivation

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx

External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.5.4.2 SWOT for sweet sorghum conversion to end use products

	Favourable to achieve the objective	Unfavourable to achieve the objective
Internal	S-1 Xx S-2 Xx S-3 Xx S-4 Xx	W-1 Xx W-2 Xx W-3 Xx W-4 Xx
External	O-1 Xx O-2 Xx O-3 Xx O-4 Xx	T-1 Xx T-2 Xx T-3 Xx T-4 Xx

S-1: Description of Strength 1

S-2: Description of Strength 2

W-1: Description of Weakness 1

W-2: Description of Weakness 2

O-1: Description of Opportunity 1

O-2: Description of Opportunity 2

T-1: Description of Threat 1

T-2: Description of Threat 2

6.6 Conclusion

Will follow

6.7 References

/Braconnier et al. 2011/: Braconnier S., Reinhardt G., Köppen S., Rettenmaier N., Detzel A., Amaducci S., Avelino J., Basavaraj G., Bursztyn M., Garcia-Zambrano E.A., Gutierrez-Diez A., Janssen R., Magalhaes J., Monti A., Parrella R., Parthasarathy Rao P., Purcino A.A.C., Reddy B.V.S., Rodrigues J.A., Rutz D., Schaffert R., Simeone M.L.F., Srinivasa Rao P., Trevino-Ramirez J.E., Zacharias A., Zavala-Garcia F., Zegada-Lizarazu W. (2011): SWEETFUEL: Sweet Sorghum – an alternative energy crop. WP 6, Task 6.1, Interim report on technological assessment: “Definitions and settings”, 8 August 2011

6.8 Annex: Schedule of SWOT analysis

The following schedule for the implementation of the SWOT analysis is proposed, indicating activities, responsible partners and a tentative timing.

Table 6-1

Activity	Responsible Partner(s)	Timing
Methodology for SWOT analysis	WIP	22 Nov. 2011
First draft of SWOT analysis for selected scenarios	WIP	16 Dec. 2011
Contributions of partners to selected thematic fields of SWOT analysis.	CIRAD, IFEU (all fields)	18Jan. 2012
[Partners are invited to contribute to all selected thematic fields, however the fields specified indicated important involvement]	ICRISAT, EMBRAPA, KWS, UNIBO (cultivation, conversion, end use)	
	UCSC, ARC, UANL (policy, social acceptance)	
Refinement of SWOT analysis for selected scenarios	WIP	February 2012
Stakeholder workshop in conjunction with the next SWEETFUEL project meeting in Bologna	Workshop organised by WIP	February/March 2012

Discussion and refinement of SWOT analysis	Participation of all partners	
Revision of SWOT analysis based on outcome of workshop in Bologna	WIP	April 2012
Discussion of SWOT analysis with external stakeholders (trade unions, NGOs, associations, other stakeholders); e.g. bi-lateral meetings, email distribution	WIP, external stakeholders	May/June 2012
Revision of SWOT analysis based on input of external stakeholders for agreement by all partners	WIP	July 2012
Final SWOT analysis	WIP	September 2012