Project Number	241535
Project Acronym	Star-COLIBRI
Project Title	Strategic Targets for 2020 – Collaboration initiative on Biorefineries
Call Identifier	FP7-2009-BIOREFINERY_CSA
Grant agreement for	Coordination and support actions (Coordinating)

WORK PACKAGE 3: Analysis of synergies, complementarities and gaps

Deliverable 3.7: Sustainability aspects within StarClusters

Due date of delivery:	30/04/2011
Actual transmission date:	07/06/2011
Start date of project:	01/11/2009
Duration:	24 months

Lead beneficiary for this deliverable Deutsches BiomasseForschungsZentrum (DBFZ)

Authors
Anastasios Perimenis (DBFZ)
Kati Koponen, Reetta Sorsa, Sampo Soimakallio (VTT)
Jasmiina Laurmaa (EuropaBio)

Dissemination level		
Public	PU	X
Restricted to other programme participants (including Commission Services)	PP	
Restricted to a group specified by the consortium (including the Commission Services)	PE	
Confidential, only for members of the consortium (including the Commission Services)	CO	

Coordinator **Johan Elvnert**
European Cofederation of Woodworking industries
Rue Montoyer 24
Be-1000 Brussels

Contact **Deutsches BiomasseForschungsZentrum**
gemeinnützige GmbH
Torgauer Straße 116
04347 Leipzig

Tel.: +49-341-2434-112
Fax: +49-341-2434-133
E-Mail: info@dbfz.de
Internet: www.dbfz.de

Anastasios Perimenis
Tel.: +49-341-2434-447
E-Mail: anastasios.perimenis@dbfz.de

Date: 07.06.2011
Project number DBFZ: 3540002

Content

Abbreviations

Abbreviation	Description
EEA	European Environment Agency
EPD	Environmental Product Declaration
EU	European Union
GHG	Greenhouse Gas
IGCC	Integrated Gasification Combined Cycle
iLUC	indirect Land Use Change
IPP	Integrated Product Policy
IPR	Intellectual Property Rights
LCA	Life Cycle Assessment
NDA	Non-Disclosure Agreement
PAH	Polycyclic Aromatic Hydrocarbons
PCR	Product Category Rules
RED	Renewable Energy Directive
SCP	Sustainable Consumption and Production
SIP	Sustainable Industrial Policy
SLU	Swedish University of Agricultural Sciences
UM	University of Madrid
USL	University of Salerno
VOC	Volatile Organic Compounds
WC	Wolfson Centre for Bulk Solids Handling Technology

Introduction

1.1 Background

The aspect of sustainability is a crucial factor of biomass production and use, subsequently also for the biorefinery concept. In Star-COLIBRI, this importance is highlighted through task 3.6 (Deliverable 3.6 - “Best practices in sustainability assessment”) and task 3.7 (Deliverable 3.7 - “Sustainability aspects within StarClusters”). Task 3.6 provided a comprehensive discussion of sustainability assessment, the pillars that need to be examined and the implementation of life cycle approaches for sustainability assessment in the case of biorefineries. As a natural continuation, task 3.7 examines the issues in 3.6 in the context of the clusters formed, with the purpose of promoting co-operation between projects within a cluster and ultimately between clusters.

1.2 Goal of task 3.7 within Star-COLIBRI

1.2.1 Initial goal

Initially, the primary goal of task 3.7 was to analyse the sustainability aspects within the *Star Clusters* formed (henceforth referred to as **clusters**). A cluster would be formed around a central project, the *Star Project* (henceforth referred to as **star**) with smaller *Comet Projects* (henceforth referred to as **comets**) complementing it and offering additional competences.

The analysis would consist, at a first stage, of a review of whether and how the stars deal with and assess issues of sustainability within their own projects, at an individual basis. Since the stars are the cores of the clusters, it was decided to place them in the centre of the sustainability discussion of the cluster they belong to. At a second stage, the comets would follow and a review of whether and how they deal with sustainability aspects would take place, again at an individual basis. At a third stage, a cluster analysis (i.e., beyond the individual basis) would take place, by identifying similarities and differences of the sustainability considerations of the stars and comets that belong to the same cluster. This analysis would point out whether the projects within a cluster use same or similar methodologies, definitions and tools concerning sustainability issues and sustainability assessment. This would give the opportunity to bring them together, promote co-operation and exchange of knowledge to achieve consistency and harmonisation of approaches. In that effort, Deliverable 3.6 would be used as the basis for the analysis. Co-operation on that respect could have different forms, for example:

- The star conducts indeed a full life cycle sustainability assessment and sets the example for a comet that focuses on the technical development of a specific technology and for that reason does not dedicate many resources to sustainability assessment, but would like to.
- A comet brings specific competence on the social dimension of biorefineries, which is the pillar of sustainability that is the least examined within the entire cluster.
- Star and comets have different views on the importance of sustainability for their purposes; through this co-operation procedure they could achieve a minimum consensus that would conform to the European policy framework that deals with sustainability.
- A comet has a strong local character (e.g. field trials from cultivation of poplar) and could share its database and inventory information, which would reinforce the regional character of the, otherwise more generic, Life Cycle Assessment (LCA) conducted within the star.

Those examples simply point out the possibilities of cooperation among projects within a cluster. As a fourth stage, there would be an attempt to examine the possibilities of co-operation between different clusters.

The entire analysis would be conducted on the basis of the current policy framework on sustainability, in order to examine whether the approaches within the cluster (and of the projects constituting it) conform to it, what are the reasons if this is not the case, what kind of problems are encountered by the clusters and what kind of actions would be needed in that case. Thereby, potential areas where the policy framework leaves open questions or that are challenging in terms of interpretation and need to be reconsidered could be determined.

The exact outcome of such a cluster analysis would largely depend on the level of involvement of the projects in sustainability issues, their willingness to co-operate and exchange information on methodologies and their dedication to the clustering procedure.

1.2.2 Adapted goal

The initial goal as described above is almost entirely dependent on the formation and the actual existence of a cluster. The clustering procedure (described in Deliverable 4.3 “Guidelines on the best practice of establishing and managing a Star Cluster”) has resulted in the realisation that no cluster in the form that was initially planned could be formed (i.e., comets that, through their projects, would bring additional competences to complement the star). Subsequently, the initial goal of this deliverable had to be adapted. A detailed description explaining the barriers encountered during the clustering procedure will be provided in Deliverable 4.3. Briefly, those barriers include issues like conflicts on Intellectual Property Rights (IPR), need for Non-Disclosure Agreements (NDA) between all parties involved, need for additional resources that could be dedicated to co-operation, lack of suitable comets and others.

From the initial attempt to create four clusters around the identified stars (i.e., EuroBioRef, Biocore, Afore, Bio4Energy), only the case of Bio4Energy showed potential for the formation of a co-operation opportunity. Nevertheless, this does not have the form of a cluster as was initially planned within Star-COLIBRI (i.e., involving projects). It is simply a form of co-operation between four institutes that share a common interest in one specific topic. In this case, the topic of interest is **biomass handling at the facility** (i.e., after the gate) and the institutes involved are

- The Swedish University of Agricultural Sciences (SLU), *member of the Bio4Energy consortium*
- The University of Salerno (USL)
- The University of Madrid (UM)
- The Wolfson Centre for Bulk Solids Handling Technology (WC)

To maintain a link with the initial task of analysing sustainability aspects within a cluster, Task 3.7 is adapted to give focus only on **this specific part** of the entire biorefinery chain by highlighting and discussing sustainability issues (i.e., environmental, economic and social considerations) of biomass handling. The institutes involved are more oriented in the technical aspects of biomass handling and the discussion here helps to extend the focus also towards sustainability issues. No sustainability assessment of this part of the chain will be conducted, rather than a discussion of sustainability issues. There are no projects behind this co-operation that could be analysed in terms of their involvement in the area of sustainability assessment, which is why Deliverable 3.6 can not be used as a basis anymore (contrary to what was initially planned).

The second goal concerning the examination of the policy framework related to sustainability issues is indeed examined in this document, but now detached from the cluster analysis. The framework no longer serves as background for the cluster analysis or to examine the conformity of the approaches followed within the cluster, because there is no cluster. Challenges and open questions deriving from the sustainability policy framework that could be relevant for biorefineries are, however, still discussed in a more general way. This part is to be seen as complementary to Deliverable 3.6 where various initiatives in the field of sustainability assessment and sustainability criteria are listed, but not from the policy point of view (e.g. projects, workshops, certification schemes, standards, development of criteria)

1.3 Methodology and structure

Following the description of the necessary adaptations to the original goal, the report consists of two parts that are no longer directly linked to each other:

- In the first part (chapter 2), a typical biomass handling chain will be defined, the stages constituting it will be briefly described and sustainability aspects along the chain will be discussed, wherever relevant. A description of the specific points of interest of the institutes constituting the group will follow; these could in the course of time take the form of a new project
- In the second part (chapters 3), the current policy framework concerning sustainability (e.g. legislations or proposals) will be presented and briefly analysed. This will be followed by a discussion on challenges (generic ones but also in the context of biorefineries) that are associated with the policy framework and that could constitute drivers for reconsideration and updating of it (e.g. areas where the framework could be ambiguously interpreted, areas that are not sufficiently treated).

2 Sustainability aspects of biomass handling

Being a subset of the whole logistics chain (i.e. from field to the conversion facility), the importance of biomass handling is often underestimated. However, it is a crucial aspect for the continuous operation of the (biorefinery) facility and a deficient design is one of the basic reasons for shutdowns.

Biomass handling is here defined as the activities taking place from the moment the biomass feedstock arrives to the facility until it is fed to the reactor, i.e. transport and other logistic operations upstream for the supply of biomass to the biorefinery facility are not included in biomass handling in this context. Focus is given on lignocellulosic material, since this is the main type of feedstock considered within the formed group; this also coincides with the overall vision of the biorefinery development regarding increase of the use of lignocellulosic resources. The basic stages of the chain are presented and the discussion is centred around sustainability considerations, wherever relevant. For that reason, a detailed description of the mechanical equipment and of the different available technologies along the handling chain is avoided, as it exceeds the scope of this document.

2.1 Biomass handling chain

A typical handling chain in the plant includes the stages depicted in Fig. 1. Whether this exact chain is actually followed depends on many factors like the type of feedstock, the type of conversion, the scale of the facility and others. This document follows the general scheme of a typical handling chain, keeping in mind that some of the stages may take place (also) before the material is delivered to the facility, or in a different order (e.g. optional pre-screening before storage), or even not take place at all.

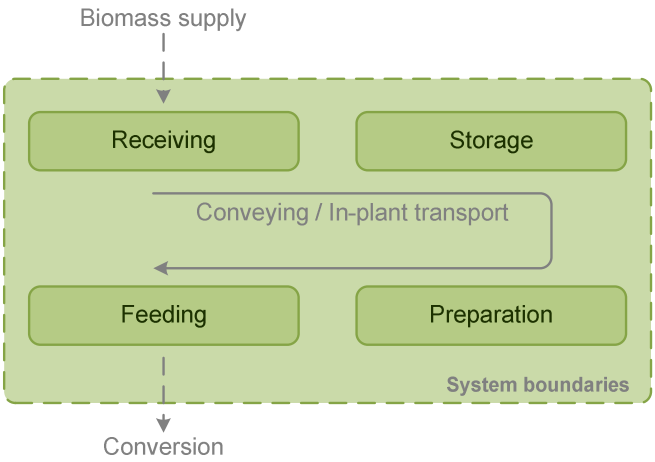


Fig. 1: Biomass handling chain

2.1.1 Receiving

In a typical large scale biomass conversion facility, transported biomass is unloaded to the receiving station (intermediate storage) and then delivered usually with conveyors or with loaders (depending on the material) to the main storage area. Depending on the transport mode used to deliver the feedstock (usually truck or train), specialised equipment is used to unload the content (e.g., hoist platforms receive the truck which is elevated at an angle to allow the load to drop into the receiving area; wagon tipplers grab the open-air wagon and rotate it 180 degrees to let the load drop into the receiving area). A good design of the receiving chain (e.g. numbers of deliveries, loads received, amounts withdrawn, etc.) ensures the uninterrupted supply of the material to the rest of the processes, which is crucial from an economic point of view. From the receiving area the material is conveyed or transported to the rest of the chain (see also 2.1.5). /1/

2.1.2 Storage

Technologies

Storage serves as the bridge of the time gap between arrival of the biomass feedstock in the facility and its treatment. The basic purpose is to retain biomass in a good condition for the subsequent treatment and to ensure the continuous operation of the facility even during discontinuous biomass deliveries. Depending on the scale of the facility, the type of biomass and the climatic conditions, storage could be:

- Outdoor, uncovered or covered under a roof or with a specific material (e.g. tarpaulin)
- Indoor, in properly designed halls or silos

For large-scale plants, above ground outdoor storage is the most economical way. Biomass needs to be piled in patterns that allow maximum flexibility in retrieval and delivery. For indoor and protected storage, silos (e.g. for grain storage) and enclosed halls (e.g. for straw bales) are typical options depending on the material. Silos are tall and large in diameter cylindrical (usually) constructions with a flat-bottom reclaimer or have the form of conical hoppers. /1/, /2/

Sustainability aspects

During storage, various metabolic activities of microorganisms take place, as a result of favourable conditions in terms of temperature and moisture levels. These activities take always place, irrespective of the feedstock type, but affect especially those materials that need to be stored for a longer time (e.g. lignocellulosic material) and have a smaller influence on material that is usually directly treated after production (e.g. oil seeds, grains) /2/. These biologic activities are the reason for some of the risks associated with storage. Those and other risks may have an environmental (e.g. emissions), economic (e.g. loss of material) and social (e.g. health and safety) impact and are discussed in the following.

Social aspects

As a result of metabolic activity of microorganisms (e.g. fungi, bacteria) present in the stored material, a rise of temperature can be observed. The rate of the increase of temperature depends on various parameters such as water content, density, specific surface (i.e., microbial activity takes place mainly at the surface of the particle), size distribution and inorganic elements of the material, type of storage (e.g., outdoor/indoor, covered/uncovered, silos), air inflow, oxygen concentration in the surrounding, etc. Biological activity can this way lead to temperature increases up to 80 °C. Further temperature increases can be attributed to a series of chemical reactions taking place in the stored material, but the exact mechanism is not clear (e.g. pyrolytic reactions, hydrolyses and catalytic effects of present metals). In extreme cases, the temperatures may increase excessively beyond 100 °C that can initiate chemical oxidation of the material, which combined with high compactions (e.g., tall piles) and insufficient heat discharge through ventilation may lead to self-ignition and burning of the feedstock. In case of very small-sized particles (~ 0,3 mm) the combustion of the material can proceed in very fast rates in form of explosions if the mixture between air and dust particles lies between the upper and lower explosion limits. Measures like storage volume limits, distances from and between storage units (outdoor), control of ventilation for heat discharge, heat sensors are important to ensure safe working conditions, which is an indispensable factor of social sustainability. /2/

The metabolic activity of microorganisms is also responsible for potential health risks during storage. At favourable temperature (i.e., 20 to 35 °C) and water content (i.e., 30 to 50% of wet biomass) conditions, fungal growth is observed. This is reinforced for densely compacted biomass, due to the absence of air flow within the stored material. The types of fungi grown vary depending on the climatic conditions, the type of material, the duration of storage, etc. Spores can be released in the atmosphere during loading/unloading and turning of the heaps and they can lead to health impacts like allergies, respiratory problems, skin irritations, intoxication up to more serious diseases like lung cancer. Apart from monitoring and avoiding fungal growth, other indirect measures, such as automation of handling processes during storage, vehicles and masks equipped with filters, correct ventilation are ways to secure the working environment. /2/

Economic aspects

The most important economic aspect during storage is the loss of material as a result of the microbial activity. This loss of "usable" material (i.e., decrease of the convertible organic fraction) subsequently leads to less product, which is an economic disadvantage for the operators. At the same time the relative composition and subsequently the quality of the material changes; the lower heating value of the feedstock is decreased and the share of inorganic material is larger, since it is mainly the organic fraction that is affected by the microbial activity. This could mean for example that the ratio between revenues and costs of ash disposal (where inorganic elements end-up) after biomass gasification becomes unattractive. The percentage of material loss depends foremost on the material and the type and duration of the storage. Table 1 presents some examples of material loss during storage for lignocellulosic material.

Table 1: Material loss of stored lignocellulosic material

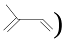
Material	Water content	Storage type	Time	Material loss	Source
Wood chips	50-55% (ar)	Outdoor, uncovered	7-9 months	20-23% (dm)	/1/
Wood chips	15% (dried)	Outdoor, covered	7-9 months	2% (dm)	/1/
Logging residue chips	42-58% (ar)	(Indoor)	6 months	6.6-15.6% (dm)	/3/

ar: as received; dm; dry matter;

Another important economic aspect is the retrieval of biomass from storage in a way that ensures continuous feeding to the reactor and avoidance of flowing problems. There are several technical possibilities depending on the type of storage (e.g. screw-type dischargers for silos, push-floor or crane systems for halls) /2/. When withdrawing biomass, it is generally desired to ensure the first-in/first-out principle, i.e., the biomass batch that was first stored is the first one to be retrieved /1/. Flow problems in conical hoppers like rat-holing, arching, bridging and cake-forming can be overcome with a careful design of the hopper, under consideration of the type and size of the feedstock, the slope angle of the discharge, the size of the discharge, the wall material and the duration of storage.

Environmental aspects

The emission performance during storage is dependent on the type and duration of storage, on the material itself and on the surrounding conditions. According to a theoretical evaluation of *Wihersaari* that was based on compost studies, outdoor storage of forest residue chips may lead to CH_4 and N_2O emissions in the magnitude of 1.3% and 4.4% of the initial carbon and nitrogen amount, respectively; the high degree of uncertainty of the estimations was specifically pointed out. Furthermore, samples of leachates (after precipitation) from piles of bark/wood chips (stored outside) from the same have also shown the existence of small concentrations of polycyclic aromatic hydrocarbons (PAH) in the magnitude of 27 µg/l. /3/

Another type of emission during storage are terpenes, volatile organic compounds (VOC) containing one or more isoprene units (C_5H_8; ) and constituting around 90% of the easily extracted material in wood. VOCs are responsible for the formation of ground-level ozone through a chemical reaction with NO_x (i.e., nitrogen oxides) and the presence of sunlight. Terpenes are also known to cause potential health effects in case of continuous exposure (dermatitis, bronchial reactivity, respiratory problems, etc). /4/, /5/, /6/

2.1.3 Preparation

Preparation (conditioning) of the biomass takes place in order to render the material suitable for the subsequent conversion processes. In principle, four basic properties are altered here: the size, density and water content of the feedstock as well as the existence of foreign materials. Any undesirable conditions regarding those properties may lead to minor or grave failures of the downstream process units and serious economic damages for the operators.

Screening

The main foreign materials in biomass feedstock are stones, glasses, ferrous metals (i.e. iron) and non-ferrous metals (e.g. aluminium). Stones and glasses may jam any conveying, feeding and process equipment and are usually removed by means of vibrating sieves or trummels combined with suitable air flow that separates materials according to their specific gravity. Ferrous metals are removed with magnets that can be placed in different places along the feed line. Non-ferrous metals are usually removed with the application of "eddy current" (i.e., creation of opposite magnetic fields between a spinning rotor and the metal particles, which allows the selective separation of the metal). /1/

Sizing

Depending on the specifications of the downstream processing activities, feedstock needs to be reduced in size. Chunking (50 to 250 mm), grinding (<80mm), chipping (5 to 50mm) and pulverising (<100µm) can be implemented for that reason. Oversized pieces that may clog any equipment can be removed in trummels prior to sizing activities. /1/

Drying

Drying is one of the most common and at the same time challenging parts of the preparation chain. Apart from natural drying taking place during storage as a result of temperature increase or drying without the use of technical equipment (e.g. air tube ventilation), there is a large number of technical possibilities (e.g. band conveyor, perforated floor, rotary cascade, a.o.) using different drying medium (air, steam, flue gas) and having different energy demand; which will be implemented depends on the type of material and the specification of the subsequent processes /7/. A typical heat demand for drying (band dryer) of wood chips (40% wt. moisture) is around 0,9 kWh/kg_{wood_chips} /8/. Usually, the material to be dried has a moisture content of 30 to 60% wt. on delivery to the facility (depending on time of harvest, storage before delivery, type of material, etc.) and requires a certain pre-treatment (e.g., size reduction) before being fed to the drying unit. A critical parameter for efficient drying is the size of the material; the drying rate (expressed as % weight loss due to diminished water content and loss of organic material) increases for decreasing particle sizes (i.e., 3 to 6 %/min for sizes of 8 to 0,7 mm, respectively) /6/.

Sustainability aspects of preparation

Overall, the sustainability of the preparation chain will be mainly determined by the efficiency of the units involved. For example, a well-designed heat recovery system (depending on the type of the conversion processes) will permit the use of internal heat sources (e.g., exhaust gases, excess process heat) for drying purposes; this would benefit not only the economic viability of the concept but also the environmental performance, through saved GHG-emissions that would have been generated from burning external fuel source for heat.

Another important aspect is the quality specifications of the feedstock, which determine whether it is in an acceptable condition (i.e., in terms of physical and chemical properties) to be processed in the conversion area. This is especially important in cases of feedstock mixtures (e.g. co-firing of biomass in coal combustion plants) where uniform flow characteristics and homogenisation of feedstock is required. This aspect is important along the entire handling chain, since the first mixing is usually taking place in the storage area or during the conveying of the different feedstock streams in the preparation area.

The main environmental concerns are situated in the stage of drying and the emissions there can be classified under three groups /7/:

- Volatile organic compounds (VOCs) like terpenes that start to appear at temperatures below 100 °C. The distribution of the emitted terpenes (mono-, di-, sesqui-) is dependent on the material that is dried, on the temperature level and on the drying medium /6/
- Condensable compounds like fatty acids, resin acids and higher terpenes that are formed above 100 °C and may condense on equipment surfaces and cause technical problems. Additionally they are the reason for the formation of the so called "blue haze", a discoloration observed at the exhaust plume and can represent an odor and visual nuisance and potential health hazard
- Fine particles or dust (average yearly emissions in the magnitude of 0.35 $kg_{fine\_dust}/t_{wood\_chips}$ for belt drying of wood chips) /8/

While at the beginning of drying thermal decomposition is slight, above 150 °C the material decomposes (i.e., destruction of hemicellulose and release of alcohols, acids and aldehydes) at faster rates with increasing temperatures, which overall represents loss in energy and material efficiency of the process. Therefore it is generally recommended to keep material temperatures during drying at a low level (< 100 °C). /7/

In a recent study, IFEU compared technical and natural drying of wood chips (40% wt. water) used for heating purposes. From an environmental point of view, it was suggested that technical drying of wood chips is friendlier (in terms of GHG emissions, primary energy demand and particulate emissions) than natural drying only if it involves integration of unused (waste) heat produced within the process, but not if external heat is required for drying purposes. The necessary energy demand and subsequent emissions from using technical means for drying the same amount of wood chips is offset by the fact that natural drying leads to material loss and provides an end-product with higher water content than technical drying (which means that less heat can produced from the wood chips). /8/

The drying unit is also an area with a risk of fire or explosion. Important parameters in that case are the oxygen concentration of the drying medium (should not be below 8 to10% vol.). The temperature level is also important since high temperatures decrease the required ignition energy and promote pyrolysis reactions and the subsequent release of carbon monoxide which is combustible. That, combined with the existence of dust particles (which promote a very swift heat transfer), presents a risk of explosion. The most important precautionary measures are ventilation, oxygen concentration sensors and keeping the drying atmosphere inert (especially during start-ups and shut-downs). /7/

Given the existence of many mechanical parts during preparation (including conveying the material along the preparation processes), this part of the chain exhibit risks for fire (e.g. sparks between metallic surfaces, foreign material like small nails). Regular maintenance of the machinery and spark sensors can minimise those risks. Furthermore, risks for shutdowns (e.g., clogging due to insufficient screening) apply here as well.

2.1.4 Feeding

The type of feeding equipment (e.g. pneumatic or mechanic) depends largely on the material and the subsequent conversion process. The ability to meter and measure the fuel feed rate is crucial since it will control the entire feed system. Failure in this final part of the chain will apparently lead to long downtimes for the entire process and to respective economic losses. /2/

2.1.5 Conveying

Conveying is mentioned last because it can take place along the entire handling chain and delivers the feedstock from one stage to the other. Depending on the material and the grade of mechanisation/automation of the facility, sometimes delivery from one stage to another may be alternatively achieved by vehicles (e.g. front loaders from receiving area to storage area). Conveying is a very crucial stage because it allows the steady flow of the material along the entire chain. Therefore, the flow characteristics of the material are important here, too. /1/, /2/

2.2 Cluster details

Although a definite set of biomass feedstock is not yet established, the activities will initially use lignocellulosic material. SLU will first comminute and dry to approximately 5% wt. two types of materials:

- Wood (Scots pine or Norwegian spruce) in chips (<2mm) and particles (<25x15x5mm)
- Straw chips (40mm; barley or reed canary grass)

The materials (in quantities of around 300kg) will be shipped to the rest of the partners that will conduct a series of measurement and characterisation tests in order to determine the specifications of the material. These include tests for particle size distribution, for tensile strength, concentration of extractives and ashes, shear tests, arching tests, explosion test and others.

One key issue of interest for the partners of the group is the characterisation of flow behaviour for the avoidance of flow interruptions that can occur along the entire handling chain and could lead to stoppages for several hours or even days. This is obviously translated into economic loss, not only because of stopped production, but also because of potential repairs and additional investments to replace or optimise equipment parts. Flow interruptions are basically dependent on the specifications of the material, based on which the entire handling chain is designed. For that reason characterisation activities and strict specification of material characteristics are of high importance. The complexity of this issue increases in case of material mixtures (e.g. co-firing), because of the inhomogeneity, the different properties and the different composition (e.g. a wood/coal mixture is more complex than a wood_1/wood_2 mixture). Demonstrating good flow properties and performing flowing assessments will minimise the necessity of specialised equipment to discharge the material and will also prevent uncontrolled flows of material (e.g. sudden collapse of material during discharge in silos)

Although conversion processes determine what exact specifications the material should have in order to be processed without problems, the partners have not determined a fixed list of processes for which the preparation of the material is envisaged. The goal is to research the flexibility of the handling chain (and the processes involved) in order to render it suitable for different materials and different conversion processes. Nevertheless, one process that is of interest (for USL) is co-gasification of the biomass material with coal in an integrated gasification combined cycle (IGCC) power plant. The biomass share in the mixture will be approximately 2 to 4% wt. The primary goal is to verify that the flowing properties of biomass are suitable for unproblematic handling in the existing feeding chain (hopper, conveyor) of a coal gasifier and what kind of actions would be required to achieve that (e.g. further preparation). Assuming no handling problems, replacement of coal with biomass will achieve reductions of GHG emissions for power production.

Further interest within the group is shown on the investigation of explosion during storage and the behaviour of equipment parts in the case of explosions. The goal is to develop numerical models that simulate and explain dust explosions in silos. For that reason characterisation of the material and determination of the “explosibility” and ignitability are crucial and will lead to a safer design of equipment and development of prevention and protection devices.

3 Policy framework on sustainability

This part of the report is dedicated to the policy framework dealing with sustainability and its relevance to the biorefinery development. The goal is to discuss generic challenges that derive from the framework and could be important also in the case of biorefineries. This could point out areas where the policy framework needs reconsideration and updating

3.1 Renewable Energy Directive

The European Union Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC), also called RED, establishes an overall binding target of a 20% share of energy from renewable sources in gross final energy consumption in the EU, as well as binding national targets in line with the overall EU target of 20%. It also sets a 10% binding minimum target for renewable energy (including biofuels) in transport, to be achieved by each member state by 2020. The directive was supposed to be implemented to the national legislation of the member states by 5 December 2010. /9/

The RED introduces environmental sustainability criteria for transportation biofuels and other bioliquids[1]. Only biofuels in compliance with these criteria may benefit from national support systems and can be counted in the renewable energy targets presented in the RED. Fuel suppliers can demonstrate their compliance with the sustainability criteria by one of three means:

- Through national schemes
- Through voluntary schemes notified by the Commission
- Through bilateral or multilateral agreements with third countries containing provisions on sustainability criteria that correspond to those of the Directive and that have been certified by the Commission.

The directive presents three types of sustainability criteria. Firstly, there are limitations concerning the areas of origin of the raw materials for the biofuel production. For example, biofuels must not, subject to certain exceptions, be derived from raw material obtained from land with high biodiversity value, land with high stocks of carbon, or peatlands. Secondly, there are there are mandatory requirements on the sustainable production of agricultural feedstock for biofuels. These requirements can be summarised under the term good agricultural practice and include criteria that are part of the cross compliance rules. Thirdly, limitations concerning the GHG emissions produced during the life cycle of the biofuels. The GHG emission saving from the use of biofuels compared to the use of fossil fuel shall be at least 35% for current biofuels and at least 50% from 1 January 2017. From 1 January 2018 the emission saving shall be at least 60% for biofuels produced in installations in which production started on or after 1 January 2017. The RED provides a list of default values of the emissions saving

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[1] *In this report the term “biofuels” is used for transportation biofuels and other bioliquids*

results for certain biofuels. It also introduces a methodology for calculating GHG impacts of biofuels and GHG emission reduction compared with fossil fuels to be replaced. The RED also encourages the use of waste and residues as raw material for biofuels, as biofuels produced from waste or residues and from non-food cellulosic and lignocellulosic materials can be double-counted towards the national renewable energy targets for transport (i.e., 1 MJ of biofuel from waste and residues can be counted as 2 MJ).

RED calculation methodology for GHG emissions of biofuels

The default values for GHG emission savings of certain biofuels provided in the RED may be used under certain conditions. If the default value for GHG saving of a production pathway is not provided in the RED, producers wishing to demonstrate their compliance with the minimum levels are required to calculate the actual emissions from their production process. Also, if by using the default value for GHG emissions given in the RED, the GHG savings lie below the required minimum level, the producers can show that the actual emission saving from the biofuel process is higher than that assumed in default values. The RED default value can be used if it is given for the specific biofuel production chain and if the emissions from the carbon stock changes caused by land use change are equal to or less than zero.

The calculation of the actual GHG emission savings follows the methodology presented in the part C of Annex V of the RED. This methodology is based on the LCA approach, as the GHG emissions of the whole life cycle of biofuels are evaluated. GHG emissions are expressed in terms of gCO_2-eq./MJ. Emissions from the manufacture of machinery and equipment shall not be taken into account. For waste and residue-based raw materials, the calculation of GHG emissions starts from the collection of the raw material. The allocation of emissions between the products inside the system boundary should be carried out in proportion to their energy content (determined by a lower heating value in the case of co-products other than electricity).

The Commission has published Communications that give more guidelines for the implementation of the sustainability criteria. They provide further insight on how the GHG emission calculation should be conducted.

- Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels 2010/C 160/02, 19.6.2010. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:160:0008:0016:EN:PDF
- Communication from the Commission on voluntary schemes and default values in the EU biofuels and bioliquids sustainability scheme. 2010/C160/01, 19.6.2010. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:160:0001:0007:EN:PDF
- Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (notified under document C(2010) 3751). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:151:0019:0041:EN:PDF

The RED calculation methodology excludes the emissions from indirect land use change (iLUC). ILUC emissions can occur when the production of biofuel raw materials transfers the production of other products (e.g. food or feed) to new areas, e.g. to natural forest. The Commission is working on this subject and has published a report related to the iLUC. The report announces that the Commission will conduct an impact assessment, thereby taking into consideration potential changes to the existing legislation[2]. /10/

3.1.1 Relevance for biorefineries

The RED is directly relevant for biorefineries that produce transportation biofuels as a main or a co-product. The RED has to be implemented in the EU Member States and the national legislation will indicate the final sustainability criteria, which the biofuel producers have to respect. The biofuel producers have to be able to describe the whole production chain with all the input and output flows in order to calculate the total GHG emissions. This can be quite challenging, when there are many different flows and economic actors included in the production chain.

The biorefineries which don't produce biofuels might also be in touch with the RED as some of their end, intermediate or co-products might be used as an input in a separate biofuel process. In this case the biorefinery actor has to be able to give the information needed for the GHG calculation of the separate biofuel product.

3.1.2 Challenges

Soimakallio et al. have published a report, where they discussed the sustainability criteria established in the RED with regard to biofuels consumed in transport, the associated terminology, and matters relating to the calculation of GHG emissions. The report was produced to support the Finnish Government in the national implementation of the RED sustainability criteria in Finland. /11/

Several issues and problems with regard to the definitions, auditing practices and verification requirements associated with the sustainability criteria included in the RED can be identified. It is obvious that detailed interpretations of certain sections of the Directive must be included in the national implementation. There is a risk that the different Member States would make different kind of interpretations of the RED and this way the sustainability criteria might vary between the Member States. Different interpretations could be made for example related to the criteria for the origin of raw materials, the definition of waste and residues, the system boundary of the calculation and to the parameters used for calculations and their cut-off criteria. As result, this situation may prove to be problematic for both developers of certification systems and biofuel producers that may find themselves in an unequal position across Member States.

In the following, some challenges and needs for further definitions related to the RED are presented in more detail. This kind of problems might be relevant for the biorefineries, if they produce transportation biofuels or if the EU sustainability criteria would be expanded to concern also other bioenergy or generally other uses of biomass, such as material use (see chapter 3.2).

Definition of waste and residue categories in the RED

The RED sets incentives for the use of waste and residues as raw material for biofuels. The contribution made by biofuels produced from wastes or residues is considered to be twice that made by other biofuels. Moreover, waste and residues are considered to have zero life-cycle GHG emissions up to the process of collection of these materials, which means that GHG emissions from the production of the raw material do not have to be taken into account. This is why agreeing on the definitions of 'waste' and 'residue' in the implementation of the RED is both extremely important and

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[2] *Visit also: http://ec.europa.eu/energy/renewables/biofuels/land_use_change_en.htm*

problematic. The RED leaves the definitions open. The Commission Communication 2010/C 160/02 gives some guidelines and examples, but still leaves open questions. For example it states that “excess production from a production process can be a residue” which is an ambiguous guideline. This means that the Member States have to make their own interpretations related to this question. The ideal scenario is that all organic waste and residues that have no other use are turned into biofuels, but there is a significant risk that raw materials that would have been utilised in any case is recorded as waste or residue in the production of biofuels. This could be the case for example with crude tall oil, which is already an important raw material for chemical industry but might be considered as a residue according to the RED (defined in the Commission Communication 2010/C 160/02). The conflict between the two use perspectives is obvious, and there is no simple or appropriate solution in sight. In practice, the options are likely to be limited to either a rigid classification system or a case-by-case assessment of which material streams can be considered as wastes and residues. The problem with a rigid classification system is that it is likely to become outdated very quickly and may prove inappropriate. On the other hand, a case-by-case assessment routine may prove burdensome. It would pose challenges to a competent authority or verifier who is making the interpretations on individual fuel production pathways in practice. In order to ensure consistency between interpretations in the validation process of applied methods, the competent authority should harmonise and compile these supply chain-specific issues in a public decision, open to appeal, outlining a methodology for monitoring production pathways, as well as terms and conditions that suppliers would have to meet (reporting obligations, etc.) along with any necessary explanations and guidelines. /11/

Determination of GHG emissions of biofuels in accordance with the RED

The framework provided in the RED for calculating GHG emissions is open to various interpretations as regards the definitions given. Ambiguities relate for example to the accuracy of the input parameters used in the calculations, acceptable emission coefficients associated with material flows that cause direct or indirect emissions, methods for calculating changes in the carbon stocks of soil and forests, the definition of a biorefinery unit, and certain principles relating to the allocation of emissions. The Commission Communication 2010/C 160/02 gives some guidelines to some of these questions, but these guidelines are sometimes ambiguous and not binding. A simple example is the emission factor of the electricity used in the biofuel production process, which can be the average emission of electricity in the EU, but also be some other regional average emission of electricity. This can have a significant impact on the GHG calculation results. /11/

The Commission Decision C(2010) 3751 defines calculation rules for carbon stock changes due to direct land use change. However rules for considering carbon stock changes due to agricultural or forest management (e.g. tillage) are not provided. In addition, uncertainties associated with ecological processes as regards nitrous oxide emissions due to fertiliser application are not given. No common approach exists for taking these factors into account in LCA. However, these factors often play a critical role in assessments of the effects that biofuels have on the climate system. This kind of practices should be harmonised both across the EU and within individual Member States in order to eliminate inappropriate deviations from the GHG emission calculations associated with different biofuel production pathways. /11/

The GHG emission saving default values given in the RED represent typical European production processes with conservative estimates for the production of biofuels. However, the conservativeness and the suitability of the RED's default values might be debatable. It can be questioned if the general default values are appropriate representations of specific biofuel chains in different parts of the EU.

Suitability of the RED for sustainability assessment

The RED sustainability criteria cover only the origin of the biofuel raw material and the GHG effects of the final biofuel products. The RED does not give any criteria for other environmental impacts than GHG emissions. However, the biofuel production might have important impacts e.g. on water use (raw material irrigation), biodiversity, and on other emissions than GHG. These effects might be very important locally and should not be forgotten. In the EU some of these effects may be controlled under other legislation but it is questionable, how well the sustainability of the biomass imported outside the EU can be controlled and verified. The RED also excludes the iLUC emissions, which might be very important, related to some biofuel raw materials (e.g. palm oil). The increased production of biofuels can also have other indirect effects, for example effects on food and feed production and prices. These kind of social aspects are only mentioned in the RED but there is no real sustainability criteria established.

It can be questioned, if an LCA based tool, as the one presented in the RED is ready to move from an analysis tool to a decision tool. The RED GHG calculation methodology for selecting the biofuels to be promoted in the EU might not ensure that GHG emissions are reduced and the biofuel production chains with the highest benefits in reducing GHG emissions are promoted. /12/

3.2 EU Commission report on sustainability requirements for the use of solid and gaseous biomass sources for electricity, heating and cooling

The RED establishes the target of 20 % share of energy from renewable sources in gross final energy consumption in the EU by 2020. This target is expected to increase the use of solid and gaseous biomass sources in electricity, heating and cooling. Thus, the trade of biomass inside the EU and imports from third countries are expected to increase. Many countries have developed their own sustainability criteria to control the sustainability of biomass used for energy purposes. To give guidelines for the member states, the European Commission has published a Report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling /13/[3]. The sustainability criteria proposed by the Commission are consistent with the EU RED (2009/28/EC). The proposed sustainability criteria include following:

- A general prohibition on the use of biomass from land converted from forest, other high carbon stock areas and highly biodiverse areas
- A common GHG calculation methodology which could be used to ensure that minimum GHG savings from biomass are at least 35% (rising to 50% in 2017 and 60% in 2018 for new installations) compared to the EU's fossil energy mix
- The differentiation of national support schemes in favour of installations that achieve high energy conversion efficiencies, and
- Monitoring the origin of biomass.

3.2.1 Relevance for biorefineries

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[3] *Visit also http://ec.europa.eu/energy/renewables/bioenergy/sustainability_criteria_en.htm*

Contrary to the RED, the sustainability criteria on other bioenergy than liquid biofuels are still voluntary. As all bioenergy applications such as production of electricity, heat and transportation biofuels may use the same biomass feedstock it might be problematic that only a part of this feedstock will be under the obligatory sustainability scheme of the EU. In this case, there would be two different kinds of biomass markets for bioenergy purposes in the Europe; the biomass under the sustainability scheme and the biomass without sustainability requirements. If the sustainability criteria concern only a part of biomass (e.g. biofuel sector) there is a risk that the raw materials fulfilling the sustainability criteria will be used in this sector and the use of less sustainable biomass would increase in other sectors. Introduction of a harmonised sustainability scheme for all bioenergy might help to avoid this kind of indirect effects. However, the sustainability criteria and especially the GHG calculation rules presented in the RED are not extensive enough to ensure sustainable use of bioenergy. Instead, more comprehensive approach is required along with additional data and indicators. /12/

If the sustainability criteria would become obligatory to all bioenergy, it could have an effect to the biorefineries, which often produce some kind of bioenergy as a main or a co-product. However, in the voluntary sustainability criteria for bioenergy, the Commission has indicated that only producers with the thermal or electrical capacity of at least 1 MW would be included in the system.

3.2.2 Challenges

From voluntary to obligatory

The voluntary sustainability scheme for other bioenergy than liquid biofuels presents a same kind of criteria as the RED. As discussed in Chapter 3.1, the sustainability scheme of the RED requires the assessment of the whole life cycle of the bioenergy products in order to calculate the GHG emissions of bioenergy product. This is a challenging process and requires collection of information and process data related to the whole bioenergy production chain from raw material production until the use of end product (bioenergy). If the sustainability criteria would become obligatory, this would cause a notable workload and additional costs for the actors of biorefinery sector, especially for those that don’t produce biofuels as they should be able to report the GHG emissions related to all input and output flows of the biorefineries. Also the allocation of the emissions between the biorefinery products might be challenging, as various end products might be used for various purposes (eq. energy, fibres, food) and finding a common allocation principle might be difficult.

Expanding to all biomass uses

Biomass is also used for other purposes than for bioenergy (e.g. food, feed, material, chemicals, etc.). If the sustainability criteria concern only biomass (or a part of biomass) used for energy purposes, there would still be two different markets of biomass, and the same risk described earlier would still take place. The biomass fulfilling the sustainability criteria could be used at energy sector and other sectors could use other biomass sources. However, it might take time until a common sustainability scheme would be established for all biomass uses and it is also questionable whether such a system is sensible and feasible. *Soimakallio & Koponen* concluded that the overall use of biomass and land for food, feed, fibre, fuels, and ecosystem services should possibly be based on a comprehensive, integrated, and sustainable action plan /12/. Integrated programs for land use and territorial planning, sectoral policies as well as targeted policy instruments, such as protected area networks were claimed by European Environment Agency (EEA) to tackle trade-offs between many interests for land use in Europe /14/.

The ambitious targets to increase the use of bioenergy will put a significant pressure to the use of biomass in the near future and this makes the position of the biomass used for energy purposes special. The bioenergy targets are often justified with the climate change mitigation and GHG reduction purposes. Therefore it should be verified, that the increased use of biomass in bioenergy sector really is sustainable enough and has positive effects on climate change mitigation

3.3 Other relevant policy instruments

While policy frameworks such as the Renewable Energy Directive have a direct impact on biorefineries and biorefinery outputs, other policy instruments (both legally binding, or voluntary schemes and guidelines) are broader but still related to sustainability and biorefineries in various ways. Due to the heterogeneity of biorefineries (biomass, products, technologies), topics that are relevant for sustainability issues can be found in many fields of policy. Some of them will be highlighted in this section.

3.3.1 Integrated Product Policy Communication

In 2001, the European Commission produced a Green Paper on Integrated Product Policy, as a starting point for discussions of European action in the field /15/[4]. Its central objective was to improve the environmental performance of a broad range of products throughout their life cycle. The Green Paper proposes a strategy to strengthen and refocus product-related environmental policies to promote the development of a market for greener products. The products of the future should be more resource-efficient, have lower impacts and risks to the environment and prevent waste generation already at the conception stage. The Green Paper focused on three main dimensions, namely demand, supply and price mechanisms to develop markets for greener products.

Building further on the Green Paper, the Commission published a Communication on IPP, which aims to minimise the impacts of products by looking at all phases of a product's life cycle and taking action where it is most effective /16/. Taking into account the wide scope of available products and stakeholders involved the IPP approach calls for the use of a combination of different policy instruments. Since the IPP promotes greener products, but not specifically bio-based, the implementation of the IPP can help promote the concept of biorefineries from the product-side, by highlighting the environmental performance of this type of products

The IPP puts emphasis on three main aspects:

- It promotes "life cycle thinking", where consideration is given to the whole of a product's life cycle, from cradle to grave, when defining measures to reduce environmental impact.
- IPP is flexible as to the type of policy measure to be used, working with the market where possible. Many different policy measures influence the environmental impacts of products such as taxes, product standards, labelling, and voluntary agreements. The chosen measure should be the most effective, or the most effective set of instruments. These policy measures as highlighted in the IPP can today be found in the recommendations and action plan of the Lead Market Initiative on Bio-based products, which focuses on demand-side measures for greener products /17/.

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[4] *Visit also: http://ec.europa.eu/environment/ipp/*

- IPP requires full stakeholder involvement. Throughout their long and complex life cycles, the environmental impacts of products are affected by the actions of many different stakeholders, such as designers, industry, marketing people, retailers and consumers. Reducing these impacts requires that all stakeholders take action in their sphere of influence: for example, manufacturers on the design and marketing of products, and consumers through product choices, use and disposal habits.

In terms of concrete measures, the IPP introduced voluntary IPP pilot projects aiming at identifying ways to reduce the environmental impact of products. Two voluntary pilot projects were launched in 2004 to demonstrate how IPP can work in practice. The chosen products were mobile phones (project lead by Nokia) and on a tropical wooden garden chair (by Carrefour). The IPP also aimed at defining product categories with the most potential for environmental improvement, which was done at Member State level. This type of pilot projects could be foreseen for a certain type of biorefinery output for instance.

The progress report of the IPP Communication analysed the progress towards the objectives set by the IPP communication, highlighting key measures on both EU and Member State level /18/. As stated in the progress report, the IPP is closely interlinked to a number of policy initiatives at the EU level:

- Eco-Management and Audit Scheme (EMAS)
- EU Ecolabel Scheme
- European Life Cycle Assessment Platform
- Environmental Technology Action Plan (ETAP)
- Green Public Procurement (GPP)
- Ecodesign of Energy Using Product Directive (EuP)
- European Compliance Assistance Programme - Environment & Small and Medium Enterprises (SMEs).
- Thematic Strategy on Sustainable Use of Natural Resources.
- Thematic Strategy on Waste Prevention and Recycling

One of the conclusions was that the main challenge of IPP implementation is to use these existing tools in a coherent and mutually-enforcing manner with the new ones to achieve policy objectives. Policy development should also involve stakeholders who are involved in product development throughout the value-chain. A number of EU policy strategies and initiatives such as the ones stated above are in line with the IPP principles. This is also the case for Member State-level programmes and initiatives, but the main challenge lies in creating a coherent framework. In order to better exploit the synergies between the different IPP instruments, a better combination of voluntary and mandatory approaches is required. The IPP approach is a very broad framework covering a large variety of products, of which biorefinery outputs can also be considered a part.

3.3.2 Sustainable Consumption and Production / Sustainable Industrial Policy Action Plan

The European Commission published the Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan in July 2008 /19/[5]. It encompasses a series of proposals on sustainable consumption and production that will contribute to improving the environmental performance of products and increase the demand for more sustainable goods and production

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[5] *Visit also: http://ec.europa.eu/environment/eussd/escp_en.htm*

technologies. A range of policies at EU and national level already foster resource efficient and eco-friendly products and raise consumer awareness, such as the aforementioned IPP framework, labelling schemes, and financial incentives granted by Member States to those that buy eco-friendly products. The Action Plan complements and integrates the potential of these different policy instruments, and provides for new action where gaps exist. The Action Plan proposes that only products that reach a certain level of energy or environmental performance are eligible for incentives and can be procured by Member States and the EU institutions. The Action plan covers a wide range of measures, namely:

- Ecodesign requirements for more products
- Reinforced energy and environmental labelling
- Incentives and public procurement for highly performing products
- Green public procurement practices
- Consistent product data and methodologies
- Work with retailers and consumers;
- Supporting resource efficiency, eco-innovation and enhancing the environmental potential of industry
- Promoting sustainable production and consumption internationally

Extension of the Ecodesign Directive and labelling schemes promoting greener products

A public consultation of stakeholders of the SCP/SIP Communication and Action Plan in 2007 included the extension of the scope of the Ecodesign. The results of the consultations were fed into the Impact assessments on the SCP/SIP Communication and Action Plan and the extension of the Ecodesign Directive.

Ecodesign is the integration of environmental considerations at the design phase of the product. The Ecodesign Directive (2005/32/EC) establishes a framework for setting ecodesign requirements for energy-using products (also called EuP Directive) /20/. This initiative aims at improving the environmental performance of products throughout their life-cycle by systematic integration of environmental aspects at the earliest stage of their design. Next to minimum requirements, the Ecodesign Directive will also define voluntary benchmarks of environmental performance, achieved by highly performing products. A number of other pieces of legislation address specific aspects of the life cycle of products, such as waste.

The Ecodesign Directive is complementary and complies to the labelling schemes set by the Energy Labelling Directive (92/75/EC), the Ecolabel Regulation (see below) and other schemes developed by Member States, retailers and other economic operators provide consumers with information on the energy and environmental performance of products.

The Ecodesign directive ensures a technical improvement of products, while labelling increases transparency for consumers by indicating the environmental performance of products.

3.4 Standards and labelling in the context of sustainability

Standards

Both the European Committee for Standardisation (CEN) and the International Organisation for Standardisation (ISO) are working on the development of standards for the sustainability of bioenergy and bio-products in general. The working group *CEN BT/WG/209* was established in an effort to explore the potential of EU-wide bio-based product standards. The technical committee *CEN/TC 383* is working on the development of standards for the verification of compliance with the sustainability criteria for biofuels and bioliquids as they are presented in the RED Directive. The technical committee *ISO TC/248* has the purpose of developing standards in the field of sustainability criteria for the production, supply and application of bioenergy (see also Deliverable 3.6, where these standards are briefly described)

Labelling

As part of the EU measures to promote more sustainable products, which falls within the principles of life cycle thinking from the Integrated Product Policy, the European Ecolabel is a voluntary scheme, established in 1992 to encourage businesses to market products and services that are environment-friendly. Products and services awarded the Ecolabel carry the flower logo, allowing end-users to identify them easily. The EU Ecolabel criteria shall be based on the environmental performance of products, taking into account the latest strategic objectives of the European Union in the field of the environment, such as the objectives set as part of the Renewable Energy Directive. /21/

3.5 Harmonisation

Scarlat & Dallemand have recently published a global overview on recent developments of biofuels/bioenergy sustainability certification (in the EU, United States, and in some other countries) /22/. Their overall conclusion is that there is a lack of harmonisation in the area of definitions, approaches, and methodologies. The discussion on what is harmonisation, if and why it is necessary, up to which level it makes sense, and what we want to achieve with it is very wide and exceeds the scope of this document. Assuming that a European Directive is the general policy to be followed by all member states (which by itself is a form of harmonisation), harmonisation can have many goals and many levels, for example:

- harmonisation of interpretations of the Directive into national policies,
- harmonisation of interpretations of a national policy by different stakeholders,
- harmonisation of methodologies (definitions, criteria) to calculate a value required from a policy,
- harmonisation of data inventories within the same methodology among different practitioners,

It is apparent that an overall claim that harmonisation is always needed is not possible. Instead, it must be carefully examined where harmonisation takes place and what is the desired objective. This report focuses on the presentation of some actual activities on harmonisation:

GHG calculation in the RED - the BioGrace Project

BioGrace (*Align biofuel GHG emission calculations in Europe*) is a three-year (i.e., 2010-2013) project funded within the Intelligent Energy Europe Programme, with 8 participating organisations[6]. BioGrace deals with the harmonisation of GHG emission calculations of biofuels throughout the European Union. The aim of the project is to support the implementation of the RED in the Member States by creating and providing tools to make and verify biofuel GHG calculations. This project freely provides:

- A list of standard conversion values that are needed to perform biofuel GHG calculations
- A software (Excel sheets) that allow stakeholders to perform calculations themselves

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[6] *Visit also: www.biograce.net*

- Excel sheets that include standard input data and that show how the 22 default GHG values as listed in the RED and the FQD (Fuel Quality Directive) were calculated.

LCA practises - The ILCD handbook

In the Communication on Integrated Product Policy (IPP) the European Commission committed to produce a handbook on best practice in LCA. In consequence, the International Reference Life Cycle Data System (ILCD) was developed by the Institute for Environment and Sustainability in the European Commission Joint Research Centre (JRC), in co-operation with the Directorate-General for Environment. The ILCD handbook consists of a set of documents with more detailed guidelines, which aim to harmonise existing LCA practices in line with standards ISO 14040 and 14044 /23/, /24/.

The purpose of this chapter is to review the ILCD handbook from the perspective of biorefineries. The main focus is on the *General Guide for Life Cycle Assessment* which provides detailed guidance for planning, developing, and reporting life cycle emission and resource consumption inventory data sets and LCA studies /25/. This guidance is applicable to many different decision-contexts and sectors. In that document, provisions are given separately for three main goal situations encountered in LCA studies. In some cases provisions are fairly similar for all of the situations, in which case only the differences between situations A, and B and C are listed. The three decision-context situations are micro-level decision support (situation A), meso/macro-level decision support (situation B), and accounting i.e. attributional LCA (situation C).

- Situation A is related to a life cycle based decision support on micro-level, such as product- or process-related questions. A key criterion is that the analysed e.g. product has a limited share of the total production of its sector, so that its production, use and end-of-life can be expected not to have large-scale consequences. For example the assessment of potential environmental impacts of a small-scale biorefinery possibly falls under situation A when the biorefinery has only small scale consequences (e.g. regional level).
- Situation B refers to a meso/macro-level decision support for different strategies such as technology scenarios, policy options etc. A key criterion is that the analysed decision has consequences on changes in production, use and end-of-life activities that will change directly or indirectly parts of the economy through large-scale effects. For example an assessment of market consequences of a large-scale biorefinery as well as a study on consequences resulting from the policy to increase the share of biofuels could possibly be classified as situation B.
- Situation C relates to studies that require a descriptive, accounting-type of life cycle modelling. Studies falling under situation C are not interested in any potential consequences on other parts of the economy but for example in the assessment of environmental impacts of a specific product. The key difference of situation C compared to situations A and B is that the study is interested in documenting what has happened or will happen based on decisions that have been made (a decision to produce the specific product). Situation C has two sub-types: C1 and C2. The main difference between them is whether existing benefits outside the analysed system are considered or not (if the substitution effects are considered or not). When verifying and monitoring of emissions related to product chains is required, this type of accounting is suitable. An example is the GHG calculation method presented in the Renewable Energy Directive (RED).

The provisions are given in terms of shall, should, and may. “Shall” means that the provision is a mandatory requirement and must be followed unless there is named exceptions. “Should” means that the provision must be followed. However deviations are allowed under specific conditions. “May” signifies that the provision is only a methodological or procedural recommendation. Such provisions can be ignored or addressed in another way without explanations or justifications.

The document gives provisions basically in every major issue addressed in the ISO standards e.g. how to define the goal of the study, when to use attributional and when consequential modelling, how to select functional unit etc. From the perspective of biorefineries, issues related to emissions from land use and land-use change related to biomass production, product substitution, and solving multi-functionality are in particular interesting. Multi-functionality poses a challenge to the assessment because the products from the same process can have entirely different end use purposes (e.g. electricity vs. chemical). Thus, it can be difficult to identify the most appropriate allocation method.

ISO 14044 states that the prior method for solving multi-functionality is subdivision, then system expansion and finally allocation /24/. The ILCD document gives more detailed provisions on how and in which situations these methods shall, should and/or may be performed. The document is applicable for a wide range of sectors, so the provisions can not be summarised to a one single rule that would apply to all biorefineries in general. The ILCD handbook can definitely be useful when performing life cycle assessment studies on biorefineries but it has to be noticed that although it completes the existing LCA standards, the handbook can not give explicit answer on how to handle the special perspectives related to LCA studies on biorefineries. In general, the procedure of conducting an LCA study varies case by case. As various methodological choices, for example selecting system boundary and allocation methods may be reasonable depending on the case, more detailed and objective harmonisation of normative choices may be very difficult.

It has to be kept in mind that uncertainties and sensitivities are always involved when life cycle assessments are being performed. The main sources of uncertainty are stochastic uncertainty (e.g. parameter uncertainty), choice uncertainty (e.g. normative choice of a system boundary and allocation method), and lack of knowledge of the studied system (model uncertainty). Monte Carlo simulation is one of the recommended methods given in the detailed guidance to assess stochastic uncertainty. The document also emphasises the importance to carry out comprehensive uncertainty analysis including normative choices and model uncertainty in order to find out the importance of the assumptions whenever necessary.

Sustainability assessment for biorefineries

In the area of biorefinery research, the European Commission has asked (June 2010) the four projects of the Joint Biorefinery Call to work together in order to achieve harmonisation in different areas with sustainability assessment being one of them. The projects (also referred to as “sister projects”) are:

- EuroBioRef (European Multilevel Integrated Biorefinery Design for Sustainable Biomass Processing)
- Biocore (Biocommodity Refinery)
- Suprabio (Sustainable Products for Economic Processing of Biomass in Highly Integrated Biorefineries)
- Star-COLIBRI (Strategic Research Targets for 2020 – Collaboration Initiative on Biorefineries)

The first three are 4-year research projects with the goal of developing technologies and integrated biorefinery chains. Each of them is planning to conduct a sustainability assessment to the developed processes. On the contrary, Star-COLIBRI is a 2-year coordinating project that discusses the term “sustainability assessment” in a more theoretical way (see Deliverable 3.6 “Best practices in Sustainability Assessment”). Although all three research projects will use similar techniques and standardised approaches, the degree of freedom that these approaches offer may render results incomparable. To avoid that and try to find common ground, the three research projects have created a working group (activities started July 2010) in order to exchange information on approaches and methodological choices. The outcome of this cooperation (so far) is a document sent to the European Commission in September 2010 describing the first results and the way forward /26/.

The working group will identify areas where harmonisation can be definitely achieved, areas where discussion is needed to overcome obstacles and areas where harmonisation is very difficult due to different of objectives. For that reason, the projects have created a spreadsheet, which includes the various dimensions of sustainability assessment (i.e., environmental, economic, social but also political and legal). Typical questions, open areas and problems within these dimensions have been short-listed and each partner will introduce their approach, in order to identify concordances and differences and achieve harmonisation. Some examples of these areas are shown in Table 2:

Table 2: Dimensions of sustainability and examples of potential harmonisation areas

Environmental	**Economic**	**Social**
Attributional/Consequential LCA	Currency	Geographical coverage
System boundaries	Price indices	Functional unit
Indirect land use changes	Costing method (e.g. annuity)	Impact categories
Functional unit	Costing metrics (e.g. IRR)	Indicators
Data inventory (ELCD)	Chain stages	Stakeholders
Regional character	Exchange rates	System boundaries
Allocation between products	Finance scenarios	Allocation between products
Impact assessment (midpoint/endpoint)	Learning rates	Data inventory
Sensitivity analysis	Sensitivity analysis	Sensitivity analysis

First results of this promising procedure are scheduled to become available in June 2011.

Calculation of product-specific climate impacts - Product Category Rules

The harmonisation process should aim at establishing common guidelines (developing global standards and systems) for the calculation of product-specific climate or other environmental impacts, in order to make data associated with different kinds of products as comparable as possible in the future. This is the aim of the Environmental Product Declarations (EPDs) and the Product Category Rules (PCRs)[7]. An EPD is a certified environmental declaration developed in accordance with the standard ISO 14025. The EPDs are used for various practical applications. Because different product groups differ in their environmental performance, some specific rules to the product group, so-called Product Category Rules, are also needed. The PCR documents are complementary to general requirements of EPD programmes. The harmonisation of general EPD programme instructions and particularly PCRs is encouraged between programmes to meet the principle of

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[7] *Visit also: http://www.environdec.com/*

comparability. This includes mutual recognition of rules with respect to PCR development, PCR review and verification procedures, administrative procedures and declaration format. To ensure comparability, programme operators are encouraged to work cooperatively to achieve harmonisation of the programmes and to develop mutual recognition agreements (ISO 14025:2006). Specific PCR-development process can be seen as an inevitable phase in the pathway towards comparable quantitative results /27/.

3.6 Outlook

The contribution of a large scale bioenergy strategy to a sustainable energy production has been questioned strongly by several researchers and non governmental organisations over the last years. Scaling up this discussion to a general bioeconomy strategy is already beginning to take place and will undoubtedly affect the development of the biorefinery concept. Social aspects of feedstock production, biodiversity issues, GHG emissions from direct and indirect land use change effects as well as several other aspects are often mentioned in this debate. As biomass and available land area are limited resources, they should be used as effectively as possible to mitigate global warming /28/. Furthermore, ambitious bioenergy and general bioeconomy goals will put significant pressure on the use of biomass resources, a fact which will render the need for sustainability of production and use indispensable. The previous paragraphs presented some policy measures (and associated challenges deriving fro them) that already exist and that could possibly be further expanded as a first basis for a sustainable bioeconomy.

The RED is the core of the policy framework and gives special emphasis on savings of GHG emissions from the production and use of transportation biofuels and other bioliquids, compared to reference fossil fuels. In the RED, an LCA based system has been established for the calculation of the GHG emissions, but it can be questioned, if it is ready to move from an analysis tool to a decision tool. The calculation methodology for selecting the biofuels to be promoted in the EU might not ensure that GHG emissions are reduced and the biofuel production chains with the highest benefits in reducing GHG emissions are promoted /12/. Next to the aforementioned ones (e.g., social aspects, emissions for land use change, etc.) other challenges such as coherent definition of waste and residues, risk for different interpretations among different Member States, expansion of mandatory sustainability criteria to bioenergy in general, illustrate the need for updating the framework.

Sustainability is a multidimensional concept with an environmental, economic, and social dimension. The definition of system boundaries is perhaps the most critical issue when determining the impacts of production and use of bioproducts (e.g. bioenergy) /28/. In principle, implementation of certain sustainability criteria for biomass use is a reasonable target aiming to ensure that the use of biomass is as sustainable as possible /28/. However, due to the complexity of the issue, it is not clear whether there should be only one common set of criteria for all biomass or more specified criteria for various regions, raw materials, and end-use applications. Furthermore, objective measurement of sustainability is a very challenging task. There is a risk that the use of a general methodology and monitoring guidelines for sustainability assessment, could result in the promotion of biomass utilisation significantly less sustainable than desired. Consequently, the need for case-specific and more comprehensive analysis with different perspectives and indicators are obvious. Both micro-level and macro-level analyses are required to ensure that biomass use is as sustainable as possible with regard to its various dimensions. Uncertainties and sensitivities related to the assessment of sustainability should be accepted and considered in both the assessment procedure and in the interpretation of results. Consequently, more attention should be paid on one hand on uncertainty analysis and on the other hand on guidelines on how the uncertain results should be interpreted and utilised in decision-making.

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