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Authors (Organisation)	Luana Ladu, Simone Wurster (TU Berlin), Demetres Briassoulis, Christos Briassoulis, DNRAE (AUA)
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Abstract

The European Bioeconomy Strategy aims at achieving an innovative, resilient and low-carbon economy that replaces fossil raw materials with biological ones, promoting resource efficiency and contributing to a more sustainable economy. Bio-based industries are aware of the need to create trust in bio-based products by implementing suitable measures to support their market uptake and by providing consumers with appropriate information on their characteristics. Eco-labels offer great opportunities to provide such consumer information, and in this report a lists of key eco-label criteria for selected case studies have been considered and analysed. Based on four case studies, the report provides a number of recommendations, which address broader public policy and existing regulations and mechanisms. They also highlight the need to update other independent mechanisms and labels.

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List of Acronyms

Acronym	Definition
(non-)GMO	(non-) genetically modified organism
AöL	Assoziation ökologischer Lebensmittelhersteller
ASTM	American Standard
B2B	Business to business (market)
B2C	Business to consumer (market)
B2G	Business to government (market)
BB	Bio-based
BDO	1,4-Butanediol
CAGR	Compound Annual Growth Rate
CEN	European Committee for Standardization
CEO	Chief Executive Officer
EC	European Commission
EFSA	European Food Safety Authority
EN	European Standard
EOL	End-of-life
EU	European Union
FAO	Food and Agricultural Organisation of the United Nations
FCM	Food Contact Material
GHG	Greenhouse gas
ILO	International labour standards
ILUC	Indirect Land Use Change
ISO	International Organization for Standardization
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
PEF	Product Environmental Footprint
PBS	Polybutylene Succinate
OEF	Organisation Environmental Footprint
PET	Polyethylene terephthalate
PLA	Polylactic Acid
PP	Polypropylene
RED	Renewable Energy Directive
SA	Succinic Acid
STAR-ProBio	Sustainability Transition Assessment and Research of Bio-based Products
UN	United Nation
US	United States
USA	United States of America
USDA	U.S. Department of Agriculture
WP	Work Package

1. Introduction

The development of public strategies and other efforts to stimulate the bioeconomy in the EU have been driven by objectives of achieving technological leadership to drive tangible improvement in Europe's social, economic and environmental welfare (EU Bioeconomy Strategy, European Commission, 2018a). Indeed, the EU Bioeconomy Strategy supports the establishment of an innovative and low-carbon economy that replaces fossil raw materials with biological ones, therefore, promoting resource efficiency and contributing to a more sustainable economy. The push towards a sustainable bio-based economy also derives from the industry, which is aware of the need to create consumer awareness of and trust in bio-based products, by providing consumers with appropriate information on their characteristics. Increased consumer awareness on environmental, social and economic performance of bio-based products would most likely lead to a rise in consumers trust on these products, and therefore, it would result in a positive impact on their market uptake. Eco-labels could help in delivering such information to consumers in a reliable and complete way.

This report identifies the eco-labels of main relevance to bio-based products and lists key criteria to assess the sustainability of bio-based products. Based on specific case studies, the suitability of typical eco-label criteria for various bio-based products is assessed and additional criteria, as well as, new product categories for the EU Ecolabel are proposed. In addition, suggestions to amend certain regulatory measures to better integrate new characteristics relevant for bio-based products into existing regulations and to cover the entire life cycle of the product are proposed. This report is structured as follows: chapter 2 provides information on the research questions, methodology and the selection of case studies and chapter 3 includes information on the general regulatory framework for bio-based products and end-of-life options. Chapters 4 and 5 describe eco-labels and selected labelling criteria. This is followed by an in depth analysis of the current framework conditions linked to selected case studies regarding eco-labels, standards and regulation in chapters 6 to 9. The report finishes with summarized recommendations and conclusions described in chapters 10 and 11.

2. Research objectives and methodologies

The aim of this research is to explore how eco-labels, improvements in the regulatory frameworks and new standards could support the market uptake of bio-based products. For this purpose, we carried out the following activities:

- Analysis of the existing eco-labels landscape
- Identification of case studies and selection of product categories
- Preparation, conduct and analysis of experts interviews
- Development of recommendations for eco-label criteria and the regulatory framework

Analysis of the eco-labels landscape

Based on information in the Eco-label Index, which provides information on 465 eco-labels[1], we identified the most relevant labels for bio-based products. We analysed 42 eco-labels (see annex), including the EU Ecolabel, the German Blue Angel, the Carbon Trust Footprint Label and the Nordic Swan. Detailed information on the eco-labels review can be

[1] It covers 99 countries and 25 industry sectors. Suitable labels were selected by using the following search terms: "bio" (52 hits), "bio-based" (2 hits), biobased" (2 hits), sustainable (34 hits), "construction" (24 hits), "building" (62 hits) "waste" (29 hits) and "plastics" (4 hits).

found in chapter 5. For each eco-label, we identified the criteria needed to grant the label. This research paved the way for the development of the interview structure to be used in the in-depth case studies analysis (see Annex 2).

Identification of case-studies and selection of product categories

The selection of the product categories built on former STAR-ProBio research, in particular on D1.2 (STAR-ProBio, 2018a), that identified bio-plastics for food packaging, bio-based mulch films for agriculture applications and PBS as promising value chains (see Table 1).

Table 1: Overview of value chains and applications

STAR-ProBio value chains and applications	
Food Packaging	bio-based plastics, bio-based packaging films in particular
Agriculture	bio-based mulch films
Fine chemicals	Polybutylene Succinate (PBS) including the fine chemicals 1,4 bio-butanediol and 100% bio-based succinic acid: bio-based food packaging and applications for the automotive sector
Manufacturing building material	bio-based insulation material

As indicated in table 1, in addition to the value chains selected in D1.2, a case study on "insulation material" was included. This decision has been taken considering the attractiveness of the product for environmental issues (energy performance of buildings). Therefore, this is seen as an opportunity to explore synergies between bio-based products and energy efficiency/low carbon economy.

Preparation, conduct and analysis of expert interviews

Carrying out interviews with professionals dealing with analysed products was the following step. The interview guide presented in annex 2 consists of six sections: background of the interviewee(s), framework conditions, eco-labels, sustainability standards, regulatory framework conditions and policy gaps. In addition to open questions, a section included a list of criteria identified in the analyses of the eco-label landscape for deeper analyses on their suitability by the case studies. Interviewees were selected to represent a wide range of stakeholders (see Table 2).

Table 2: Overview of participants to the interview series

Case study and interviewees	Food packaging made of PLA	Bio-based car components	Bio-based mulch film	Bio-based insulation material
Producers, retailers etc.	1	2	5	2
Certification bodies, testing laboratories, standards bodies	1	2	-[2]	-
Procurement (e.g. farmers using mulch film, food sector)	4	[3]	2	-
Other (government, research)	-[4]	2	-	1

[2] The project consortium itself has expertise in this field.
[3] Instead of a public procurer, an expert of a governmental organisation with a specific focus on bio-based car components was contacted (see "Other").
[4] The case study was enriched by an interview with a representative of a big stakeholder network. Due to the high consistency of the results of the first interviews, it was then decided to finish the interview series on food packaging.

The interviews took place between May and September 2018. The results were enriched by the analysis of additional sources provided by the interviewees.

Development of recommendations for eco-label criteria and the regulatory framework

Based on all the gathered information, we finally developed a set of recommendations supporting the use of sustainable bio-based materials and products in eco-labels. Some recommendations also address the improvement or revision of the regulatory frameworks and standards applying to the selected bio-based products.

3. General regulatory framework of sustainable bio-based products

STAR-ProBio's deliverable D9.1 (STAR-ProBio, 2018c) describes the regulatory landscape for sustainable bio-based products based on the analysis of 50 key documents at European and Member State levels. The analysis showed that there is an increasing reference to sustainability requirements and sustainability criteria, increasingly supported by certification and labels.

According to STAR-ProBio (2018c), the policies with direct influence on the bio-based industry mostly tackle single and specific sustainability issues/sectors with high public interest (e.g. biofuels, genetically modified organisms (GMOs), forestry, waste, etc.). Framework Directives also play an important role laying down key principles applying to any product. This document considers specifically the RED, the EU forestry policy and the EU waste policy.

Renewable Energy Directive (RED)

The Renewable Energy Directive provides legally binding environmental sustainability criteria for liquid biofuels and bioliquids. The main sustainability requirements are:

- Greenhouse gas emission saving from the use of biofuels and bioliquids shall be at least 50% compared to fossil fuels (60% for biofuels produced in plants whose operation started after 1st January 2017) (see European Commission, 2018b)
- (Sustainable) biofuels and bioliquids shall not be made from raw material obtained from land with high biodiversity (such as primary forests or highly biodiverse grasslands)
- (Sustainable) biofuels and bioliquids shall not be made from raw material obtained from land with high carbon stock (such as wetlands or forests)

The soon to be revised RED applying after 2021 will expand sustainability criteria to all sectors of bioenergy including heat and power production from solid, liquid and gaseous biomass. This is an important first step to address leakage effects as well as potential market barriers, which result from a limitation of mandatory sustainability requirements to a single sector of the bioeconomy (see STAR-ProBio, 2017a).

The RED is an example for an approach where public regulations recognise private initiatives, such as voluntary certification schemes, as a way to prove compliance with mandatory criteria. In this regard, certification schemes and labels beyond the biofuel sectors could be potentially used to show compliance with sustainability criteria. Precondition for this is the official recognition of the scheme or label by the EU.

This report will analyse the needs for an update of the regulatory framework to better support bio-based products, the need for harmonization of regulations, which address different bio-based products with inconsistent requirements and also to what extend RED criteria are relevant for bio-based products.

EU forestry policy

The policy review of STAR-ProBio deliverable D9.1 has also shown that two sustainability certification schemes, FSC® and PEFC, have become a benchmark for minimum sustainability requirements for forestry and timber products. The schemes play, for example, an important role in public procurement in Germany and Ireland (BMEL, 2018 and Department of the Environment, Community and Local Government, 2012). Details on FSC and PEFC will be provided in chapter 5.

EU waste policy

The Waste Framework Directive promotes the waste hierarchy as a guiding principle. This hierarchy sets out a preference for waste prevention, followed by the sequence reuse, recycling, recovering energy and finally landfill.

The hierarchy does not explicitly address biodegradation or composting, although they are captured by the 'recycling' element. STAR-ProBio considers that within the recycling element, there is another hierarchy: mechanical recycling is the preferred option in terms of material use and preservation, chemical recycling comes next and finally organic recycling (aerobic composting and anaerobic digestions).

Source: European Parliament and Council of the European Union (2016)

Figure 1: EU waste hierarchy

Although little product-specific legislation addresses end-of-life management preferences, these depend on the product application. Some pieces of legislation tend to favour mechanical recycling (packaging related legislation), some others tend to promote preparation for reuse and mechanical recycling (WEEE Directive), some combine the promotion of waste prevention and organic recycling (such as the Directive 2015/720/EU on plastic carrier bags).[5]

4. Eco-labels

4.1. Introduction to eco-labels

The international standards organisation (ISO), defines a label as a "tag, brand, mark, pictorial or other descriptive matter, written, printed, stencilled, marked, embossed or impressed on, or attached to the packaging or container of a finished manufactured product." (ISO 21371:2018(en), 3.1). The aim of product labelling varies according to the context in which the label is placed. For example, product ingredient lists on food provide information on what is present in the product, whereas the EU Energy Label provides information on

[5] This Directive aims at reducing the overall consumption of plastic bags while, for the residual amount of plastic bags on the market, promoting the use of biodegradable plastics bags and making them more easily recognisable for consumers.

the energy efficiency of a product. In this report, we focus on product labelling as an instrument for promoting markets for products with specific characteristics. Such labels offer potential buyers the possibility to select a product based on features that would otherwise remain unobservable or very difficult to assess. Labelling also offers the basis for a markup (or premium) in price compared with similar products, if the label maintains a certain level of credibility and trust and is well accepted by consumers (Sejo's and Swallow's (2002) article discusses this in detail).

Labelling can address many issues including:

- environmental sustainability which covers protecting and preserving the environment
- social sustainability, which identifies the needs of individuals and their well-being and covers a range of issues from social inclusion to eradicating poverty
- safety and health, through demonstrating compliance with safety requirements and providing health relevant information, such as content of hazardous substances
- animal welfare, which shows species-appropriate keeping and treating of animals

Labels can be used as compulsory or voluntary instruments. Compulsory versions are "increasingly used to communicate on nutritional matters, health and safety, country of origin, environment, energy efficiency and ingredient lists" (Retail Forum on sustainability, 2011). The number of voluntary labelling schemes is increasing as well (Retail Forum on sustainability, 2011).

An important category of labels are the eco-labels, defined as "*seals of approval given to products that are deemed to have fewer impacts on the environment than functionally or competitively similar products*" (OECD 1991, 1995, see also Preiss, 1997*).* They address the growing global concern for environmental protection on the part of governments, businesses and public. According to an EU-wide survey conducted by TNS Political & Social at the request of the European Commission, Directorate-General for Environment (2012) and involving 26,568 persons in the EU, *most people are willing to consider environmental factors when making purchases*. For such reasons, companies are increasingly using quality seals to communicate environmental product characteristics (see Bröring et al., 2017). However, the above-mentioned survey also shows that *many Europeans don't feel fully informed about environmental product characteristics,* which is an important indicator of the need for improvements in the eco-label landscape.

As the overview reported in table 3 shows, ISO distinguishes between three types of eco-labels:

Table 3: Eco-label types

Source: own figure based on Retail Forum on sustainability (2011)

Label and characteristics	Type I: Environmental labels (classic eco-label)	Type II: Environmental claims (self-declared certification)	Type III: Environmental Product Declarations (EPDs) of the environmental quality of a product
Standard	ISO 14024	ISO 14021	ISO 14025
Main application	B2C, B2B, PP	B2C, B2B	B2B, (B2C)
Life cycle perspective	Yes	No	Yes, through LCA
Environmental criteria	Claims are based on Multi criteria set by third parties	Single attributes claims are based on self-declarations by manufacturers or retailers	Claims consist of quantified product information based on a full life cycle impacts
Verification	Yes, 3rd party private or public bodies	self-declaration by manufacturers or retailers	3rd party for B2C
Examples	Nordic Swan, Blue Angel labels, EU Ecolabel	Energy Star, SCS recycled content	Eco-profiles, Environmental Product Declaration (EPD) systems e.g. Swedish EPD

Type I eco-labels are the strongest ones (Stichnothe, 2018). Three relevant multi-issues eco-labels based on ISO 14024 type I in Europe include: the EU Ecolabel, the Nordic Eco-label, and the Blue Angel eco-label. Specific product categories that include bio-based products under these labels are lubricants, sanitary products, food disposables, and office materials. Type II (ISO 14021) claims are based on self-declarations by manufacturers or retailers. Type III labels do not set any thresholds and do not claim overall environmental preferably. They enable to prove the fulfilment of one product characteristic (being biodegradable, or bio-based) but do not claim overall environmental preferably provide information on a product as a whole.

Effects of eco-labels

According to OECD (2005) and Bröring et al. (2017), eco-labels have the following effects on various stakeholder categories:

- effects on producers: manufacturers are "increasingly demanding proof of their products' environmental soundness in order to prevent future liability or negative publicity"
- effects on consumers and consumer behaviour: most European consumers are willing to consider environmental factors when making purchases
- market effects: by building consumers awareness on environmental issues and by influencing consumers' behaviour, eco-labels can be used to stimulate market development. For certain products, they have the power to translate "environmental concerns" into market advantages and therefore they encourage demand/supply of products and services that cause less stress to the environment
- environmental effects: positive environmental effects are a key goal of eco-labels. Example-based evidence for positive effects is, for instance, provided by the overview of OECD (2005). The analysis, based of 10 studies on the effect of specific eco-labels, lead the authors to state: "it is found that most eco-labels have a positive effect on the environment"

Nevertheless, there are also potential negative effects such as increased consumption. It is argued that "consumers that change their purchasing behaviour to purchase 'green products' can be led to believe that they have 'done their bit' for the environment […], which could result in consumption levels continuing to increase rapidly over time."

According to OECD (1997), "the environmental benefits of eco-labelling will be achieved when a balance is reached between the number of eco-labelled products and the stringency of the criteria." In general, eco-label criteria are set so that only a small percentage of products in a product category (typically, 5 to 30%) can meet these criteria.

4.2. Eco-labels for bio-based products

An overview of eco-labels suitable for bio-based products, added by detailed information on each eco-label is provided by the Fachagentur Nachwachsende Rohstoffe e. V. (FNR). As Figure 2 shows, the majority of the relevant eco-labels for bio-based products refer to textiles, wood products and various other areas, while the specific products of interest for STAR-ProBio (mulch film etc.) need further research. In particular, issues regarding bio-plastics, waste and sustainability require further considerations. For this reason, a detailed analysis of eco-labels was conducted. The results are presented in chapter 5.

Blauer Engel: labels a large number of environmentally friendly products, is the best-known German environmental seal.	Best-Siegel: labels textiles made of 100% natural fibres.	Bluesign: labels textiles that are produced in a particularly sustainable way.	Cradle to Cradle: labels products that are particularly easy to recycle and environmentally friendly.	DIN Geprüft: labels products that are based on renewable raw materials.
Eco Control: labels natural cosmetics that consist of ecologically grown raw materials.	ECOCERT: labels ecological detergents with at least 95% ingredients of natural origin.	EU Ecolabel: labels a wide range of environmentally friendly products and is the European eco-label.	FSC: labels wood and paper products from sustainable forestry.	GOTS: labels textiles consisting of 70% organically grown natural fibres.
HOLZ VON HIER: labels wood products from regional sustainable forestry.	IBO-Prüfzeichen: labels environmentally and health-compatible building products.	Natureplus: labels sustainably produced building products with a high proportion of NAWARO	Naturland: labels in addition to food also textiles made of natural fibres from ecological cultivation.	Nordic Ecolabel: labels a variety of environmentally friendly products from Scandinavia.
OEKO-TEX®: labels textiles that have been tested for harmful substances and produced sustainably.	Österreichisches Umweltsiegel: labels a variety of environmentally friendly products from Austria.	PEFC: labels wood and paper products from sustainable forestry.	Seedling: labels biodegradable products.	Vincotte - Ok biobased: labels products with a high proportion of renewable raw materials.

Source: FNR, own translations and figure

Figure 2: Selected eco-labels for bio-based products

An interesting approach outside Europe is provided by the U.S. BioPreferred programme, managed by the U.S. Department of Agriculture (USDA), which combines specific guidance for public procurers with a labelling initiative (Figure 3) to encourage the purchase of bio-based products.

Source: USDA

Figure 3: The USDA BioPreferred label

According to USDA (2018a, b), the programme has two major parts:

- Mandatory federal purchasing requirements for federal agencies and their contractors: to date, USDA has identified 109 categories of bio-based products with mandatory purchasing requirements, with minimum bio-based content standards
- The USDA Certified Bio-based Product label, a voluntary labelling initiative for bio-based products, designed to provide useful information to consumers about the bio-based content of a product based on third party product certification

A product must meet or exceed the minimum bio-based content percentage in its given category in order to be qualified for certification (see chapter 5). Products belonging to those categories for which the minimum bio-based content requirement has not yet been established, must contain at least 25% bio-based content.

5. Selected eco-label criteria

5.1. Introduction

A key aim of STAR-ProBio's activities is to identify suitable eco-label criteria for further promoting sustainable bio-based products and ingredients. While a few of those criteria and indicators can already be found in several eco-labels, an overview of additional suitable eco-label criteria for promoting sustainable bio-based products is a result of this research.

This chapter provides a summary of relevant existing criteria in selected eco-labels, which are grouped as follows:

a) Sustainability criteria include:

- Environmental criteria, such as sustainable sourcing of biomass, greenhouse gas emissions, toxicity, durability end-of-life options, added by considerations on re-usability and reparability
- Social criteria such as corporate social responsibility and fundamental principles at work
- Economic criteria, in particular regarding costs and efficiency

b) Additional criteria include:

- Percentage of bio-based product content
- Percentage of bio-based content in packaging
- Fitness for use

A specific approach to consider various criteria is provided by life cycle assessments (LCA). The application of LCA varies between the different label types. Type III labels, which may build on a single criterion or multi-criteria sets, use LCA but do not provide thresholds. Type I labels use multi-criteria sets but do not use LCA, although covering the entire life cycle of a product. Unlike type III labels, they require thresholds. LCAs are considered in detail in section 5.4.

5.2. Sustainability criteria

5.2.1. Sustainable sourcing of biomass

The RED has established clear requirements on sustainable sourcing of biomass in the field of bio-energy and its compliance is encouraged by monetary incentives. The markets for bio-based products do not have such guidelines. According to UBA (2018), regulation/sustainability certification for material use of bio-based raw materials is missing in Europe.[6] Nevertheless, there are label pioneers, who deal with sustainable sourcing in the assessment of bio-based products. A good example is the Roundtable on Sustainable Biomaterials (RSB). Based on its sustainability requirements, the RSB Principles & Criteria (RSB-STD-01-001), any biomass producer and industrial operator in the scope of certification shall follow the principles shown in Table 4:

Table 4: RSB's sustainability principles

Source: own overview based on RSB-STD-01-001

RSB's sustainability principles			
1 Legality	4 Human and Labor Rights	**7 Conservation**	**10 Air**
2 Planning, Monitoring and Continuous Improvement	**5 Rural and Social Development**	8 Soil	**11 Use of Technology, Inputs, and Management of Waste**
3 Greenhouse Gas Emissions	**6 Local Food Security**	**9 Water**	**12 Land Rights**

According to the principle 7 on conservation, operations shall avoid negative impacts on biodiversity, ecosystems and conservation values.

In addition, it is important to mention the following certificates, which include relevant sustainability principles: ISCC PLUS, FSC®/PEFC (see STAR Pro-Bio, 2018c). PEFC also includes social criteria (see section 5.2.6) and requires that genetically modified organisms are not used.

[6] UBA adds that the German Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz BMELV supports the "Initiative for the Sustainable Supply of Raw Materials for Material Use" (INRO), which is coordinated by an external policy consulting office. INRO is not intended to develop new systems, but to make existing systems or systems in development applicable in the material field. The aim is to reach a voluntary agreement. Whether this is sufficient is questionable from UBA's point of view.

5.2.2. Greenhouse gas emissions (GHG)

The measurement of GHG emissions is often used as a proxy to measure the impact of a product or process on climate change. GHG emissions are also often accounted for a life cycle perspective and used in various Type III labels, such as the Carbon Trust Footprint Label. Accordingly, the Ecolabel Index includes 25 eco-labels that focus on the carbon footprint of products or processes[7].

Different options are available for measuring GHG emissions. Some schemes focus on verifying GHG emissions reductions of specific products when compared to a baseline. This is the case of all the schemes recognized by the EU in the RED, such as RSB, or ISCC Plus, which provide requirements that enable quantifying the GHG emissions of the production of biofuels compared to fossil ones.

Some schemes, such as the Carbon Trust Footprint certify that a product, process or company's carbon footprint is quantified, managed and implements measures to reduce it.

Some other schemes, such as CO_2 neutral, indicate that a product, process or company is carbon neutral, meaning that all GHG emissions caused by this product, process or company is compensated by the creation of carbon sinks (e.g. afforestation programmes) corresponding to the emissions. The variety of options shows the need for detailed information on how to account for GHG emissions in an eco-label.

The scope of GHG emissions covered by the scheme is also a key element. The vast majority of existing schemes do not take into account indirect land use change emissions (see STAR-ProBio 2017a and 2018b). Following the adoption of the RED in 2009, the question around GHG emissions caused by iLUC started to emerge in the EU. This led to the adoption in 2015 of an amendment to the RED that introduced iLUC factors on biofuels per feedstock that Member States were to use for reporting purposes. The quantification of such emissions was and remains the biggest issue. The importance of this debate also led several schemes to develop methodologies to reward low iLUC risks, such as the RSB low iLUC risk biomass programme.

The use of biomass in products may help reduce the global warming potential of our economy. Open-Bio (2016), for example, has shown that various bio-based products have the advantage of a lower CO_2 footprint during production compared with alternative fossil-based products.

Referring to bio-based plastics, CE Delft (2017) highlights the advantages of bio-based products in this context specifically: "Compared to fossil-based plastics, most biobased plastics realise a reduction in climate change impact. The type of raw material that has been used influences mostly the cradle-to-gate climate change impact. Also the type of electricity being used in the production of bio-based plastics can have a significant influence, while the transportation distance of the raw materials is insignificant (…)" (p. 62). CE Delft (2017) further suggests that a sustainability scheme for bio-based plastics could set targets for GHG emission reduction with a view to minimise (in)direct land-use change. Life cycle aspects are discussed further chapter 5.4.

[7] A quick search in the Ecolabel index showed about 25: (see http://www.ecolabelindex.com/ecolabels/?st=category,carbon) [last consulted on 15 October 2018]

5.2.3. Toxicity

According to the standard EN ISO 472:2013 Plastics – Vocabulary, the term toxicity refers to the ability of a substance to produce an adverse effect upon a living organism.

As mentioned in the previous section, various labels consider toxicity as a criterion (e.g. toxicity to aquatic organisms is considered in different categories of the EU Ecolabel). The label ÖkoControl requires that "Substances with certain classification may not be used in the products (e.g. very toxic, toxic, etc.)" (source: internal eco-label database).

The label OK biodegradable SOIL formulated the following recommendation: "*All food additive approved ingredients are regarded as fulfilling the compost quality requirements. This must be verified for all constituents that are not tested for ecotoxicity, do not appear on the positive list and are not food additive approved ingredients"* (source: internal eco-label database).

5.2.4. End-of-life criteria

The importance of end-of-life criteria for consumers interested in green products is shown by various studies, e.g. TNS (2012). Depending on product properties and on what substances they may contain, a number of end-of-life options can be considered for bio-based products. More specifically, the end-of-life options for bio-based products include:

- mechanical and chemical recycling
- organic recycling (biodegradability in soil, fresh water and marine water, compostability – both industrial and home composting, anaerobic digestion)
- incineration
- disposal to landfill

An analysis of existing end-of-life options led to the following results:

Mechanical recycling: Effective recycling requires clean and homogenous material streams, whereas the type of material (fossil-based or bio-based) does not play such an important role. Currently, the only bio-based materials specifically required to be recycled or composted are household packaging (paper, cardboard and wood) and construction and demolition waste (not specific to wood or other bio-based materials). However, the need for clean materials for recycling often excludes much food packaging because they are 'contaminated' by food residues.

Organic recycling: EU Packaging and Packaging Waste Directive 94/62/EC allows for and defines organic recycling as "the aerobic (composting) or anaerobic (biomethanization) treatment, under controlled. A material could be organically recycled if it is biodegradable or compostable under specific processing conditions.

Usually, organic recycling (including composting) is not the first end-of-life (EOL) option but follows after mechanical recycling. There are however, some specific applications for which a targeted EOL option is the only possibility and the products are designed to follow that option. A specific example for this is mulch films, which should be biodegradable in soil.

Incineration with or without energy recovery: Although the EU Waste Framework Directive includes incineration as part of the waste hierarchy, no legislation exists that encourages incineration as an end-of-life option.

Littering: Unfortunately, large quantities of food packaging ends up uncontrollable in the environment. Researchers estimate that food packaging debris add up to 31% of the plastics in the sea.

The EU Ecolabel, for example, includes end-of-life criteria as follows:

- percentage of recycled material of the packaging or the products shall be biodegradable or compostable (e.g. footwear)
- biodegradability (e.g. for rinse of cosmetics fulfilment of strict biodegradability requirements is required).

A number of labels address only specific stages in the life cycle. For example, the Compostability Mark of European Bioplastics (Figure 4) is specifically focused on the end-of-life stage.

Source: European Bioplastics

Figure 4: Seedling logo of European Bioplastics

Likewise, OK biodegradable SOIL guarantees that the products with this label will completely biodegrade in the soil. It specifies a set of adverse effects on the environment and ensures that these effects do not occur.

These labels provide information on the recyclability, compostability or biodegradability of a product, without considering other product attributes. Life-cycle-based eco-labels usually include criteria on end-of-life management, to communicate to consumers that recycling or composting is preferred to other management options located lower on the waste hierarchy. Given the partial or total biological origin of bio-based products, their end-of-life management can be important so as to avoid losing materials that can more naturally be returned to biological cycles. Indeed, the waste hierarchy encourages the prevention of waste or the return of materials into the economy, which has to be considered specifically in the prioritisation of end-of-life options.

It is important to highlight that not all bio-based materials/products are automatically biodegradable or compostable and that such treatment could also mean the loss of potentially reusable materials and/or the transfer of potentially problematic substances to environmental media such as soil or water. It is also important to note, that not all biologically sourced materials can be added to biological cycles. Besides this, fossil-based plastics can also be biodegradable, since biodegradability depends on the structure of the polymer chain.

5.2.5. Further considerations: durability, re-usability and reparability

Figure 1 presented a pyramid with priorities for end-of-life options with the separate goal waste prevention, reuse of goods coming first. Numerous LCA studies have shown that the environmental and economic costs of disposable products is overall significantly higher than the cost of reusable goods whenever reused a certain number of times[8].

The durability, reusability and reparability of a product are often linked: it is very likely that a reusable product is also designed to last longer (by opposition to a single use product) while and easily repairable product will also likely last longer. Although products will show their ability to last longer, being repaired and reused only at the use phase of the life cycle of the product, all three characteristics depend on choices made by producers when designing their products. This is why, making a systematic link between the design of the

[8] To name but a few: McGain, et al. (2010) and Jewell (2014)

product (for instance, its ability to be disassembled easily, without having to break components or to be upgraded) and its use by consumers (for instance, facilitate the actual repair of the product) is important.

From a regulatory perspective, there are three ways to increase the durability, reusability and reparability of products: either by disincentivizing the placing on the market of short lasting, single use products, or by providing information to consumers to make better-informed choices or by encouraging long-lasting, reusable and easily repairable products. The EU and the EU Member States are tackling the issue from both ends:

1. Disincentivizing the placing on the market of short-lasting, single use products

The 2015 EU Directive on lightweight plastic bags is a good example of a policy whose prime objective is to reduce the overall consumption of single use plastic bags by defining a maximum annual consumption level (90 lightweight plastic carrier bags per person by the end of 2019 (a 50 % reduction compared to 2010)) and ensuring that, by the end of 2018, lightweight plastic carrier bags are not provided free of charge at the point of sale of goods or products. In October 2018, the European Parliament approved the Directive on marine pollution and single-use plastics, which imposes a ban on plastic cutlery and plates, cotton buds, straws, drink-stirrers and balloon sticks.

Commission proposed banning from the EU market as of 2021 specific single use plastic products for which longer-lasting alternative exist. This proposal currently targets products such as single use plastic cotton buds, cutlery, plates and straws and is under discussion in the European Parliament and the Council.

2. Ensuring appropriate framework conditions for the market of long-lasting, reusable and repairable products

In a reflection on material efficiency started in 2016, the European Union is also looking into the measurement and promotion of durable and repairable energy-related products under the Ecodesign framework. Although a small proportion of products covered by the Ecodesign Directive are relevant to the bioeconomy – mostly casing of electrical and electronic appliance – the reflection around material efficiency can be generalised to all products. An attempt to assess the durability, reusability and reparability of products is currently taking place within the CEN-CENELEC Joint TC 10 on 'Material Efficiency'. Important aspects in this regard are for instance the ability of a product to be disassembled, the availability of spare parts, or easy access to repair manuals for repair operators.

3. Providing information to consumers to make better informed choices

The Gallup Organisation (2009) found that the most important information gained from environmental labels is whether it is possible to reuse or recycle a product. Similarly, a recent study for the European Commission found that consumers provided with information on durability and reparability of products in the place of purchase are almost three times more likely to choose products with the highest durability on offer, and more than two times more likely to choose products with the highest reparability ratings (see European Commission, 2018c). The study further recommends to '*(1) integrate durability and reparability information into existing (EU) labels; (2) Develop new EU rules for this purpose'.*

5.2.6. Social criteria

Social eco-label criteria address general social issues as well as specific working conditions of the employees, who work in the various value chains of the entire life cycle of a bio-based product. An important social aspect to be considered is "food security", which is also mentioned as one of the SCAR's five principles for the bio-economy (see European Commission, 2015) and also considered, for example, by RSB (see chapter 5.2.1).

Furthermore, according to BBMG et al. (2012), the majority of the consumers worldwide regard it is extremely important that companies care for:

- safe drinking water as part of their products, services or operations (92%)
- health care (87%)
- fair wages and safe working conditions (87%)
- jobs and economic opportunity (86%)

The majority of eco-labels have a strong focus on environmental aspects, compared with social and economic ones. Indeed, there are only few examples of eco-labels that include social criteria. One of them is the EU Ecolabel, which in the categories "Textiles and footwear" and "Personal care products - absorbent hygiene products", requires corporate social responsibility to respect "fundamental principles and rights at work." As described in the International Labour Organisation's (ILO) Core Labour Standards, the UN Global Compact and the OECD Guidelines for Multi-National Enterprises shall be observed by production sites along the supply chain used to manufacture the licensed product(s). As another good practice example, it is important to mention that PEFC does not only require food security (PEFC principle 6) but also to respect human and labor rights (principle 4), demanding:

- freedom of workers to organise themselves and their representative and to negotiate with the employer
- no forced and child labour
- equal employment opportunities and equal treatment for all workers
- working conditions that do not affect occupational safety or health (see PEFC, no date)

The Cradle to Cradle® label considers the social impact of product cycles and production. More information in this regard will be given in chapter 5.4.

The history of the RSPO certificate (see EIA, 2015) showed the importance of not only formulating social sustainability criteria but also of assessing compliance appropriately.

5.2.7. Economic criteria

According to the OECD definition presented chapter 4, eco-labels are mainly seals that show environmental impacts of products. While our analyses also unveiled many social criteria, economic criteria are used very rarely in the current eco-label landscape.

This section presents three economic criteria. 'Energy efficiency' and 'biomass utilization efficiency' criteria are closely linked to the environmental pillar. However, due to the efficiency aspect, they are presented here. In addition, life cycle costing is briefly introduced. It is a specific horizontal issue, which will be further described in chapter 5.4.

Efficiency of the production stage: the attractiveness of the criterion energy efficiency

While economic criteria are rarely considered by eco-labels, the Cradle to Cradle® concept considers the use of materials, energy and water in the production. The production stage of bio-based products can provide various advantages compared to fossil-based products. Chapter 5.2.2 discussed GHG emissions in this regard.

Based on the example of smart drop-ins, Carus et al. (2017) highlight that the production of bio-based products may require significantly less energy compared with the production of comparable fossil-based products. To show this advantage of relevant bio-based chemicals and products appropriately, the consideration of a specific criterion on the use of energy in the production process is suggested. Specific advantages of these products could be shown by a criterion, which compares the use of energy with a conventional benchmark product.

Biomass utilization efficiency

The biomass utilization efficiency (BUE) factor was developed by Iffland et al. (2015). It is defined as "percentage of initial biomass ending up in the end product based on the molar mass of the reactant (= biomass) and target bio-based product."

The biomass utilization efficiency was also identified as a specific assessment gap in STAR-ProBio's first two tasks, summarized by its deliverable D1.1 (STAR-ProBio, 2017a). According to chapter 5.4, the Cradle to Cradle® scheme considers the use of materials in the production. In this context, attractive options to include assessment criteria to highlight advantages of specific bio-based products exist.

Iffland et al. (2015) found that materials made from vegetable oils and cellulose-derivatives have the best BUE values in a comparison of 30 bio-based feedstocks, processes and products (chemicals, polymers and fuels). Furthermore, the authors found that PLA (polylactic acid) and SA (succinic acid) also exhibit a highly efficient material use of biomass. The examples show the attractiveness of a BUE criterion. It was further analysed in our in-depth case analysis, presented in chapter 6.

Life cycle cost

An additional economic criterion is life cycle cost (LCC). According to Vertech (2014), LCC is a method for evaluating all relevant costs over time of a project, product, or measure. It takes into account: initial costs (including capital investment costs, purchase, and installation costs); future costs (including energy costs, operating costs, maintenance costs, capital replacement costs, financing costs); and any resale, salvage, or disposal cost, over the lifetime of the project, product, or measure (Fuller, 2005). Bio-based products can provide various cost advantages. Regarding the end-of-life stage of plastics, for example, rigid bio-based packaging, together with commercial films, is considered as the market segment that is likely to have the most attractive recycling cost-benefit balance (see WEF, 2016).

The Cradle to Cradle® approach considers environmental and economic aspects. The consideration of life cycle costs provides opportunities to highlight specific advantages of bio-based products. For example, FNR (2017) found that the life cycle costs of ten environmental-friendly products are lower than those of fossil-based alternatives (e.g. flooring, copy and print paper, multifunction devices and cleaning supplies). LCC will be discussed further in chapter 5.4 in a broader context.

5.3. Additional criteria

5.3.1. Bio-based content in products

CEN/TS 16137:2011 (Plastics – Determination of bio-based carbon content) requires minimum bio-based content. It expresses the bio-based carbon content as a fraction of the sample mass, or the total carbon content, or the total organic carbon content.

Bio-based content is already required by some eco-labels. In this regards, two kinds of criteria can be distinguished: i) criteria requiring bio-based content in general; and ii) criteria that require a specific percentage rate of bio-based content.

ÖkoControl as an example for group i demands that all labels for furniture require renewable raw material. USDA provides an example group ii. Another example are the eco-labelled Blue Angel detergents, which should preferentially use sustainable renewable raw materials in their manufacture (see Blauer Engel, 2016). The EU Ecolabel considers bio-based content in various product labels as well. Some labels include even specific categories for bio-based products, for example, SMaRT Consensus and USDA. The categories can include bio-based products exclusively, or, as in the case of SMaRT Consensus Sustainable Product Standards, also have the nature of a mixed category. According to the following subsection, there are even labels, which specify percentage rates for bio-based packaging.

5.3.2. Bio-based content in packaging

Several eco-labels require bio-based content in packaging. Examples can be found in the following table:

Table 5: Examples for bio-based criteria for packaging

Label/product categories		Bio-based criteria and indicators
EU Ecolabel	Coverings - Wooden floor coverings	Packaging: materials taken from renewable resources
EU Ecolabel	Furniture - Wooden furniture	Packaging: materials taken from renewable resources
Blue Angel	Disposables for food	At least 90% by weight of the disposable article must be bio-based or made from recycled plastic

Since many products are sold packaged, opportunities for the implementation of more requirements of these kinds for additional products exist. Section 6 will provide specific findings on food packaging.

5.3.3. Fitness for use

Functionality and performance are key product attributes. Therefore, various eco-labels include a 'fitness for use' criterion. A good example is the Blue Angel label for shampoos with specific indicators and thresholds (e.g. 80% positive responses in tests according to RAL, 2016). According to an interview series conducted in a previous activity of STAR-ProBio, there are stakeholders, who are unsure about the performance of bio-based products, and in particular on their characteristics compared to conventional ones. Therefore, to facilitate comparisons with traditional fossil-based products, a criterion on functionality/performance would be of major importance for raising trust on bio-based products. The use of such a criterion could be voluntarily and product-specific to keep labelling efforts as low as possible.

5.4. Life cycle assessment

Life cycle assessments (LCA) are "compilation(s) and evaluation(s) of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14044). Their foundations are laid by the two general standards ISO 14040 and 14044, while EN 16760 describes how to handle the specificities of the bio-based part of a bio-based product in an LCA. In particular, Environmental Product Declarations (EPDs), which are Type III labels according to the ISO classifications, are a famous direct application of LCAs.

STAR-ProBio highlights the important role of a LCA perspective in assessing the sustainability of bio-based products. Experts interviewed in early stages of the project implementation stressed that many bio-based products perform better than traditional alternative products over their entire life cycle, mostly in terms of important environmental impact categories (for example, end-of-life options and GHG emissions). However, currently existing eco-labels only relate to specific stages in the life cycle, for example, extraction/production of raw materials or end-of-life. In addition, many labels only refer to environmental aspects, and not so much on social and economic issues.

The Blue Angel is an eco-label that considers the entire life cycle, for example for panel-shaped materials.[9] However, it is not specifically for sustainable, bio-based products.

Cradle to Cradle® is a good example of a scheme that considers the whole life cycle of a product with regard to different sustainability dimensions. The scheme design includes a detailed rating key and considers environmental, social and economic issues: the materials used, their viability, the use of energy and water, and the social impact of product cycles and production. It is used for B2B and consumer markets and provides a method to analyse the use of selected end-of-life options for biological nutrients, which seems to be interesting for the STAR-ProBio research.

As a limitation, Bakker and Rever (2008) describe that the "LCA and C2C (Cradle to Cradle) can and should be used as complementary tools" (p.2) but represent different approaches. This means that the opportunities to use the C2C approach to reach conformity with the standards described before is only limited. The need for further research on LCA is even more fundamental considering that there are many open questions. As the project Bio-Mat_LCA highlighted, at the moment no common LCA approach exists. Results vary a lot (see Görmer, 2018 for details). Harmonisation and common calculation guidelines for LCAs are needed to avoid inconsistencies and contradicting results due to the use of different calculation methods.

[9] The relevant documents can be downloaded at: https://www.blauer-engel.de/en/companies/basic-award-criteria

6. PLA food packaging: eco-labels, standards and regulations

6.1. Introduction

Poly Lactic Acid (PLA) is a bio-based biodegradable thermoplastic that can be used in a wide range of applications, including packaging films for fresh food, window films, labels films, overwrap films and twist wrap (see Green & Kunnemann, 2006). This report considers its application for food packaging in particular. This includes lidding and produce packaging, bread bags and bakery boxes, food service items such as cups, plates and bowls; dairy packaging for yogurt and desserts; meat packaging as well as foamed/expanded trays and clamshells. An overview of existing standards, regulations and eco-labels governing potential applications of PLA is provided. In addition, possible recommendations for promoting the use of PLA through eco-labels, standards and regulations are given.

According to Table 2, this case study builds on the views of different stakeholders' categories, including PLA producers, food organisations and restaurants.

The first stakeholder is a producer of PLA. The second one is an organisation that manages 57 canteens, cafeterias and coffee bars and serves around 35,000 guests daily, of which many prefer opportunities to eat lunch quickly. In addition, smaller canteens often do not have sufficient capacity to enable all guests to eat on-site in a short time. Therefore, to-go food must be offered. It makes up a relatively large part of sales. In 2018, the procurement of to-go packaging for cold food changed to focus on PLA-based packaging only. This includes, for example, PLA packaging for salads (mainly) and yoghurt or quark. In some cases, PLA packaging is also used for wrapping sandwiches.

The third stakeholder is an organisation responsible for providing meals for 130,000 students – as full board service or by providing food in cafeterias. Their offer also includes sandwiches and similar products sold in paper packages with a plastic window. Between 800,000 and 1 million sandwiches of this kind are sold per year.

The fourth interviewee represents an organisation, which provides between 25,000 and 30,000 people with food daily, including 12,000 portions of warm meals per day. Its specific focus is the avoidance of waste of any kind. For this reason, this interviewee did not specify eco-label criteria for short-life bio-based products but provided very useful recommendations regarding the regulatory framework on the durability of products and additional measures in the society to make it more sustainable.

The fifth stakeholder is an association of twelve organic food producers and the product considered was PLA-based packaging for organic food.

The sixth stakeholder belongs to the stakeholder group "certification, related laboratories, test houses, standards bodies." It is a certification laboratory specialized in EOL issues.

6.2. Eco-labels

An important eco-label for bio-based food packaging applications is the Nordic Swan, which also considers products that are partly bio-based. For example, the requirement "material composition" of the category "disposables for food" demands that at least 90% by weight of the disposable article must be bio-based or made from recycled plastic. Another important label is the EU Organic Label (EC No 834/2007 and EC No 889/2008).

State of the art

Two important analyses are provided by Sengstschmid et al. (2011) and Scuola Superiore Sant' Anna and Ökoinstitut (2018).

Sengstschmid et al.'s (2011) feasibility study on a EU Ecolabel for food and feed products revealed that a credible environmental label for these products should provide an indication that a product is processed and packaged in an environmentally-friendly way. Potential product groups suitable for an introduction of an EU Ecolabel for food, feed and drink would be: dairy, bread, non-alcoholic beverage and processed fish products. In principle, organic food might provide specific advantages for a label for bio-based packaging due to the specific focus of the buyers.

The feasibility study of Sengstschmid et al. (2011) suggests an integration of packaging-related criteria in food labels. Regarding separate labels for the packaging, it highlights risks of double labelling, referring to potential confusions on the side of the consumers. Nevertheless, practical examples for food packages, labelled with specific packaging labels exist. For example, the German brand "Gutes Land" offers organic milk, whose package includes, in addition to the WWF label for the product, a specific label for the packaging.

By the time the study was published, the Commission was "not intending to develop Eco-label criteria for food and feed products at this time. However, it was communicated that the Commission could, however, revisit this question at some point in the future considering the possible role of the EU Ecolabel within the framework of the development of a wider EU food strategy" (European Commission, 2011).

Seven years later, Scuola Superiore Sant' Anna and Ökoinstitut identified a change in the framework conditions and new opportunities to establish an eco-label for food as a possible "window of opportunities for the EU Ecolabel in the transition to the circular economy":

> "The inclusion of food and catering services together with the EU Organic Label (...) may contribute to establish an overall and harmonized approach on food." (Scuola Superiore Sant' Anna and Ökoinstitut, 2018).

An advanced approach to assess PLA and other bio-based packages is, although not used for an eco-label, provided by the Biokunststofftool of the Assoziation ökologischer Lebensmittelhersteller (AöL). However, according to our interview series, its content could be used to support the development of an eco-label in the future. The Biokunststofftool (AöL, 2018) is a web-based software tool that provides "decision support for assessing and comparing bio-based packaging" (AöL, 2018, translated). It evaluates PLA-based food packaging based on four dimensions shown in Table 6:

Table 6: Assessment criteria of the Biokunststofftool

Source: own table based on information at biokunststofftool.aoel.org not presented in table form

Ecology	**Social sustainability**
- land use/food competition - environmental friendly farming - certified farming - gene technology - End-of-life (recycling, composting) - life cycle assessments - bio-based content	- social standards in cultivation - Social standards in processing
Safety and technology	**Quality**
- migration and interaction - machine requirements - barrier characteristics - other	- legal requirements - product requirements - consumer requirements - marketing - Stability and handling - other

Annex 5 summarizes the information on PLA provided by this assessment tool. Additional criteria of the Biokunststofftool refer to marketing, stability and handling as well as other issues although this is not linked with specific requirements. In summary, the previous work of AöL as well as its assessment methods and data provide valuable input for STAR-ProBio future work.

Eco-label criteria

The interviewees' views on specific sustainability criteria are summarized in Table 7. As indicated, all criteria are regarded as relevant by the majority of them.

Table 7: Relevance of selected eco-label criteria for PLA food packaging

Assessment criteria	Relevance according to the interviews on food packaging	Assessment criteria	Relevance according to the interviews on food packaging
Sustainable biomass		Social criterion "fundamental principles and rights at work"	
CO_2 emissions		Energy requirement during production	
Toxicity		Biomass utilisation efficiency	
End-of-life options		Life cycle values	
Fitness for use		Life cycle costing specifically	
Social criterion corporate social responsibility			
Legend: relevant in > 50% of the interviews; not relevant > 50% of the interviews; relevant in 50% of the interviews,			

Regarding **sustainable biomass**, interviewees highlighted the importance of environmental criteria for the cultivation of land, the role of land use and transparency regarding the origin of the biomass, and to consider the environmental effects of transportation. Transparency of farming practice, in particular regarding the use of pesticides is also important. Sustainable biomass of food packaging is taken into consideration by existing certificates, such as ISCC PLUS and Bonsucro and should be considered as best practices for further certification schemes. With the packaging for bio food specifically, two particular issues were highlighted: "No GMOs and controlled agriculture (although not on eco agriculture because this does not provide enough yield)." The option to make PLA of residues also promotes goals such as biodiversity as well as the protection of forests and the nature in general.

Regarding **CO_2 emissions**, it was suggested to set the main focus on the production stage. Thresholds are needed.

Toxicity, meant as human toxicity, influencing the health of the consumers, was a specific issue. It was highlighted that "the packaging must not contain any substances, which could be transferred into the food" and that "toxic gases must be avoided." As a general challenge, it was stressed that the packaging has to fit to the specific food because the toxicity values for different packaging-food combinations vary. Four indicators to measure toxicity issues were specified: vapour permeability, O_2 penetrability, nature of additives and the risk that something can diffuse into the food. The various kinds of food set different requirements regarding vapour permeability and O_2 penetrability while PLA is suitable for all kinds of food.

Regarding **End-of-life options** and circularity, three issues were highlighted with regard to the recycling of PLA: Can the recycled PLA offer the same characteristics as the original

PLA, which colour should the material have and, because thin packages may facilitate the recycling, which thickness is appropriate?

To ensure an efficient recycling of PLA-based packaging, it was also stressed that a minimum amount of PLA is needed. The use of water was mentioned as a specific issue in the EOL context. PLA assimilates water, including the cleaning water, which makes recycling more complex compared to fossil-based products.

Industrial composting, conducted in a quick manner, is also regarded as useful and seen as the appropriate composting option for PLA. In contrast to this, appropriate scientific data on the effects of cellulose composting on compost piles at private homes do not yet exist, as one interviewee described. If the products end up in the waste to be incinerated, it must be ensured that releases of toxic gases are avoided. Interviewees also suggest an assessment criterion on which information and guidance for the EOL is given to the users.

Regarding **fitness for use**, the interviewees were not only in favour of this criterion, they also described useful assessment items in detail. The quantity/weight for which the PLA packaging is suitable, is to be indicated, e.g. for 300 ml of liquid food or drinks. Food-specific barrier criteria have to be specified as well. Emphasizing the findings for the toxicity criterion, it was highlighted that PLA is suitable for packaging all kinds of food although it not for hot food and beverages.

In contrast to several other case studies, interviewees were in favour of both **social criteria**. By mentioning i) cultivation, harvesting and use as well as ii) the producers of the biomass and the ones of the packages specifically, it was shown that social criteria have to be considered for various life cycle stages, e.g. based on the international labour standards (ILO). Under social life cycle considerations, it was regarded as useful that (PLA) manufacturers and suppliers also indicate their sources of supply.

As shown at the beginning of this chapter, ISCC PLUS, SEDEX and Bonsucro can be used to give proof of sustainable farming of PLA biomass in the food package context. Considering these labels, which are also relevant for assessments against environmental criteria, could be beneficial. However, it should be emphasised that AöL allocates these labels mainly to the farming stage, which shows a gap regarding later stages in the product life cycle and supply chain.

As shown before, ILO standards were mentioned as important documents. Many organisations follow these standards organisation-wide, and not only related to bio-based products. The attractiveness of demanding compliance to ILO as well as the formulation of additional social requirements remains an issue for further work here.

The number of additional comments on the **energy criterion** were limited in the interviews. However, the importance of considering the whole production chain, starting with the farming stage was highlighted.

In addition to the support of the **biomass utilisation efficiency** criterion, facilitating comparisons with alternative packaging options was suggested.

The support for the items **life cycle values** and **life cycle costing** specifically was described in various ways. For several providers of final packaging products, carbon footprint evaluation is relevant, meaning also that they require LCA-related information from the providers of intermediate products.

Additional assessment criteria are described in the section on standards. As discussed below, the interviewee, who provided this input, favours the creation of a standard instead of a label.

Eco-label options

The question on the need for a separate eco-label for food-packaging was an important issue in this interview series. A variety of opinions, shaped by the specific situations of the different interviewees, was observed in this regard.

One interviewee, who offers mainly intermediate products, was not aware of a need for an eco-label on their specific value chain stage. Instead, certificates such as OK compost INDUSTRIAL, OK BIOBASED and the Seedling logo are important for their intermediate product. They are required because certified intermediate products facilitate the certification of the final ones. It is interesting to note that this need for certificates for the *final* products was highlighted specifically.

Another interviewee, whose organisation procures packages separately to package fresh food on its own, would regard an eco-label as very useful for internal buying decisions. A third interviewee, who referred to pre-packaged food mainly, is more focused on the end consumer and wants to avoid an additional label on the packaging (see also Sengstschmid et al. (2011) for this viewpoint). Alternatively, it was suggested that all relevant characteristics could be considered through, using product information material. The first example is different in that way that the label would mainly support procurement decisions of organisations, which procure food and food packaging separately. In summary, several members of the demand side of the market would regard an eco-label as very useful. One interviewee regards existing alternative certificates as sufficient but highlighted that the customers need additional labels for the *final* product.

As mentioned before, Sengstschmid et al. (2011) suggest integrating packaging-related criteria in food labels. An interviewed expert recommended creating a standard that provides all relevant requirements. Simultaneously, this suggestion can serve both options and should be favoured: a standard with requirements can be used for an individual assessment *and* eco-labels but it can also be used for other certificates and tools, also including the SAT-ProBio blueprint, which is planned as one of STAR-ProBio's main outcomes.

Considering food packaging based on non-plastic material, an expert suggested before the conduct of this interview series to explore options to promote bio-based products through the inclusion of relevant assessment criteria in the lists of the labels FSC (see e.g. http://www.fsc-deutschland.de/de-de) and PEFC (see e.g. https://pefc.de/). Both labels have a specific focus on forest products. Nevertheless, this suggestion is significant in the given context.

Intermediate PLA products can be integrated in such packages and, in particular, bags. The interview series included the discussion of an organisation's example, which sells up to 1 million food products in such packages per year while opportunities to offer such bags with bio-plastic windows and/or related labels were unknown.

Another interesting issue is a consumer view in a general stakeholder discussion by STAR-ProBio. Mentioning recycling problems of these bags made of paper and plastics and highlighting a need for action was regarded as important.

Independently of this, an expert recommended an extension of the paper label PEFC to other application areas. There are paper bags with windows for bread, rolls and similar products, which are PEFC certified for the paper part, visualized by a logo on the bag. Examples of the various organisations, which provide such food bags to be filled with bakery products by their clients, are for example, the supermarket chain Netto with 4,200 stores according to Netto (2018) and the Berlin-based supermarket Ullrich, which also sells fresh bakery products, as well as having a bakery in the same building.

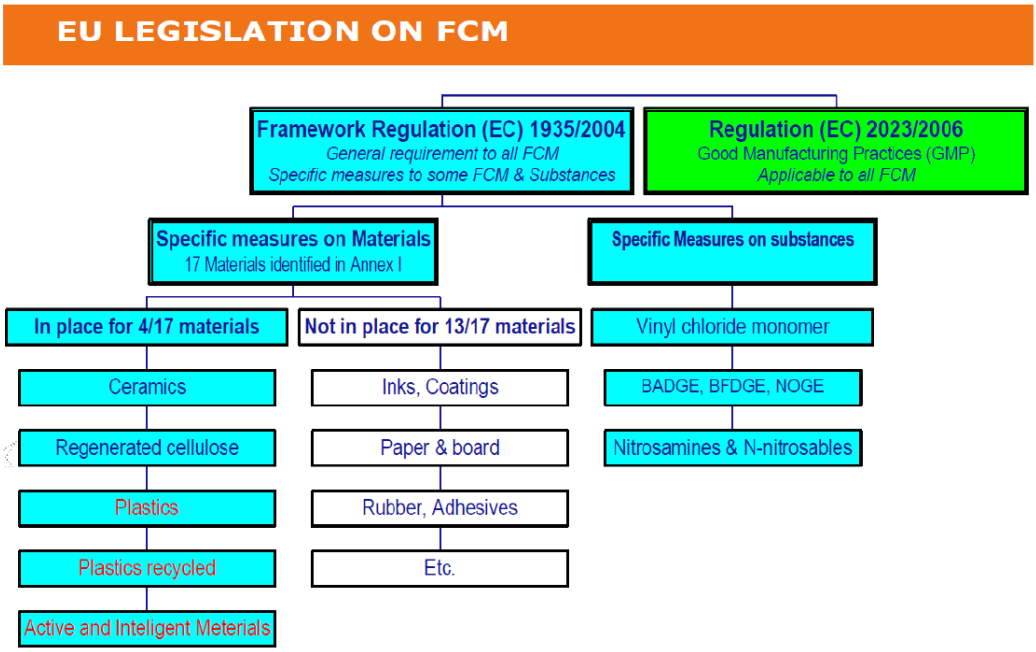
PEFC's importance in the regulatory framework, described in chapter 3, should also be noted in the given context. Based on these interesting framework conditions, contacting PEFC (or, if suitable, representatives of similar labels) to explore options for an extension of their label for paper products to consider bioplastic components is suggested as well.

An additional interesting option was identified by Scuola Superiore Sant' Anna and Ökoinstitut (2018) and their work on "possible windows of opportunities for the EU Ecolabel in the transition to the circular economy". The authors suggest to "harmonize the criteria with the EU organic label and cover those aspects that are not addressed appropriately by the EU organic label (e.g. processing, logistics, packaging etc.)". The findings of this section provide solutions to address the need for packaging criteria.

6.3. Legislation

The regulatory landscape of food packaging and, more generally, food contact materials (FCMs) is complex. Many specifications and requirements can be found in different regulatory frameworks often causing confusion to the food packaging industry.

The EU legislation on FCMs, which has to be considered in eco-labelling activities serves two basic goals: the protection of consumers' health and the effective functioning of the internal market. The following figure presents the current legislative framework on FCMs.



Source: EFSA, taken from Karamfilova (2016)

Figure 5: EU legislation of Food Contact Materials

Framework Regulation (EC) No. 1935/2004 lays down common rules for packaging materials and articles which come, or may come, into contact with food, either directly or indirectly. This regulation is applicable also to bio-based packaging materials. According to the general requirements of the Framework Regulation all packaging materials which come, or may come, into contact with food, either directly or indirectly:

> *"shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could:*

(a) endanger human health; or

(b) bring about an unacceptable change in the composition of the food; or

(c) bring about a deterioration in the organoleptic characteristics thereof.

The labelling, advertising and presentation of a material or article shall not mislead the consumers."

In Article 15 the requirements of Labelling are laid down.

Even if it is mandatory to comply with the legislation for FCMs which come, or may come, into contact with food, the use of the symbol shown in the figure below representing the suitability of a material for food contact' is voluntary (export.gov, 2017).

Source: Regulation (EC) No. 1935/2004

Figure 6: Voluntary symbol for food contact materials

In Annex I of the Framework Regulation (1935/2004) seventeen categories of FCMs are being listed aiming at the adoption of specific safety requirements for them. For the time being the requirements for only four FCMs: plastics (including recycled plastics), ceramics, regenerated cellulose and so-called active and intelligent materials have been harmonized. For the rest of FCMs (e.g. paper & board, metals & alloys, glass, coatings, silicones, rubbers, printing inks etc.). Member States are allowed to adopt their own safety measures (see European Parliament and of the Council, 2005).

The **European Food Safety Authority (EFSA)** evaluates the safety of Food Contact Materials and is responsible for the authorization of all packaging materials under Regulation 1935/2004 prior to being placed on the market. A publicly-available online list with all the food packaging materials that have been authorised is maintained by the EFSA.

In addition to the general legislation, the following legislations are relevant for FCMs while the first three in particular appear to be relevant for bio-based food packaging made of PLA:

- Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food
- Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006
- Commission Regulation (EC) No 450/2009 of 29 May 2009 on active and intelligent materials and articles intended to come into contact with food
- Commission Directive 2007/42/EC of 29 June 2007 relating to materials and articles made of regenerated cellulose film intended to come into contact with foodstuffs
- Council Directive 84/500/EEC of 15 October 1984 on the approximation of the laws of the Member States relating to ceramic articles intended to come into contact with foodstuffs.

Another important document that covers food package is the **Directive on packaging and packaging waste**: Directive 94/62/EC and its various amendments. Articles 8 and 8.a of Directive 94/62/EC prescribe the requirements for the marking and identification system of packaging, including bio-based packaging.

Harmonised standards under Directive 94/62/EC, covering the whole cycle of preventing, reducing, reusing, recycling, recovering and disposing waste are EN 13427-13432 (see chapter 6.4. The standards provide suitable foundations for the specification of eco-label criteria, their requirements and test methods.

In addition to the European level, specific framework conditions have to be considered in the different European Member States. In Germany, relevant documents include, for example: German packaging regulation and law / German packaging law on recyclability, German food law, German law on consumer goods and animal feed, German packaging regulation and law, European directive Plastic – Cellulose – Ceramic, Regulation GMP and Contamination law.

The German packaging law on recyclability refers also to bio-based plastics including PLA. It considers reusable packaging and the chemical exploitation. Its main focus is on licensing: appropriate recycling leads to lower recycling fees. A gap is, that the document only considers the EOL option recycling.

On organization-specific level, interviewees highlighted the importance of the EMAS Regulation 1836/93, which was first introduced in July 1993 as an environmental policy tool devised in a step towards fulfilling the EU goal of sustainable development. Currently, its third, extended version is available (see EMAS, 2017). Caring for sustainable bio-based food-packaging can be regarded as in line with this directive due to the common goals regarding environmental protection.

EU labelling rules (labelling and nutrition) provide comprehensive information about the content and composition of food products helping consumers to have a clear enough picture of the food they buy (European Commission, 2018d). Apart from these requirements, **no EU Ecolabel for food packaging has been developed yet.**

On member state level, Belgian law forbids labelling packaging material as 'biodegradable' or 'biologically degradable' to prevent possible increases in litter. The law addresses a widespread misconception that something either is or is not biodegradable. The environment of the end-of-life stage as well as the character of a product (composition, thickness, shape), play an important role. Therefore, the claim 'made from biodegradable material' does not mean that the whole product is biodegradable (see CE Delft, 2017, p. 122).

Interview-based suggestions

The case study discussions on potential needs for new regulatory documents led to interesting results, also regarding the RED (see Table 10 for a summary). With a specific focus on packaging for organic food, a revised RED was discussed as a possible foundation for further regulatory steps. In addition, it was suggested to provide a classification of packages to facilitate the assessments and selections by (food) producers. To support the end-of-life of bio-based products, it was suggested to develop suitable assessment criteria to facilitate comparisons with fossil-based products, also to improve the acceptance of PLA packages by recyclers. Regulatory gaps regarding composting were also unveiled.

Table 8: Relevance of RED criteria in the case study on food packaging

Element of the RED directive	Relevance for stakeholders of bio-based food packaging				
	F1	F2	F3	F4	F5[10]
Greenhouse gas savings	N.A. It was suggested to discuss this with stakeholders on earlier life cycle stages	x	-	x	x
No use of areas converted from land with previously high carbon stock		x	-	x	x
No use of raw materials obtained from land with high biodiversity		x	-	x	x

It should be noted that the relatively high number of interviewees who regard these criteria as relevant, consist of procurers of food packaging and related representatives. On the other hand, the situation on the side of the packaging producers and feedstock providers has to be analysed carefully to avoid unnecessary burdens on their side.

As AöL has shown by the Biokunststofftool, recycling solutions would also require the specification of a percentage rate to what extent bioplastic can be added to conventional plastic recycling processes without causing problems.

6.4. Standards

Relevant standards include, in particular, standards on bio-based content and standards for the end-of-life based on Directive 94/62/EC.

Regarding bio-based content, chapter 5 mentioned CEN/TS 16137:2011. It also specifies the following three test methods, building on EN 16575:2014 (Bio-based products – Vocabulary):

- EN 16640:2017 (Bio-based products. Bio-based carbon content. Determination of the bio-based carbon content using the radiocarbon method)
- EN 16785-1:2015 (Bio-based products - Bio-based content - Part 1: Determination of the bio-based content using the radiocarbon analysis and elemental analysis)
- EN 16785-2:2018 (Bio-based products - Bio-based content. - Part 2: Determination of the bio-based content using the material balance method)

Harmonised standards under Directive 94/62/EC on packaging and packaging waste, cover the whole cycle of preventing, reducing, reusing, recycling, recovering and disposing waste. They include in particular

- EN 13427:2004 Packaging - Requirements for the use of European Standards in the field of packaging and packaging waste
- EN 13428:2004 Packaging - Requirements specific to manufacturing and composition - Prevention by source reduction
- EN 13429:2004 Packaging – Reuse
- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling
- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value

[10] Interviewee F6 did not provide information related to this question.

- EN 13432:2000 Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging

EN 13432 specifies requirements and procedures to determine the compostability and anaerobic treatability of packaging and packaging materials by addressing four characteristics: 1) biodegradability; 2) disintegration during biological treatment; 3) effect on the biological treatment process; 4) effect on the quality of the resulting compost. In case of a packaging formed by different components, some of which are compostable and some other not, the packaging itself, as a whole is not compostable.[11]

Besides this, private standards such as IFS and standards for the production of plastic have to be considered.

Need for new standards

Some experts see a need for a new standard to assess bio-based food packaging with criteria and requirements considering the whole product life cycle.

In this context the importance of comparisons with petrol-based products to highlight advantages of bio-based products was described, in particular to overcome the disadvantage that PLA-based packages are more expensive. In particular, comparisons with conventional products are regarded as important, e.g. concerning: CO_2 emissions, biodiversity, use of natural areas, use of water, pollution of water, land use, eutrophication of water and transportation.

The suggestion to compare transportation data builds on the fact that from a European perspective, biomass is often, although not always, available in closer distance than fossil oil,[12] which is mainly sourced outside Europe. As a current disadvantage of PLA in such comparisons recyclability issues were mentioned.

6.5. Main findings

This section provides an overview of the main findings of the research conducted in the framework of this case study. They will represent the basis for formulating recommendations for the assessment of bio-based food packaging regarding bio-based content, end-of-life options, the consideration of specific product properties and tests and also recommendations regarding the extension of existing eco-labels for food packaging using bio-based plastics in a mix of materials. A basis requirement is that bio-based food packaging has to comply with EU regulation. This requirement refers to the provisions of the Framework Regulation (EC) No. 1935/2004 and EFSA for FCMs.

Bio-based content

CEN/TS 16137:2011 requires minimum bio-based content, which could be considered as an eco-label criterion. As described in chapter 6.4, it also specifies three test methods to determine bio-based content by referring to several other EN standards. These test methods and requirements shall be integrated in all eco-labels on packaging.

End-of-life options

Preferred end-of-life options for PLA packaging are reuse, recyclability (mechanical and chemical) and compostability (organic recycling aerobic and anaerobic). However, specific

[11] EN 14995 Plastics - Evaluation of compostability - Test scheme and specifications has the content, but broadens the scope to non-packaging applications

[12] As a general example, the Italian company Novamont collaborates with local farmers.

compostability issues were highlighted regarding products, which are industrial compostable but not home compostable. Avoiding unnecessary barriers is important.

Specific recommendations regarding the labelling of food packaging include principle issues such as the consideration of migration and barrier properties as well as related tests.

Consideration of migration and barrier properties

Integrating assessments on migration and barrier properties of packaging in the criteria catalogues of eco-labels on packaging is suggested.

A bio-based material should meet the migration requirements in order to be approved for food packaging applications. Blends with bio-based components should also fulfil the requirements for food contact materials.

The case study unveiled the importance of barriers in food packaging. Barrier properties of a material refer to the function of permitting the diffusion of gases, water vapour, liquid and organic substance, etc. from one side of the material to the other. The property of a material to act as water vapour barrier is crucial for preventing products from becoming dry or stale.

According to additional research, there are materials for plastic bottles, such as bio-PE and PEF (Polyethylene Furanoate) that have better barrier properties than traditional materials and could become alternatives to PE and PET.

Barrier properties for gas (oxygen and/or CO_2) are also very important for the preservation of the quality of food. The flaw of plastics in functioning as sufficient gas barriers, is being dealt with the application of multilayer structures (laminates). For the multilayer films it is important that the coating, which is being used to provide the gas barrier properties, does not exceed the limit of 1% nondegradable components set by the EN 13432 standard. Furthermore, efforts are being made to examine alternative films with coatings of SiOx (glass) or Al_2O_3 (aluminum oxide) (see Babu et al., 2013).

Various EN and ISO standards, which provide testing methods for the gas barrier properties (oxygen and CO_2 permeability, water vapour permeability) of the plastic food packaging films, are available.

Consideration of the mineral oil aromatic hydrocarbons (MOH) test

Integrating a mineral oil aromatic hydrocarbons (MOH) test in the criteria catalogues of eco-labels on packaging is suggested specifically.

The PLA case study highlighted MOH-related risks and the benefits of a test method proposed by the Fraunhofer Institute. PLA was regarded as an excellent barrier to mineral oil. The conventional material PET is also a good barrier and could be used as benchmark. The test can prove that PLA is as good a barrier as conventional solutions.

Extension of labels for paper products for products, which also include bio-based plastics

A mix of issues discussed in different interviews led to the formulation of a very specific recommendation. Paper packages with a plastic window, in particular paper bags, play an important role in this regard. As described in detail in chapter 6.2, extending the labels for such plastic products, e.g. PEFC, by a criteria set to assess the (bio-based) plastic parts.

7. Bio-based automotive applications: eco-labels, standards and regulations

7.1. Introduction

In 2010, an average car consisted of approximately 150 kg of plastics and plastic composites and approximately 1,160 kg of iron and steel. Plastics are used, for example, for the interior, seating, bumpers, exterior, electrical components, etc. Also, natural and synthetic rubber is used in car tires. A number of automotive applications for bio-based materials has been identified, partly already in use. Example applications include bio-resins, fibre-based solutions for the interior parts, composite materials and organo sheets (see e.g. CE Delft, 2017). Bio-based polyurethanes have started to replace fossil-based foams while bio-based polyamides also have the potential to replace petrochemical alternatives (see e.g. CE Delft, 2017, p. 30 and related sources). Specific research activities have also included PLA and PBS. The annex presents the results in detail.

This case study builds on interviews with representatives of a big car manufacturer and a big automotive supplier. Furthermore, it reflects the requirements explained by a governmental agency, which has a specific focus on bio-based car components and recommendations of two experts specialized in automotive field tests. It also mirrors the suggestions by a research institute, which conducts research on bio-based materials, including the development of materials for automotive applications.

In particular, PBS and PLA applications in the automotive sector were discussed. While the industry's experience with PBS is still limited, different material related issues were highlighted by the interviewees in the discussions on automotive PLA applications. For example, PLA material's reactions to temperature differences and humidity are current challenges that require further research. For this reason, the scope of this case study was broadened to bio-based car components in general. Based on the attractiveness of car components made of composite materials, they were considered specifically in this case study.

Three automotive applications were discussed in particular: a) side doors with interior cladding of composite materials using natural fibres such as flax, hemp, linen and a bio-based resin, b) mirror covers and turn signal covers made of bio-based polyamides/PPT and c) car interiors made of Polypropylene combined with natural fibres. An advantage of the interior parts is that their functional requirements are lower compared to exterior ones.

7.2. Eco-labels

As an important prerequisite in the automotive sector, interviewees highlighted that certification can only take place with regard to single car components. Realising an eco-label for entirely bio-based vehicles would not be possible because they consist of too many different materials. Due to the newness of the topic bio-based car components, no specific eco-labels on sustainability and bio-based issues exist. Therefore, several labels with a more general focus are discussed as a starting point.

RSB and ISCC PLUS are regarded as important certificates to prove the sustainability of biomass. Limitations, in particular highlighted for ISCC PLUS, are that they do not refer to (car) components but just to the material. Furthermore, ISCC PLUS is not an eco-label and its scope excludes, for example, end-of-life issues.

Other general labels for bio-plastics mentioned in interviews are, for example, the labels from DIN CERTCO and Vincotte. In addition, the Blue Angel (Blauer Engel) label started focusing on bio-based plastics regarding recycling aspects. A general gap not addressed by the labels on plastics refers to bio-based cellulose fibres.

On the level of assessment criteria, it was also highlighted that fuel consumption stays on the top of the lists of environmental characteristics, as fuel efficiency is a legal obligation in the automotive sector. Any material used for building a car has to support this goal. The weight of a car has a specific influence on its fuel consumption. Therefore, all suitable materials and components have to ensure that cars of an appropriate weight can be built.

Regardless of the existing solutions for selected specific questions. In summary it was highlighted clearly that no eco-label for bio-based automotive applications exist. One expert added: "Such a solution would be a 'super' output of STAR-ProBio to provide customers with transparent information."

Explicitly, it was also mentioned that an EU-wide label such as the EU Ecolabel would be interesting for the automotive industry. Regarding the scope of a potential label, the importance to distinguish between different target groups was highlighted. B2C markets need labels, which are easily understandable, while issues, as for example LCA, are more important for B2B markets.

The high number of options for the various car components is perceived as a challenge for the development of labelling specifications. An agreement on focusing on specific components by the car industry might be necessary. Currently, many areas of the market for bio-based car components are still in the testing stage. The test results will also play an important role in potential further steps regarding eco-labelling.

The interviewees' view on selected sustainability assessment criteria is shown in the following table:

Table 9: Relevance of selected eco-label criteria for bio-based car components

Assessment criteria	Relevance according to the interviews	Assessment criteria	Relevance according to the interviews
Sustainable biomass		Social criterion "fundamental principles and rights at work"	
CO_2 emissions		Energy requirement during production	
Toxicity		Biomass utilisation efficiency	
End-of-life options		Life cycle values	
Fitness for use		Life cycle costing specifically	
Social criterion corporate social responsibility			
Legend: relevant in > 50% of the interviews; not relevant in > 50% of the interviews; relevant in 50% of the interviews			

Regarding **bio-based content**, the need for reference products facilitating comparisons was described. Furthermore, it was suggested to decide appropriately between optimizing the values for the criteria **origin** of a product and the **amount of bio-based content**, if material with a higher percentage rate of bio-based content is only available abroad/outside Europe and requires more transportation efforts, which also affect the environment.

Regarding **sustainable biomass**, experts drew attention to two important general challenges regarding the use of bio-based materials in the automotive industry: land use versus assurance of food security and the avoidance of GMOs. Regarding interior linings of car doors, for example, promising options to use material from residues were highlighted. Regarding GMOs, it was added, "We could check where the seeds came from, but it would be too costly." Labelling could reduce such a cost.

In general, the assessment criterion "sustainable biomass" is regarded as more suitable for B2B markets than for B2C markets. B2C markets would require detailed explanations of the concept.

In a further discussion on the suitability of RED criteria it was mentioned that the use of bio-based products could be monitored by the following two specific principles: no conversion of land with previously high carbon stock and no use of raw materials obtained from land with high biodiversity such as primary forests or highly biodiverse grasslands. These aspects might be interesting issues that would specify the criterion "sustainable biomass" appropriately.

As mentioned earlier, the **origin** of the material was another issue brought into the discussion. However, it was highlighted that the selection also depends on the availability of suitable material. An additional suggestion was to communicate the **type of feedstock**. Specifically, a label such as the one of Vincotte with a fix and a variable part was considered while the variable part could, for example, provide information on the raw material.

CO_2 emissions should be measured in the various life cycle stages including production, transport, use and end-of-life.

Regarding the **EOL** stage in general, automotive applications require specific end-of-life solutions. Recycling and incineration/energetic combustion are the key options. Compostability and degradability are outside the scope of car applications. One reason is the potential risk that the degradation could begin in the use stage already. Regarding materials, which cannot be recycled, it was highlighted that energetic combustion must be preferred instead of incineration.

Furthermore, it was pointed out that not only recyclability is important. The possibility to separate the bio-based parts is of particular importance. Other interviewees highlighted the need for energy as an important issue of this stage. They conducted a comparison with the disposal of carbon fibres, which requires significantly more energy than the disposal of bio-based fibres

The need for the **toxicity** criterion is a specific one. Composite materials, which cannot be recycled, need to be incinerated or used for energetic combustion. For this reason, toxicity is a particular end-of-life issue for car components of these specific materials.

Most interviewees suggested to exclude the item **fitness for use** from eco-label criteria catalogues. The reason is that this issue is assessed much earlier in the life cycle of the car than eco-labelling takes place. Components, which do not meet necessary functionality requirements are de-selected early in the car design stage.

By describing specific comparisons, it was also highlighted that the **energy** balance of bio-based composites is better than the one of an alternative carbon product. However, the different options to use renewable or non-renewable energy would require considerations.

Specific discussions on the **social** criterion "fundamental principles and rights at work" led to the suggestion of an integration into the other social criterion "corporate social responsibility."

Regarding the **biomass utilisation efficiency** criterion, interviewees stressed that the high technical requirements, in particular on functional and exterior car components, determine clearly which material and biomass is suitable. Material with optimal BMU values does not necessarily have the characteristics/quality needed in the car industry. For this reason, the BMU criterion has a lower priority although it cannot be ignored.

According to interviewee opinion, **LCA, LCC** (and also biomass utilisation efficiency) are regarded as particular items for certificates for B2B markets; less for B2C markets.

Car manufacturers are obliged to prepare energy footprint information for each vehicle and several experts stressed the potential usefulness of label information on LCA and LCC. However, it is likely that suppliers certify individual parts only, for which the creation of separate data might be difficult. A comparison for entire vehicles is regarded as challenging as well, since vehicles can exhibit many differences. Car components are also often exchangeable, which means that their lifetime differs from the one of a whole car. For this reason, the realisation of appropriate LCA and LCC show need for further research.

A specific recommendation was to specify the number of LCA criteria under efficiency considerations. Specifically, it was suggested to consider the environmental criterion CO_2 emissions only.

To summarize the findings in Table 9, key criteria for stakeholders of the automotive sector are sustainable biomass, CO_2 emissions, EOL and social responsibility, added by LCAs with a specific focus on CO_2 emissions. The interviewees also specified additional sustainability criteria, which they regard as important, in particular: the extent of water use (in the production); the use of energy beyond the production stage or better and the total use of non-renewable energy.

The existence of bio-based materials leading to a weight reduction when replacing fossil-based materials was highlighted specifically. This weight reduction also implies petrol consumption savings which would justify an additional assessment criterion to highlight the advantages of bio-based car components compared to traditional ones. However, only LCAs addressing cars as a whole would make this possible. A specific recommendation in this context referred to the facilitation of a classification of cars regarding energy issues as well as fuel consumption (which is to be optimized also by characteristics of the material used in the production of the cars).

Looking into the future, interviewees also regard aircraft and public transport with bio-based components as conceivable.

Regarding eco-labels in general, the implementation of a programme like BioPreferred (USDA, 2018) was suggested. Specifically, a European register of bio-based products meeting selected criteria was proposed. The implementation of such a register of certified bio-based products could start with selected product categories only.

Regardless of having a national or European/international focus, the various existing private labels do not address the needs of the market appropriately according to expert opinion. An independent label is necessary. The development of one of the existing labels for such a solution would be interesting as well but its realisation at the member state levels is regarded as difficult. Therefore, a European solution is suggested, at least for the public sector. Regarding an eco-label for the automotive industry specifically, interviewees stressed the importance of the interest by (more) manufacturers for successfully establishing an eco-label in the given area.

7.3. Legislation

The current regulatory framework of bio-based car components includes, in particular, general EOL regulations for cars, e.g. the End-of-Life Vehicles Directive (Directive 2000/53/EC) and related national legislation such as the "Altautoverordnung" in Germany. Based on the directive, cars are dismantled and separated into their different materials. However, current European and national regulations are not specific enough for bio-based car components according to some interviewees. Examples in this regard refer to various life cycle stages: the development of components with appropriate characteristics, e.g. regarding recyclability, the use of energy for the production and the requirement to minimize the amount of residues.

Issues of recycling have to be considered as well. They include, for example, questions on which material mix is possible and which bio-based material can be recycled together with fossil products. It is also considered important to involve recycling companies in these considerations.

The usefulness of elements of the RED directive was discussed in particular. The following table summarizes the results.

Table 10: Relevance of RED criteria in the case study on bio-based car components

Element of the RED directive	Relevance for the stakeholders				
	C1	C2	C3	C4/C5	C6
Greenhouse gas savings	No	(x)	No (mainly an issue of fuels)	x	(x)
No use of areas converted from land with previously high carbon stock	No	(x)	No[13]	x	(x)
No use of raw materials obtained from land with high biodiversity	No	(x)[14]		x	(x)[15]

Four different views were observed:

- these criteria are important
- these criteria are important but could also be considered by a position paper of the car industry instead of a regulation
- the adoption of the criteria is useful but the Member States shall have the opportunity to decide on the adoption individually on a national level
- the "regulatory burden" should be kept as low as possible

As an example for the third view above, specific types of grassland were mentioned which could be replaced for the cultivation of renewable raw materials without negative consequences.

The variety of the views requires further research. STAR-ProBio kept the contact with the automotive industry in this regard.

An additional issue was raised within the interview topic "potential eco-label criteria on life cycle assessment and life cycle cost." It was suggested to require exemplary calculations by a European regulation. This would help to show the advantages of bio-based products from cradle to grave and consider in particular the disadvantages of the disposal of carbon, which can be replaced by bio-based alternatives.

7.4. Standards

As an important pre-requisite for standardisation considerations in the automotive sector, it was mentioned that the automotive industry is an international one and needs common guidelines for production processes worldwide.

There are various standards for materials traditionally used in this industry, for example, for steel and glass, addressing safety issues in particular. In addition, there are standards for composite materials, which apply to bio-based composites as well.

[13] Relevant but no need for further action because this is considered by ISCC PLUS already
[14] The topics are regarded as relevant but a position paper of the car industry might be an instrument, which is regarded as to be more attractive for these stakeholders.
[15] See explanations in the text under the table

Regarding sustainability issues of bio-based materials, the following standardisation topics were discussed in the interviews:

- life cycle assessment
- sustainable material flows
- reduction of energy use and use of renewable energy
- minimisation and appropriate use of residues
- recyclability
- social issues
- life cycle cost

The desired guidance refers in particular to the use of energy, renewable energy specifically, the appropriate use of residues and recyclability while the complex specification of end-of-life measures may require an additional standard.

7.5. Main findings

A key finding was that existing eco-labels do not refer to car components and that a need to address this gap exists. Focussing on the biomass specifically, an additional labelling gap regarding the assessment of bio-based cellulose fibres was identified.

Regarding regulatory requirements, our interviews led to the conclusion that current European regulations are not specific enough for the emerging field of bio-based car applications. Gaps refer, for example, to the development of the components, the use of energy in the production, the recyclability and the requirement to minimize the amount of residues. It should be specified which bio-based materials can be recycled together with fossil products and which mix of car components is possible to facilitate appropriate recycling.

In addition, the development of exemplary LCAs and LCC for both bio-based and fossil-based products on a European level was suggested to show the advantages of bio-based materials. In particular bio-based car components which facilitate a reduction of petrol consumption make this interesting.

Last but not least, the development of a LCA standard for bio-based car components, specifically addressing the use of energy and the end-of-life stage was suggested, with recyclability as the key end-of-life issue.

8. Bio-based mulch films: eco-labels, standards and regulations

8.1. Introduction

According to European Bioplastics (2016), biodegradable mulch films have been available on the market for more than 17 years,[16] backed by solid scientific and technical knowledge, and meeting a high level of acceptance among European farmers growing fruits and vegetables. These films deliver the same positive agronomical effects as the conventional counterparts such as increasing yield, improving quality of crops, weed control, reduction of use of irrigation water and pesticides. Additionally, they offer advantages at the end-of-life because they can simply be buried in the soil.

While there are no official international or European statistics covering plastics used in agricultural applications, according to a research based on various sources, it is estimated that the agricultural plastics production reached 6.5 Mt in 2011 worldwide (see Scarascia-Mugnozza et al., 2011). The total plastics demand in EU was 49 Mt in 2015, whereas in agriculture 1.6 Mt (3.3%) were used (PlasticsEurope, 2017). Polyethylene (PE) is the dominant agricultural plastic with a share more than half of this amount and is being used mainly for the protection of cultivations (e.g. greenhouses, mulch films, small tunnels, temporary coverings of structures for fruit trees, etc.), irrigation etc.

Bio-based plastics used in agricultural applications still represent a rather low percentage of the overall agricultural plastics market at the moment but it is expected to grow strongly in the next years (see European Bioplastics, 2016). Already, 5% of the global production of bio-based plastics, which amounted to 2.1 Mt in 2017, was used in agriculture showing a 126% increase since 2013 (Aeschelmann & Carus, 2015).

Biodegradable mulch films provide two advantages in particular. Firstly, the process of biodegradation of bio-based mulch films in soil is not expected to create ecotoxicity effects as it is a biological process. Furthermore, mulch films do not contain heavy metals that could cause ecotoxic effects (see De Wilde, 2002). However, the possibility of ecotoxicity due to remaining toxic residues (e.g. metabolites) after the biodegradation should be tested. Earthworm acute toxicity test (OECD, 1984) and Terrestrial plant test (OECD, 2006) are two testing methods that could be applied to assess ecotoxicity in soil after the biodegradation of bio-based mulch films.

The second advantage refers to the after use phase of mulch films because the EU waste framework prohibits the burying or burning of the conventional mulch films in the fields. However, recycling is not an option for the end-of-life treatment of the conventional mulch films due to technical and economic reasons (see Briassoulis et al., 2012, 2013a). An alternative can be given by the use of biodegradable in soil mulch films that could be incorporated into the soil following the end of the cultivation season (see Briassoulis et al., 2012).

8.2. Eco-labels

Although several "eco" or "green" labelling schemes have been developed covering a wide range of bio-based products, services and processes, there is still a gap concerning the bio-based products applied in the Agro-Food sector. Only selected certification schemes related to bio-based content and end-of-life criteria (presented in section 5.2.4) can be considered. The OK certification scheme owned by TUV AUSTRIA includes the following

[16] 15 years by the time of the source's publication

labels: OK compost INDUSTRIAL, OK compost HOME, OK Bio-based, OK biodegradable SOIL, OK biodegradable WATER and OK biodegradable MARINE. It is based on the European standard EN 16785-1. OK biodegradable SOIL is particularly important for mulch films, because it guarantees that products with this label will completely biodegrade in the soil.

The EU Ecolabel scheme does not cover bio-based plastics used in agricultural applications (such as mulch films). The only relevant product group with agriculture, "Gardening / Growing media, soil improvers and mulch", is not relevant to agricultural plastics for professional agricultural use because of their specific characteristics and their end-of-life options. However, it would be important to classify mulch films and other plastics used in agriculture under a broader category of agricultural production equipment and materials. This is especially the case for bio-based soil biodegradable plastic mulch films (Behrens et al., 2016).

Relevance of criteria and labels for stakeholders of the mulch film case study

The importance of the criteria identified in chapter 5 for the interviewed experts is shown in table 11. It visualizes that all criteria were selected by at last 50% of our interviewees. It was highlighted that any label should include two requirements in particular: the reduction of plastic waste and the biodegradability in soil without any immediate or future negative impact on soil. This shows the need to prove the avoidance of any adverse environmental effects based on EN 17033 (see sections 7.3 and 7.4 for details).

Table 11: Relevance of selected eco-label criteria for bio-based mulch films

Assessment criteria	Relevance according to the interviews	Assessment criteria	Relevance according to the interviews
Sustainable biomass		Social criterion "fundamental principles and rights at work"	
CO_2 emissions		Energy requirement during production	
Toxicity		Biomass utilisation efficiency	
End-of-life options		Life cycle values	
Fitness for use		Life cycle costing specifically	
Social criterion corporate social responsibility			
Legend: relevant in >50% of the interviews; not relevant in >50% of the interviews; relevant in 50% of the interviews			

As shows in the table, the importance of sustainable biomass was clearly confirmed by our interviewees. Regarding CO_2 emissions, suggestions to include this criterion in the criteria list dominate as well. However, it was emphasized that the producers do not have the possibility of controlling these emissions when the mulch film is used. A distinction between production, use and after use would be necessary. Furthermore, assessing the after use stage is regarded as difficult and additional studies are needed. It is also to consider that bacteria release CO_2.

All interviewees confirmed the usefulness of EOL criteria with a main focus on biodegradation but also considering eco toxicity, which is mainly an issue of the EOL stage. The "OK biodegradable SOIL" label provides adequate criteria and test methods to assess ecotoxicity (see Vinçotte, 2012).

Regarding the fitness for use criterion, the importance of following the relevant EN standards was stressed (see section 7.4). Furthermore, it was expressed that biodegradable mulch films perform better than conventional ones because they allow an exchange of

humidity from soil and atmosphere. In addition, a performance criterion on mechanical and optical properties is regarded as very important.

Referring to energy issues, it was commented that the production of bio-based mulch film requires less energy compared to traditional mulch film, due the lower process temperatures.

Regarding life cycle costing, it was highlighted that the cost of managing the benchmark product non-biodegradable mulch film has to be considered. In this context, analysing the EOL stage is important, e.g. concerning labour cost for disposal and removal. EOL is regarded as the key life cycle cost element. Economic consequences of removing conventional films from the floor are currently not considered. Issues that should be taken into account are therefore:

- EOL scenarios are currently not precise. Only the recycling option is considered. Modifications to consider these externalities explicitly are needed
- The cost of a hectare of soil with plastic should be considered since many hectares are affected in Europe
- Standards for non-biodegradable films require minimum thickness: visibility is important to facilitate their removal. For biodegradable mulch film such a minimum requirement is not needed

Specific recommendations on how eco-labels could support bio-based mulch film based on legislation are provided in chapter 8.5.

8.3. Legislation

This section discusses four instruments and their possible contribution to support bio-based biodegradable in soil mulch films in particular: the Common Agricultural Policy, the European Fertilizers regulation, Regulation on European Nature 2000 sites and Regulation with RED elements.

Common Agricultural Policy

Specific focus of this case study is put on the importance of the Common Agricultural Policy (CAP) and related support measures, including: i) direct payments for ensuring income stability and remunerate farmers for environmentally friendly farming; ii) market measures, to support difficult market situations such as a sudden drop in demand due to a health scare; iii) rural development measures, which address the specific needs and challenges facing rural areas.

The CAP include measures to improve the markets for environmental friendly products, such as biodegradable mulch films. Some EU Members States, such as Portugal, Spain and France financially supports the utilisation of biodegradable plastic mulch through the Producer Organizations (PO) schemes, and farmers are partially refund with the cost difference between biodegradable and conventional PE mulch (Agrobiofilm, 2013). These incentives are provided as a measure to overcome barriers linked to higher costs of biodegradable mulch films. By providing these incentives, governments recognize the important role that the use of biodegradable mulch films can play towards a sustainable development in agricultural sector. Indeed, they can be plugged in the soil, after its use, together with the crop residues (Santo et al., 2014). For example, in Portugal the financial support for the application of biodegradable mulches was 31% of product cost (Santo et al., 2014), and in Spain the incentive for the use of oxobiodegradable and biodegradable plastics was a lump sum equivalent to 35 % of the cost of such plastics (Royal Decree 1337/2011).

The common organization of the markets in agricultural products (CMO) pillar of the CAP is based on Regulation (EU) No 1307/2013, determining measures on fixing certain aids and refunds related to the common organisation of the markets in agricultural products and Regulation (EU) No 1308/2013) for the market measures. It includes measures addressed to big stakeholders, normally organized in producer's organizations to improve relevant markets (European Parliament Think Tank, 2018). Four EU countries (France, Italy, Portugal and Spain) included mulch films as a possible CMO environmental measure. This facilitates for example the receipt of subsidies for the use of biodegradable mulch film, which is usually more expensive than traditional fossil-based films. Currently, only the above mentioned four countries as main European producers of vegetables use high quantities of mulch films and therefore have strong interests in such measures.

The CAP's rural develop part focuses on a regional level and to the single farmers. In this regards, three Italian regions can be cited for inserting biodegradable mulch film in rural development plans,[17] supporting growers. According to the interviewed experts, no other legislation in Europe provides subsidies for mulch films. Referencing standards in CMO measures is regarded as important. Until 2018, CMO has referenced an Italian standard with minimum requirements on the material. Such national standards had existed in Italy (UNI 11462) and France (NF U52-001) only (see chapter 8.4). In other countries a reference to standards was missing due to the absence of a harmonized EU standard on biodegradable mulch film. According to additional expert opinion, a condition that will facilitate the receipt of CAP/CMO-based subsidies for the use of bio-based biodegradable in soil mulch films can be eco-labelling.

In order to support the update of biodegradable mulch films in Europe, CEN-TC 249 on Plastics published the standard EN 17033 on the biodegradation of plastic mulch films in soil with clear criteria for biodegradation, ecotoxicology, and characteristics of biodegradable mulch films in January 2018 (see chapter 8.4 for details). Eco-labelling could cover all requirements set by both EN 17033 (functionalities) and sustainability issues (bio-based and sustainability standards). In that way, sustainability could be linked directly with policy and the CAP subsidies supporting system. The subsidies should not depend only on the characteristics/ functionalities defined by EN 17033 but should also cover important sustainability characteristics of these products (e.g. standards for bio-based content and sustainability) and should be applicable across the EU.

European Fertilizers regulation

An important achievement in the regulatory framework applied to bio-based biodegradable mulch films is their inclusion in the proposal for a revised Fertilising Products Regulation. Amendments acknowledge the innovative potential of these products to provide positive agronomical effects and to help avoid the accumulation of microplastics on fields and are linked to the criteria of EN 17033. Showing compliance with this new regulation will require an eco-labelling of mulching films.

Regulation on European Nature 2000 sites

Additional interesting information was provided on a national level with regard to European Nature 2000 sites. Natura 2000 is "a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right." (European Commission, 2018e). Nature 2000 includes 18 % of the EU's land area and almost 6 % of its marine territory, involving all European Member States. The German federal state of Brandenburg plans to release a regulation on films for asparagus in these conservation areas. It addresses the death of species due to the covering of soils by the films, causing, for example, that birds cannot reach their food. To protect these

[17] Sicily, Emilia Romagna, and Umbria

regions better, the ministry has worked on the relevant regulation since 2016. An article published in July 2018 demands results until the end of this year. For this reason, it should be checked whether these regulatory efforts can also be used to support bio-based, biodegradable in soil mulch films. A relevant issue would be, for example, a specification on how quickly films shall biodegrade.

Regulation with RED elements

The interviewees consider RED elements and a similar regulation for bio-based products as well. The importance of protecting forests and peatland was highlighted. The requirements are also relevant in normal farming (e.g. public funding).

8.4. Standards

A key standard for mulch films is EN 17033:2018 "Biodegradable mulch films for use in agriculture and horticulture - requirements and tests methods", published on the 24th of January 2018 (see European Bioplastics, 2018), which replaces national standards such as the French NF U52-001. According to this standard, an absolute or relative biodegradation level of at least 90% after 24 months is required for a bio-based mulch film be labelled as biodegradable in soil. Moreover, it is required that the addition of any masterbatch or additive during the manufacture may not result in a mulch film in conflict with the standard's requirements related to biodegradation and environmental safety.

Other biodegradability specifications are defined in the national standards NF U52-001:2005 and UNI 11462:2012. However, certain technical flaws have been identified especially for the case of mulch films. NF U52-001 does not require the compulsory evaluation of biodegradability in the soil and the time frame and biodegradation rate ≥60% in 12 months do not guarantee the long term biodegradation in soil (see Briassoulis et al., 2014). EN 17033 includes requirements regarding the nitrogen content of soil and a comprehensive ecotoxicity testing and evaluation scheme taking into account:

- relevant terrestrial organism groups such as plants, invertebrates (e.g. earthworm), and microorganisms (e.g. nitrification inhibition test)
- important ecological processes that are critical due to their role in maintaining soil functions by breaking down organic matter and formulating soil structure and ecologically recycling of materials and
- relevant exposure pathways of degradation products such as soil pore water, soil pore air and soil material.

Moreover, the standard strictly defines use restrictions regarding different potentially harmful constituents, such as regulated metals and substance of very high concern. For this reason, it builds a suitable foundation to provide specified eco-labelling and certification services in the future. The standard also sets limit values for heavy metals, fluorine, minimum volatile solids content as well as the evaluation methods, which shall be considered appropriately. European Members States have to adopt EU standards at a national level, and EN 17033 should be enforced by the end of July 2019. It is stricter than current national standards.

Specifying the findings on the importance of the fitness for use criterion in the eco-label section of this case study, EN 17033 covers three functional characteristics that bio-based biodegradable in soil mulch films should fulfil. Interviewees highlighted the usefulness of this standard in particular for establishing a link with the Fertilizers regulation.

In order to exclude the possibility that very small amounts of non-biodegradable in soil polymeric constituents are present in the synthesis of the biodegradable mulch film, the

standard should be improved in its next revised version by making it obligatory to only use minor polymeric constituents whose biodegradability in soil has been assessed separately and certified.

Other relevant standards are linked to testing method for determining the ultimate aerobic biodegradability of plastic materials in soil is being specified in ISO 17556:2012. This method was adopted by CEN, as no relevant European standard (EN) has been developed (EN ISO 17556:2012). The measurement of biodegradation is achieved through the oxygen demand in a closed respirometer or the amount of carbon dioxide evolved. An equivalent test method (measuring evolved carbon dioxide as a function of time that the plastic is exposed to soil) has been developed by the standard ASTM D5988:12.

8.5. Main findings

Based on our analyses, the following proposed technical criteria are considered to be fundamental for the scientifically valid development of a new eco-label (category) for bio-based, soil biodegradable plastic mulch films:

1. **Bio-based content / composition of the product:** The "bio-based" criterion of plastic mulch films shall be defined according to the relevant European and international standards (e.g. CEN standards). A minimum percentage rate of bio-based content of the total weight of the organic material in the mulch film may be considered. Under sustainability considerations it is of significant importance that the biomass is sustainably sourced. The bio-based content is determined and declared by various standards of CEN/TC 411. CEN/TS 16137:2011 specifies the three different methods to calculate it: EN 16640:2017, EN 16785-1:2015, EN 16785-2:2018 (see section 5.3).
2. **Sustainability of raw materials - to be considered as an additional criterion:** It is important to assure that the raw materials used for the production of bio-based products are not competing food production. Sustainable bio-based feedstocks must derive from agricultural management based on specific criteria that meet sustainability goals. These criteria have been developed by multi-stakeholder organisations that have a broad-based membership including NGOs, industry and government. A minimum limit for sustainable raw materials used for the production of bio-based products must be set. Third-parties (e.g. ISCC, RSB, RSPO, BONSUCRE) or any equivalent scheme based on multi-stakeholder management criteria will be responsible for the certification of the sustainability of the raw materials (see Vinçotte, 2012).
3. **Functionalities:** Third-party certification according to EN 17033 specifications shall be used.
4. **Biodegradability in soil as the only end-of-life option:** Third-party certification according to EN 17033 specifications shall be used here as well with an absolute or relative biodegradation level of at least 90% after two years; testing biodegradation according to EN ISO 17556:2012 and ecotoxicity based on the Earthworm acute toxicity test (OECD test 207, see OECD, 1984) and the Terrestrial plant test (OECD test 208, see OECD, 2006).

Recommendations regarding the regulatory framework refer to four kinds of regulatory documents in particular: the Common Agricultural Policy the Fertilizers regulation, a document comparable with the renewable energy directive and laws related to Nature 2000 regions.

9. Insulation materials: eco-labels, standards and regulation

Written by Mathilde Crepy and Doreen Fedrigo-Fazio (ECOS)

9.1. Introduction

Modern building insulation can be made from materials of a petrochemical, non-biological (glass-based) or biological nature. The five most common insulation materials are: fibre-glass (glass-based), mineral wool (glass-based), cellulose (bio-based), polyurethane foam (petroleum-based), and polystyrene (petroleum-based).[18]

Those insulation materials of a non-biological origin are obtained from petrochemicals (mainly polystyrene) or from natural sources processed with high energy consumptions (glass and rock wools). These materials cause significant negative environmental impacts particularly in the production and end-of-life stages. These impacts relate to the use of non-renewable materials and fossil energy consumption, and the difficulty of reusing or recycling the products at the end of their lives (Asdrubali et al., 2015).

Inspired by the introduction of the "sustainability" concept in building design processes, research has increased on the development of thermal and acoustic insulating materials using natural or recycled materials. These materials extend to: wood fibre, cellulose, wool, hemp and hempcrete, and straw. Further "unconventional" bio-based materials include: reeds, corn cob, cotton, date palm, durian, oil palm fibre, pineapple leaves, rice, sanse-vieria fibre, and sunflower (see Asdrubali et al., 2015).

According to Asdrubali et al. (2015), developments in insulation product materials are tending towards more 'environmentally friendly' buildings and therefore towards new sus-tainable materials. These new materials can come from residues of agricultural production and processing industries or from recycled materials or industrial plants by-products. Their performance is comparable to conventional materials (e.g. recycled cotton or sheep wool compared to EPS (Expanded polystyrene) or XPS (Extruded polystyrene)). For some recycled materials ((such as PET and textiles), their environmental performance was shown to be better than rock wool.

Schiavoni et al (2016) assessed a number of conventional, alternative and advanced insu-lation materials for a number of properties also integrating a lifecycle assessment ap-proach. They identified cellulose as one of 3 materials having the best performance in terms of embodied energy and global warming potential, using a cradle to gate approach. Taking a cradle to grave approach, and so also assessing the end-of-life stage, cellulose is not identified as a performant material, although the study mentions that cellulose insula-tion can be recycled (and specifically that it should not be composted due to the presence of boron salts added as a flame retardant).

This case study was built on cellulose-based insulation material, particularly given that the source of the cellulose is recycled paper. Focusing on such a material source helps to build stronger links between the bioeconomy, the circular economy, and energy efficiency. Ac-cording to CE Delft (2017), insulation material can also be made of PLA. To discuss a variety of topics in this report, the focus of the current case study is on cellulose-based insulation material instead.

For the sake of this case study, we focused on product-specific eco-labels focusing on the construction sector and with a potential European interest. Two labels were identified: IBO

[18] See https://www.thermaxxjackets.com/5-most-common-thermal-insulation-materials/, accessed 17 September 2018.

Prüfzeichen (IBO, 2018) (an Austrian construction eco-label) and natureplus® (an eco-label created by the International Association for Sustainable Building and Living based in Germany, see natureplus (2018). Given the international European status of natureplus®, we have focused specifically on this eco-label.

Three interviews were held with representatives from different aspects of the building sector. One works in an internationally-known and respected building design company, with particular responsibility for advising on sustainability in building design. A second represents an American federation promoting wood and wood-based products. The third represents an EU Member State national agency supporting sustainable use of natural resources. Despite numerous attempts to engage cellulose-based insulation material producers in several EU countries, it was not possible to gain such contribution. Through discussion with building sector representatives, it was often communicated that such companies are usually very small (with even 2-3 employees) and therefore with little time to take part in such activities.

In any case, as European efforts to improve the energy performance of buildings has a regulatory basis, there appears to be a secure future for the increased use of building insulation materials but it is not yet clear how sustainable use of bio-based products specifically will be promoted.

9.2. Eco-labels

Overview

The Ecolabel Index lists 66 eco-labels on "buildings"[19], with focuses ranging from building products and furniture, to building environmental assessment methods, and avoiding biodiversity deterioration in the construction sector.

Given the complexity of the sector, different labels will be of more interest to some users than others. The interviewees responsible for the design and improved performance of buildings and for promoting wood and wood-based products identified **FSC**, the **German Blue Angel** and even the **C2C family of labels**[20], while the interviewee responsible for the promotion of the sustainable use of natural resources with a focus on products mentioned the **natureplus® eco-label**. The building engineering company interviewee also cited the importance of the existence of **Environmental Product Declarations** (EPDs) that are an implementation tool of the Construction Products Regulation (see more in the Regulations section below). The relevant information on sustainability aspects of the product should be clearly set out in the product's EPD, although for this building sustainability advisor, specifications for building construction or refurbishment would not normally go to the level of detail found in EPDs. Rather, certification of sub-contractors or product providers to the **ISO-14001** environmental management system standard was the more used means of ensuring better environmental performance and selection of products. The interviewee also cited BREEAM and LEED as reference initiatives. **BREEAM** (see BREEAM, 2018) is a sustainability assessment method for 'masterplanning' projects, infrastructure and buildings, developed by the UK's Building Research Establishment. Tools include standards,

[19] See http://www.ecolabelindex.com/ecolabels/?st=category,buildings, accessed 17 September 2018

[20] The Cradle2Cradle approach is a circular one whereby materials used in products can be reintroducted into biological or technical processes. The Cradle2Cradle Institute has developed a number of standards which can be found here: https://www.c2ccertified.org/get-certified, accessed on 6 November 2018.

training, and third-party assessment of an asset's (such as a building) environmental, social and economic sustainability performance. **LEED** (USGBC, 2018) is an American 'green building' rating system similar to BREEAM.

As shown above, the interviewee responsible for the promotion of the sustainable use of natural resources mentioned the natureplus® eco-label specifically. It is described in detail in the following sections.

The natureplus® eco-label

According to the natureplus® association, it created this eco-label to offer European consumers and construction professionals clear selection guidance for construction products. It sets out compliance with high quality standards for all areas relevant to sustainability, and is recognised across Europe by building specialists, consumers environmental organisations, government bodies and building evaluation systems.

According to the Basic Criteria award criteria document (natureplus, 2011) the natureplus® eco-label is a Type I classified environmental label (as per ISO 14024) and takes into consideration the EU Ecolabel Regulation (Regulation (EC) No 66/2010) and the EMAS regulation on environmental auditing (Regulation (EC) No 1221/2009). The natureplus organisation clearly states high ambition levels in its approach to its eco-labels: main focuses are on protection of limited resources by the minimising the use of petrochemical substances, sustainable raw material extraction/harvesting, resource-efficient production methods and the longevity of products. Preference for certification is given to building products made from renewable raw materials, raw materials unlimited in their availability or from secondary raw materials (see natureplus, 2011).

In addition to the basic criteria, specific criteria exist for several construction products, and those applying specifically to insulation materials are from renewable raw materials (detailed below), external thermal insulation composite systems (insulating boards made of cork, wood fibre, hemp, reed and mineral foam), and insulation materials from expanded or foamed mineral raw materials (insulation from materials such as natural stone, clay and glass).

Specific criteria on insulation materials from renewable raw materials exist for insulation made from a wide range of materials including hemp, flax, sheep's wool, wood fibre, jute, cork and meadow grass. For the sake of this case study, we have focused on "Blown-in, Cellulose-based Insulation" as the cellulose can come from a number of bio-based materials issuing from (until now, paper) recycling activities, and therefore potentially having particular environmental considerations of interest to the project, further to the obvious links to reducing some of the significant impacts of buildings and homes.

The May 2011 version of the Basic Criteria references the (then future) Construction Products Regulation (more in the Legislations section below) and its requirement for environmental product declarations on product environmental performance. According to natureplus, its eco-label already provides this performance evidence based on criteria and requirements exceeding these legal requirements. Annex 6 provides a detailed overview on natureplus' criteria. It shows, for example, that economic issues only play a marginal role in the current version of the document.

Stakeholders opinion on key eco-label criteria

Focussing on current assessment items of natureplus (e.g. regarding sustainable biomass, end-of-life options and social issues) as well as additional criteria identified by STAR-ProBio, targeted discussions with the interviewees take place. The interviewees' opinion on key sustainability criteria is summarized in the table below.

Table 12: Relevance of selected eco-label criteria for bio-based insulation material

Assessment criteria	Relevance according to the interviews	Assessment criteria	Relevance according to the interviews
Sustainable biomass		Social criterion "fundamental principles and rights at work"	
CO_2 emissions		Energy requirement during production	
Toxicity		Biomass utilisation efficiency	
End-of-life options		Life cycle values	
Fitness for use		Life cycle costing specifically	
Social criterion corporate social responsibility			
Legend: relevant in > 50% of the interviews; relevant in 50% of the interviews; not relevant > 50% of the interviews			

In addition to the information in the table, specific suggestions were given.

All the interviewees stressed the importance of **greenhouse gas emissions and energy requirement during production** for this product group, not necessarily because of the potential impact of this product group but rather as an obvious 'given' for avoiding climate change. As insulation products form part of the embedded energy and of the energy performance of a given building, greenhouse gas emissions and energy requirement during production need to be integrated into the whole lifecycle assessment of the building.

While most interviewees where in favour of the **biomass utilisation efficiency** criterion, one interviewee stated that it would not be interesting for this product group given the insulation is made of recycled paper. If a utilisation efficiency criterion would be proposed, it would be for 'waste' utilisation efficiency.

Regarding **social requirements,** interviewees had ranging views, such as:

- social criteria normally applied to materials from outside the EU were less of a priority given that the recycled paper comes from EU sources
- fundamental principles and rights at work were important because wood and wood-based products are not 'friendly' to work with regardless of the material
- the ISO 14001 certification for a potential service providing company is of relevance for the management process of such issues
- communicated in relation to the issue of **toxicity**, this was considered perhaps the most important because bio-based materials can be less easy to install and can require more installation support such as glue or other adhesives and additives

For two interviewees, the issue of functionality and performance were considered important. From a building perspective, **performance standards** and tools such as ISO 14001, FSC, and EPDs helped to more easily integrate performance into building construction specifications although such specifications will remain limited in terms of level of detail on specific materials to be used.

One interviewee found that unconventional or non-traditional products have a difficult time penetrating the building sector, so a '**functionality**' criterion would be even more important than further sustainability standards or criteria (given that recycled paper is considered as automatically sustainable). Such a criterion would serve to help **professionals** (not just in the construction sector, such as architects, designers, specifiers, etc. but also green public procurers) and non-professionals to be more open to using bio-based insulation on their construction or refurbishment projects.

No interviewees suggested that LCA or LCC were particularly interesting as specific new criteria for any given label. For the building sustainability advisor, the reference LCA tool was ISO 14001.

One interviewee went on to highlight that **durability** is a subject having wider public attention more recently, and it is of relevance to the building sector. In any case, they also highlighted, there is still little financial incentive to recycle many materials in construction and demolition activities.

For another interviewee, beyond durability, the **maintenance cycle** of the product was also of relevance because this had an impact on the running life of a building, as well as having the **social aspect** of potentially putting maintenance staff at more frequent risk if they are required to work regularly on exterior surfaces of very tall buildings.

Specific recommendations for natureplus and eco-labels in general derived from the interviews are presented in chapter 9.5. Besides the use of new and modified sustainability criteria for an update of natureplus, attractive opportunities for further activities are described by Scuola Superiore Sant' Anna and Ökoinstitut (2018). Based on the item "building insulants" in the list of product/service categories/groups not covered by the EU Ecolabel", the source describes the focus on construction services and materials as a "possible future approach" for the EU Ecolabel. Addressing "possible windows of opportunities for this label in the transition towards a more circular economy", the source recommends to "focus on building materials and services", highlighting that construction & demolition is a priority sector in the EU circular economy action plan.

9.3. Legislation

The main European legislation addressing construction products and buildings are the Construction Products Regulation (CPR), Energy Performance of Buildings Directive (EPBD), and the Energy Efficiency Directive (EED).

The CPR is a Regulation laying down conditions for the placing or making available on the market of construction products by establishing harmonised rules on how to express the performance of construction products in relation to their essential characteristics and on the use of CE marking on those products. As it is a Regulation (and not a Directive), it must be transposed directly in its entirety by Member States with no variations as allowed in Directives.

Implementation of the Regulation is heavily linked to standardisation processes, with the European Commission issuing standardisation requests (called 'mandates' at the time the Regulation text was finalised) and harmonised technical specifications for the preparation of basic requirements for construction *works* set out in Annex I of the Regulation (more on this below). Similar processes apply for essential characteristics of construction *products* for which harmonised technical specifications are to be laid down in relation to the basic requirements for construction *works*. For specific *families of construction products* covered by a harmonised standard, the European Commission (through delegated acts) determines the essential characteristics for which the manufacturer shall declare the performance of the product when it is placed on the market.

Annex I sets out seven headline basic requirement areas, two of which are hygiene, health and the environment; and sustainable use of natural resources. Hygiene, health and the environment includes emissions of dangerous substances into different environmental media (indoor and outdoor air, different water bodies, soil, and to drinking water).[21] Sustainable use of natural resources includes reuse or recyclability of the construction works, their

[21] Regulation 305/2011/EU, Annex I

materials and parts of demolition; the durability of the construction works; and use of environmentally compatible raw and secondary resources.

So, the CPR takes a lifecycle approach and considers release of dangerous substances and discharges of different types to the environment, as well as requiring reusability, recyclability, durability and environmental compatibility.

One interviewee mentioned the need for the Construction Products Regulation to have bio-based products more specifically integrated into the legislation, as was suggested by the European Commission's Expert Group on Bio-based Products in its final report[22] (see more in the Recommendations section below).

The EPBD promotes the improvement of the energy performance of buildings, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. It lays down requirements on how to calculate the integrated energy performance of buildings and building units; applying minimum requirements to the energy performance of new buildings and new building units, to existing buildings, building units and building elements in different contexts.

In late 2016, as part of the EU's "Clean Energy for All Europeans" package, the Commission proposed an update to the EPBD to, amongst other issues, streamline existing rules and accelerate building renovation with the vision of achieving a decarbonised building stock by 2050. It also launched a funding initiative - the Smart Finance for Smart Buildings initiative - to direct investment towards the renovation of building stock. Member States must transpose provisions of the revised 2018 EPBD by March 2020. They are also meant to establish stronger **long-term renovation strategies** to achieve the decarbonisation target, which can be included in their National Energy Efficiency Action Plans. **Health and well-being of building users** will be promoted, for instance through an increased consideration of air quality and ventilation.

In addition to building renovation strategies, all new buildings must be **nearly zero-energy buildings** by 31 December 2020 (public buildings by 31 December 2018).

Although building insulation is not specifically mentioned as a building renovation or design element in the legal text, it does feature in an Annex list of "Common general framework for the calculation of energy performance of buildings", which sets out what the common methodology for calculating energy performance of buildings must include. Insulation features are part of the actual thermal characteristics of the building, alongside its thermal capacity, any passive heating, cooling elements and thermal bridges. Insulation is therefore an integral element of the building envelope, **although bio-based insulation materials are not explicitly mentioned or promoted over non-renewable materials**.

The EED establishes a common framework of measures for the promotion of energy efficiency to ensure the achievement of the European Union's 2020 20% headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond 2020. It lays down rules designed to remove barriers in the energy market and overcome market failures that are a barrier to efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.

[22] The Commission Expert Group for Bio-based Products existed from 2013 to 2017 with the aim of monitoring and supporting the development of the policy framework, and proposing policy actions to promote uptake of the products. The Group produced a final report at the end of its mandate in 2017, and the report features policy recommendations to help in the development of the sector. See https://ec.europa.eu/docsroom/documents/26451/attachments/1/translations/en/renditions/native, accessed 7 October 2018

It includes a chapter on "efficiency in energy use" made up of articles on building renovation and on various other aspects of building improvements, whether to public bodies' buildings or residential buildings.

Post-2020 energy efficiency targets were agreed in principle in June 2018: **a binding EU target of 32.5% by 2030 and including a clause for revising this target upwards by 2023**. This political agreement needs to be formally adopted by European Parliament and the Council.

All interviewees mentioned the role of **building regulations** and the different levels at which they are applied: nationally or regionally, depending on where public responsibility has been set within the national context. These regulations usually set out a minimum level of safety of a constructed 'product', and can vary in terms of further requirements of certain aspects (such as dangerous substances, etc.). As the level at which these regulations are set varies across EU countries, it is important that EU objectives relating to buildings be integrated in a coherent way across the different EU legislations addressing buildings, to ensure better integration into the building regulations within the EU Member States. One interviewee specifically mentioned the importance of **green public procurement criteria** in this respect, particularly as the potential for uptake of bio-based products and therefore the increase in demand through public procurement is so significant.

9.4. Standards

Implementation of regulations – notably the CPR and EPBD – is done through standardisation processes. One CEN technical committee in particular is involved in those standardisation processes, TC/350 "Construction products".

As the various impacts of construction can be significant, efforts have been increasing to make the sector more sustainable. Design and information are an important element of these sustainability efforts, for transparency reasons as well as for calculations of overall building performance. Since sustainability is assessed at building level, not at product level, relevant product related data is essential in a harmonised format for those building assessments.

This product related data needs to be life-cycle based and cover various environmental impacts from cradle to grave, so from raw materials to recycling/disposal/reuse after the end of the product's first life. The key standards developed are on the sustainability assessment of buildings (EN 15978) and on relevant product information (EN 15804).[23]

EN 15804 *"Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products"* provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service. It:

- defines the parameters to be declared and the way in which they are collated and reported
- describes which stages of a product's life cycle are considered in the EPD and which processes are to be included in the lifecycle stages
- defines rules for the development of scenarios, includes the rules for calculating the lifecycle inventory and the lifecycle impact assessment underlying the EPD, including the specification of the data quality to be applied

[23] See https://www.eco-platform.org/cen-tc-350.html, accessed 20 September 2018

- includes the rules for reporting predetermined environmental information, that is not covered by the LCA for a product, construction process and construction service where necessary

EN 15942:2011 *"Sustainability of construction works - Environmental product declarations - Communication format business-to-business"* specifies and describes the communication format for the information defined in EN 15804 for business-to-business communication to ensure a common understanding through consistent communication of information. Business to consumer communication is not addressed by EN 15942:2011, but a future communication format for consumers is to be developed.

CEN/TR 15941:2010 *"Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data"* is a technical report supporting the development of EPDs according to the PCRs set out in EN 15804. It does this by helping using generic data in a consistent way. It also helps in applying generic data to the environmental performance assessment of buildings according to another harmonised standard EN 15978.

Another technical report CEN/TR 16970:2017 *"Sustainability of construction works - Guidance for the implementation of EN 15804"* also helps by providing general guidance on EN 15804 and in preparing complementary Product Category Rules (c-PCR's). It sets out general principles for the use of EN 15804 by the many CEN Technical Committees for construction products (e.g. CEN TC/88 "Thermal insulating materials and products") to ensure consistency among the complementary PCRs produced by the different TCs. It also addresses questions raised by different players helping to deliver the CPR requirements, including CEN construction products TCs, product manufacturers and the sub-contractors providing LCA studies that form the basis of EPDs, and by EPD programme operators who include c-PCR of specific subcategories in their PCR registry (see CEN TC 350, 2018).

In relation to insulation products, CEN TC/88 "Thermal insulating materials and products" is responsible for terminology and definitions, list of required properties for different applications, methods for determining these properties, sampling procedures, conformity criteria, specifications for insulating materials and products, marking and labelling of insulating materials and products (see CEN TC 88, 2018).

The Committee's working group 23 on "Vegetal fibers based products" has produced EN 15101-1:2013 *"Thermal insulation products for buildings - In-situ formed loose fill cellulose (LFCI) products - Part 1: Specification for the products before installation."*

Analysing an EPD listed in the ECO Platform website for information provided of relevance to the project[24], it is interesting to note that end-of-life aspects of the product state that if the material is not contaminated it can be reused and that it otherwise should be incinerated (rather than disposed of in a landfill). However, what is particularly interesting is that the German Federal Institute for Research on Buildings, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung) considers the energy produced during waste treatment is declared as 'exported' energy and the produced 'benefits' (the energy gained from the burning of the product) from incineration are declared in 'benefits and loads'. So, incineration of the end-of-life product is not only encouraged, but it considered as a benefit.

As recognition of the need to better integrate (sustainable use of) bio-based products into building-related legislation and standards continues to develop, there will be future opportunities to ensure such integration.

[24] See the list of all ECO Platform EPD at https://www.eco-platform.org/list-of-all-eco-epd.html, and the specific EPD at https://www.eco-platform.org/files/img/gen/epd_download.png, both accessed on 21 September 2018

9.5. Main findings

Several recommendations at different levels result from the analysis and interviews undertaken.

Better integrating bio-based materials and products considerations into regulations

The EU legislation addressing buildings – the Construction Products Regulation, the Energy Performance of Buildings Directive, and the Energy Efficiency Directive – were written before the development of the emerging and increasingly established political focuses of the bio-economy and the circular economy. The potential for bio-based products to contribute to the sustainability of buildings and their improved performance on several aspects is such that these pieces of legislation should be revised to explicitly integrate circularity and wider resource efficiency requirements including the use of bio-based products in the legal text.

Indeed, the European Commission's Bio-based Products Expert Group (BBP EG) stated a belief that "special emphasis should be placed on the contribution of renewable, sustainably sourced and environmentally sound, bio-based products to the development of a resource efficient circular economy" (BBP EG, 2017). The Group called for policy signals, measures and incentives for bio-based products, and coherent and holistic frameworks that emphasise the links between the circular economy, the bio-economy and the role of bio-based products.

As part of the Group's various activities, it provided policy recommendations in an evaluation of European Commission efforts at promoting bio-based products. Specific recommendations for buildings and/or insulation include that the Construction Products Directive (sic) promote the 'specificities' of bio-based products (specifically mentioning foams for insulation).

From a more holistic perspective, the convergence of the three pieces of legislation mentioned above would strongly benefit building-related activities in efforts to build a circular and resource efficient economy that integrates (in the words of the Expert Group) 'renewable, sustainably sourced and environmentally sound, bio-based products'. These would then more easily be integrated into building regulations at national or regional levels depending on how these are administered within the EU Member States.

Leveraging public procurement more effectively

One interviewee specifically mentioned the importance of green public procurement in promoting the use of bio-based products. The European Commission's Bio-based Products Expert Group already recommended that contracting authorities in all EU Member States should be encouraged to give preference to bio-based products in tender specifications. In the Group's view a requirement or a recommendation to give preference can be laid down in a national action plan adopted by EU Member States.

Through the EU GPP criteria process, criteria for "Office Building Design, Construction and Management" were created in 2016 (see European Commission, 2016). The criteria reference insulation only in relation to the performance of the main building elements (insulation being listed as one element) as part of the elements to be prepared for reuse, recycling or other forms of material recovery in demolition waste audit and management plans, as an element to be included in site waste management plans, as part of the quality of the building (ensuring continuity of insulation). There are no mentions of specific insulation materials being encouraged, or that these should be specified. This gap exists similarly in the guidance document (JRC, 2016) prepared to support these criteria.

Bio-based products could be more explicitly mentioned in various GPP criteria, particularly starting with the high impact 'products' such as buildings.

GPP criteria could also help to support the market penetration of less 'accepted' products such as bio-based insulation materials, which continue to remain marginal due to resistance from sector professionals.

Standards contributing to sustainability

As has been highlighted by one of the interviewees, it is difficult for unconventional or alternative products, including bio-based construction products, to penetrate the construction sector, and this could be supported by the creation of EU standards on bio-based construction products. These can then more easily be integrated into a highly regulated sector with a very conservative approach to products and methods.

An interviewee also suggested that product testing methods could be revised to prove some of the beneficial impacts of bio-based insulation materials such as vapour permeability and heat storage capacity.

There is also a need to realign LCA value allocations for some bio-based products (perhaps those containing a high minimum percentage) so that incineration as a means of gaining energy recovery is no longer considered a benefit in LCA or EPDs. This would serve to avoid the material loss from end-of-life products and encourage more cascading uses of biomass.

Eco-label recognition and take-up

As the natureplus eco-label already exists and is a comprehensive European Ecolabel for insulation materials addressing triple bottom line aspects of sustainability, there is no identified need for the creation of a new eco-label.

New criteria could be developed to more explicitly address longevity or durability, and as one interviewee suggested, functionality, as a means of gaining confidence in unconventional or alternative products.

There is also the question of how to better integrate the natureplus eco-label into a policy mix addressing sustainability in buildings. One interviewee suggested that labels have an end consumer (public) focus and more effective take-up of bio-based insulation materials needs more attention on tools focusing on professionals where there is resistance to change. In the view of the interviewee, these tools are standards and green public procurement.

10. Recommendations

Based on the findings of the case studies, this chapter provides recommendations for eco-labels, standards and adjustment of the regulatory framework. Table 13 summarizes the results. In addition, overarching recommendations are included in section 10.4.

Table 13: Summary of recommendations

Case study	Recommendations		
	Regarding eco-labels and criteria	Regarding standards	Regarding the regulatory framework
Food packaging made of PLA (film)	Integration of specific criteria in existing labels for packaging consisting of different materials	Development of a LCA standard	Development of a regulation with a classification of (food) package products to facilitate the choice of a product under sustainability considerations
Bio-based car components	Development of an eco-label, in particular for interior parts[25] and for bio-based cellulose fibres	Development of a LCA standard with a specific focus on energy use and CO_2 emissions	Improvement of the framework conditions for the end-of-life stage,[26] in particular to facilitate a separate recycling of bio-based and non-bio-based components
Bio-based mulch films	Development of an eco-label/EU Ecolabel category	Specification of some functional characteristics are needed	Consideration of bio-based mulch film in agricultural regulations and in regulations to protect Nature 2000 areas, if possible
Bio-based insulation materials	Existing European independent eco-label criteria to be taken up in other EU tools such as GPP	EU-level standards needed on more bio-based products including, but not limited to, different insulation materials	Introduction of explicit objectives and requirements on bio-based products into the Construction Products Regulation, the Energy Performance of Buildings Directive and the Energy Efficiency Directive

10.1. Eco-labels

For each case study on food packaging, car components, mulch films and insulation materials, research was conducted for analysing the importance of proposed eco-label criteria.

PLA-based food packaging

Paper bags with plastic windows were identified as a field of specific interest, and it has been suggested to integrate criteria on bio-based plastics in existing labels for these paper products.

Considerations on the bio-based content criterion also led to further conclusions regarding bio-based packaging. Statistics in Annex 3 show the importance of bio-based plastics specifically. Besides food, various other products are also often sold packaged, such as, for example, cosmetics and textile products. In addition, options regarding the packaging of clean-up products, including for example liquid detergents, appear to be relevant. For this reason, including a criterion "bio-based packaging" across the labels that consider packaging is recommended.

[25] No eco-label exists for bio-based car components yet.

[26] Specification of bio-based material that can be recycled together with fossil-based products and of possible mixes of car components to facilitate an appropriate recycling.

Bio-based car components

The automotive sector provides very attractive framework conditions for the use of bio-based materials and currently eco-labels are missing. Creating an eco-label for car interiors seems to be an interesting starting point while at the same time accepting existing eco-labels for the material should be considered. In addition, the need for an eco-label for bio-based cellulose fibres was expressed.

Bio-based mulch film

The creation of an eco-label, preferably as an EU Ecolabel category was suggested. Emphasis was put on the consideration of the eco-label criteria bio-based content, sustainability of raw material, fitness for use, biodegradability in soil, ecotoxicity and life cycle values.

Bio-based insulation material

As the natureplus Ecolabel already exists and is a comprehensive European eco-label for insulation materials addressing triple bottom line aspects of sustainability, there is no identified need for the creation of a new eco-label. New criteria could be developed to more explicitly address longevity or durability and functionality. Furthermore, more effective take-up of bio-based insulation materials needs more attention on tools focusing on professionals where there is resistance to change.

Possible patterns to adjust the eco-label landscape

The case studies unveiled three principle options to adjust the eco-label landscape to better address the needs of bio-based products.

- specification of additional product classes in eco-label categories to consider bio-based content
- inclusion of a criterion requiring bio-based content in existing eco-labels
- specification of criteria sets for products with bio-based content

Specification of additional product classes in eco-label categories to consider bio-based content, in particular in the EU Ecolabel

The EU Ecolabel does not refer to mulch films, car components or food-packaging. Regarding mulch films and car components, the introduction of an eco-label category shall be considered. In the food context, eco-labelling options exist, although the needs of packaging with PLA parts have not yet been appropriately considered. The PEFC label might provide framework conditions for these activities as well as joint actions for the EU organic label and the EU Ecolabel.

Inclusion of a criterion requiring bio-based content in existing eco-labels

Requiring sustainable bio-based content supports bio-based products in a unique way. As mentioned before, the PEFC label is used for paper-bags even if they include plastic parts. Adding a criterion requiring bio-based plastic content as well as criteria specifying the characteristics of this content is suggested. Besides this, our analyses have shown that several eco-labels for specific products already require bio-based content, in one of the following options:

- bio-based content of the product and/or
- bio-based content of the package, if the product is sold packaged.

Various existing labels have shown that specifying a minimum percentage of bio-based content is possible. Nevertheless, the EU Ecolabel example stresses the importance to negotiate appropriate solutions that are supported by all relevant stakeholder groups.

Specification of additional and modified criteria for products with bio-based content

The interview series unveiled various useful criteria to assess bio-based content and enrich existing eco-labels. This applies in particular to eco-labels for paper-based (food) package with plastic windows, considering the use of PLA specifically. Insulation material is another example: new criteria could be developed for the relevant eco-label natureplus to more explicitly address longevity or durability, and functionality.

Findings on eco-label criteria

Table 14 summarizes the importance of the various eco-label *criteria* in each analysed case study. In addition to the discussion of the pre-selected criteria, an extension of the criteria list by the following items should be considered:

- bio-based car components: land use to ensure food security, consumption of water in the production, total use of non-renewable energy, specific RED criteria regarding sustainable biomass[27]
- PLA/Food packaging: land use, consumption of water, use of pesticides, migration test, colors as specific EOL issue, functionality criteria as well as additional criteria according to the suggestion for a standard
- mulch films: biodegradability in soil (EOL), fitness for use/performance criterion on mechanical and optical properties
- insulation material: longevity or durability, and functionality

Rich information was provided in particular regarding the fitness for use criterion and its nature in the different case studies.

As the table shows, four criteria are important for all product groups while the results for the other criteria were mixed. No criterion was deselected in all case studies although an appropriate use of the criterion life cycle costing requires specific consideration.

[27] No conversion of land with previously high carbon stock, no use of raw materials obtained from land with high biodiversity

Table 14: Relevance of eco-label criteria in the case studies

Assessment criteria	Relevance according to interviews			
	Bio-based car compo-nents	PLA/Food packaging	Mulch Films	Insulation materials
Sustainable biomass/ bio-based content				
CO_2 emissions				
Toxicity				
End-of-life options				
Fitness for use				
Corporate social responsibility				
Fundamental principles and rights at work				
Energy requirement during production				
Biomass utilisation efficiency				
Life cycle values				
Life cycle costing specifically				
Specific additional suggests	See below			

Legend: relevant in > 50% of the interviews; relevant in 50% of the interviews; not relevant in > 50% of the interviews

As the table shows, four criteria are important for all product groups while the results for the other criteria were mixed. No criterion was deselected in all case studies although an appropriate use of the criterion life cycle costing requires specific consideration.

Additional recommendations

Consider the specific characteristics of B2B and B2C markets in the creation of eco-labels

There is a need to specify clearly whether the target group of a label consists mainly of end-consumers or professional procurers. Interviewees distinguished specifically between B2B and B2C markets because the interest in eco-label criteria differs. In general, end consumers are interested in smaller criteria sets while professionals prefer more detailed information, for example, regarding LCA and LCC.

Specify thresholds for bio-based content together with the requirements of key sustainability criteria

The percentage rate of bio-based content and other sustainability effects have to be considered together. This applies, for example, to the origin of feedstock: it is to ensure that maximizing the amount of bio-based content is not realised by using raw materials whose sourcing requires long transports.

Develop specific circular economy measures for bio-based products

In the context of bio-based products, realising the circular economy makes a clear distinction between material and biological recycling necessary, which must be considered by the

relevant products and labels. The case study on bio-based car components emphasised this in particular.

Consider individual product characteristics in the creation of eco-labels appropriately

The different eco-label criteria discussed in our interviews are of varying importance for the different case study products. Individual criteria could therefore be excluded from a specific product category's criteria set or be considered as additional voluntary assessment options, enabling the product providers to show additional advantages of their products, if they wish.[28]

10.2. Legislation

The analysis of the regulatory framework led to general recommendations but also to suggestions to support the specific product categories of selected case studies.

General recommendations

As various interviews have shown, selected RED criteria are interesting for the assessment of bio-based products.

While the benefits of a GHG criterion and the pressure created by related thresholds require additional analyses, the requirements: i) to avoid biomass made from raw material obtained from land with high biodiversity (such as primary forests or highly biodiverse grasslands) and; ii) to avoid the use of raw material obtained from land with high carbon stock (such as wetlands or forests), appear to be useful in the context of bio-based products as well. However, having them as eco-label criteria instead of a regulatory document appears to be more interesting for many target groups, in particular in the automotive sector.

Both topics are important items in the context of sustainable biomass sourcing. Various times, the opportunity to make bio-based products from residues and/or waste was highlighted. The CE Delft (2017) study highlights various specific advantages, which bio-based products derived from waste and by-products can provide: no competition with food production, when used for other purposes, part of the environmental impact is allocated to those purposes (in LCA). Potentially, wastes and by-products have even higher GHG emission savings (see CE Delft, 2017, pp. 5, 32, 36). The authors highlight for the PLA production from sugar cane, for example, that there is even a net-production of energy if the by-products are used as feedstock for energy production (see CE Delft, 2017, p. 36). Besides this, a group of interviewees highlighted that there are labels on biomass, which consider RED criteria. As an alternative to a regulatory document, requiring these labels could be part of STAR-ProBio's broader assessment solution. Another option is to follow the example of these labels and use RED criteria directly as part of STAR-ProBio's blueprint.

PLA-based food packaging

The case study on PLA-based food packaging has shown much support for a potential RED-like document. In addition, the creation of a classification of bio-based package products was suggested in our interviews. The expected impact of this measure is the facilitation of assessments and decisions by (food) producers. In general, suggestions to create classifications were given frequently in our case studies. While these recommendations referred to the use of energy in the context of bio-based car components, the creation of a classification based on a detailed criteria set was suggested for food packaging.

[28] Different preferences by end-consumers or professional procurers, which require consideration, were also shown in the first round of STAR-ProBio work package 5's Delphi study.

Bio-based car components

Our interviews led to the conclusion that current European regulations are not specific enough for the emerging field of bio-based car components. A specific gap refers, for example, to the recycling stage, for which two specific recommendations could be derived. It should be specified which bio-based material can be recycled together with fossil products and which mix of car components is possible to facilitate an appropriate recycling.

Mulch film

Various regulations on film-based agriculture exist while a higher level of environmental protection is desired. Bio-based films are currently not considered specifically but could be included in this series of documents. A specific push for these products can be expected from such measures.

Insulation material

The EU legislation addressing buildings – the Construction Products Regulation, the Energy Performance of Buildings Directive, and the Energy Efficiency Directive – were written before the development of the emerging and increasingly established political focuses of the bio-economy and the circular economy. Specific recommendations for buildings and/or insulation include that the Construction Products Directive promote the 'specificities' of bio-based products (specifically mentioning foams for insulation). From a more holistic perspective, the convergence of the three pieces of legislation mentioned above would strongly benefit building-related activities in efforts to build a circular and resource efficient economy that integrates bio-based products with attractive properties.

10.3. Standards

PLA-based food packaging

Detailed suggestions for standardisation were given for pre-packaged food. The criteria set for the suggested assessment standard could be comparable with the criteria suggested for an eco-label. The suggested LCA standard should facilitate comparison with petrol-based products to highlight advantages and to overcome the disadvantage that PLA is expensive.

Bio-based car components

For bio-based car components, a standard on end-of-life issues and an energy standard were suggested. In terms of the end-of-life standard, recyclability should be a key issue. As the case study on food packaging shows in particular, specific emphasis was put on LCA issues and comparisons with fossil-based products.

Mulch film

Biodegradability, its specific requirements and appropriate testing methods are already considered by the new standard EN 17033:2018. Besides this, most interviewees highlighted functional characteristics of bio-based biodegradable mulch film as an important field for action (see results for the "fitness for use" criterion). Further guidance to specify functional characteristics is provided by Briassoulis and Giannoulis (2018).

Insulation material

Due to the difficulties for unconventional or alternative products, including bio-based construction products, to penetrate the construction sector, the creation of EU standards on bio-based construction products could provide support. These can then more easily be integrated into a highly regulated sector. In addition, product testing methods could be

revised to prove some of the beneficial impacts of bio-based insulation materials such as vapour permeability and heat storage capacity. There is also a need to realign LCA value allocations for some bio-based products.

10.4. Overarching recommendations

Written by Mathilde Crepy and Doreen Fedrigo-Fazio (ECOS)

The following recommendations address broader public policy and existing regulations and mechanisms, and highlight the need to update other independent mechanisms and labels.

The EU's Bioeconomy Strategy needs to further define sustainability for bio-based products

The EU's bioenergy agenda has driven the wider development of bio-based products, yet until now sustainability criteria for biomass feature solely in the EU's Renewable Energy Directive. Similar **sustainability criteria are required for other significant sectors with a potentially high demand for bio-based products** including construction products and buildings. Bearing in mind that biomass is a resource shared for the production of food, products and energy, there is a need to **ensure coherence across the various biomass related sustainability criteria**, to avoid conflicting objectives and market distortion as well confusion among producers, procurers and the general public.

The Bioeconomy has to go beyond a cradle to gate approach and provide more clarity on the use phase and end-of-life management

Policy objectives need to contribute to **extend the lifetime of a product, promote its reuse** and clearly state a preference for **organic recycling** over energy recovery. There is also a need to develop more clarity on how to **manage the co-existence of similar bio- and fossil-based products** (their identification, collection, sorting, recycling).

The EU's product policy has to better account for bio-based products

The 2018 Bioeconomy Strategy highlights the importance to better link bio-based products with EU product policy instruments such as the EU Ecolabel, Green Public Procurement or the Product Environmental Footprint. **EU product policy instruments provide the framework to move from the resource based focus of the Bioeconomy Strategy (focusing on the use of biomass for food, products and energy) to a life cycle approach of products, making it much easier to bridge to a circular economy.**

LCA is an important decision-making tool needing further embedding in EU policy development and implementation

The life cycle assessment (LCA) methodology helps to provide information about a product's ecosystems, health and resource impacts, identifying hot spots where significant impacts are made and therefore where intervention is needed most. Its integration into EU policy development is unequally distributed across policy areas, and only formally integrated into some EU product policy mechanisms such as the Product and Organisation Environmental Footprints (PEF and OEF). Despite the integration of LCA into policy development, **the selection of LCA-based policy options remains a political decision**, particularly as trade-offs between impacts require prioritisation of activity and as thresholds or limit values imply categorisation of the impacts.

For bio-based products it is a key priority to **revise LCA methodology** to no longer view incineration of such products as beneficial for their energy recovery. The cascading use of bio-based materials and products to ensure the optimisation of their use is completely undermined by this LCA methodology. It is also important to continue exploring the possibility of comparing the environmental footprint of bio-based products with fossil-based ones, notably by developing data on the impact of fossil resources use.

There is a need to create more coherence between different EU policy mechanisms

A patchwork of approaches to requirements on bio-based materials and products has been identified: the RED has strengthened sustainability criteria and PEF is beginning to become more detailed on some bio-based products product categories, while a harmonised update could be made to the EU Ecolabel's requirements, and GPP guidance. Centralisation of preparation of criteria for the Ecodesign Directive, the Ecolabel and GPP has been implemented. **A harmonised approach to integration of requirements on bio-based products is also needed, not just for products made primarily from bio-based materials** but also to potentially integrate bio-based plastics as preferable to fossil-based ones when there is enough proof of their high environmental performance. These requirements include sustainable production of the biomass, sustainable sourcing, and cascading use in end-of-life management to avoid automatic incineration. Such requirements are also an opportunity to develop an EU approach to the issue of biodegradability and the need to avoid increased littering activities. **Work currently underway on EU Product Policy to support the circular economy should better integrate sustainability considerations of bio-based products**.

More coherence is needed between legislation and other market mechanisms like standards and certification schemes

Since the development of sustainability criteria in the Renewable Energy Directive, standards have been created that set out similar sustainability criteria for non-RED-related products (including for biomass more broadly). More clarity for market players and public and private users (consumers, companies, authorities, etc.) could be achieved through an assessment of **needed updates and revisions in legislation and standards, and of how to integrate certification schemes as a sign of conformity.**

A minimum biomass content should be implemented together with sustainable biomass production criteria

Most bio-based products are only partly bio-based. The introduction of minimum bio-based contents per product category is an efficient instrument to encourage the use of renewable resources. In addition to that, sustainability criteria for biomass production ensure that the raw materials used have a limited impact on the environment. This combination of criteria ensures that first, a known and significant part of a bio-based product is actually bio-based and second, that this bio-based content was produced sustainably. While claims such as 'made from plants' can be misleading for consumers who may think that products are fully bio-based and have a limited impact on the environment, **green claims should only be allowed when combining minimum bio-based content with sustainability criteria for biomass.**

Some sustainability criteria need to be product specific

While certain sustainability criteria may apply to bio-based products as a whole (e.g. production of biomass), others need to be product specific. This is notably the case for **criteria measuring the impact of a product's use stage and its end-of-life**. We note for instance that biodegradability may be a key feature for certain products such as mulch films, and not relevant for other product types such as insulation.

Multi-criteria approach allows for a 'fuller' treatment of sustainability

Instead of making use of several single issue labels to assess the sustainability of bio-based products, **the use of existing type I eco-labels** (such as the EU Ecolabel) **should be prioritized** as they are already well-known, make very easy the identification of a good performer on the market, and are so comprehensive they limit the risk of false/misleading claims.

11. Conclusions

This report assessed the suitability of different eco-label criteria for bio-based products and intermediate products, based on specific case studies. Options for a potential expansion of European eco-label criteria and even for new eco-label product categories were discussed. In addition, suggestions to amend certain regulatory measures to better integrate new characteristics relevant for bio-based products into existing regulations and to cover the entire life cycle of the product were proposed.

The work on this report unveiled key criteria, which are not only relevant for eco labels but also for the STAR-ProBio blueprint and further standardisation activities although specific indicators and thresholds will require further research.

The analyses also showed the importance to consider product-specific characteristics in the sustainability assessment of bio-based products and highlighted the need to customise sustainability assessment solutions for B2C and B2B/B2G markets. Product specific characteristics and applications have, for example, specific influences on the relevant EOL options and desired properties such as biodegradability and compostability.

As CE Delft (2017) found already, application of biodegradable bio-based plastics is recommendable in those applications with either a direct functionality or those with co-benefits. In the context of the presented case study, such a direct functionality refers, in particular, to biodegradable mulch film, which avoids the need to take the films back from the fields after use.

Case study-specific conclusions

The analyses led to various conclusions for the four case study applications. Regarding **PLA food packaging**, it is recommended to focus the work on an advancement of the eco-label landscape specifically on paper packages, particularly bags, with a plastic window. This can, for example, mean to extend the scope of the FSC® / PEFC label. Our analyses also led to the suggestion to create an LCA standard to analyse bio-based and non-bio-based packaging. In addition, the results on eco-label criteria aim to support the potential joint labelling initiative of the EU Ecolabel and the Organic Label in the food sector. Specific recommendations also refer to the development of regulatory solutions for the EOL stage. There is a need to promote the separate collection of bio-based waste to specify requirements for the integration in bio-waste streams and to promote organic recycling through legislation.

In the automotive industry, new segments of **bio-based car components** are developing although eco-labelling opportunities are rare. Addressing this gap through suitable eco-label development activities is suggested. According to an expert quoted before, "such a solution would be a 'super' output of STAR-ProBio to provide customers with transparent information." In line with the food package case study, is also recommended to address the need for guidance to separate bio-based and non-bio-based parts appropriately in the EOL stage by regulatory measures. A specific recommendation refers to the creation of an LCA standard for selected car components.

Regarding **Bio-based mulch films,** the analysis has led to suggesting eco-label criteria specific for bio-based mulch films. In addition, various opportunities to support the use of bio-based mulch through regulation are provided.

Bio-based insulation materials analysis has shown that a clearer integration of bio-based products into legislation on construction products and on environmental performance of buildings would help to provide a more supportive regulatory framework for the

uptake of such products. The construction sector remains conservative and it is difficult for 'alternative' or 'unconventional' products to break into already established markets. No need for a new eco-label was identified, particularly as an international one already exists which addresses many potentially key sustainability aspects. Building on a minimum percentage of bio-based material criteria, suggestions were made to introduce criteria on durability (lifetime of the product), functionality and performance. As for standards, the implementation of the Construction Products Regulation is based on environmental product declarations. Through a clearer integration of support for bio-based products in the Regulation, a knock-on effect would be a revision of the EPD methodology and considerations.

Conclusions for the bio-economy and the SAT-ProBio blueprint

According to experts, various case study findings are relevant for the bio-economy as a whole, for example, the relevance of the assessment criteria sustainable biomass/bio-based content, CO_2 emissions, end-of-life options and corporate social responsibility as well as the need for regulatory support for the realisation of organic recycling and the integration of bio-based products in organic waste streams.

A general suggestion is also to accept third-party certificates (e.g. ISCC, RSB, RSPO, BONSUCRE) or any equivalent scheme based on multi-stakeholder management criteria to prove the sustainability of the raw materials.

Besides providing suggestions for eco-labels, the standards landscape and the regulatory framework, one of STAR-ProBio's main goals is the development of a **sustainability assessment blueprint**. Important work in this regard was done in STAR-ProBio's deliverable 2.2 "Selection of environmental indicators and impact categories for the life cycle assessment of bio-based products" (see STAR-ProBio, 2017b). According to the following figure, ten clusters of indicators were selected:

<table>
<tr><td>Acidification</td><td>Ecosystem quality (biodiversity)</td><td>Human health – Toxicity</td></tr>
<tr><td rowspan="2">Air quality</td><td colspan="2">Eutrophication
terrestrial fresh water</td><td>Mineral and fossil resources</td></tr>
<tr><td rowspan="2">Climate change</td><td colspan="2" rowspan="2">Land use
soil quality soil erosion</td><td rowspan="2">Water availability/ use of water</td></tr>
<tr><td>Wastes</td></tr>
</table>

Figure 7: Selected clusters of indicators

Based on our findings, the following conclusions can be drawn:

The core set of STAR-ProBio's **D2.2 indicators for STAR-ProBio's blueprint** is covered by our criterion "sustainable biomass." Our stakeholders specified it further by criteria regarding the above mentioned issues: land use and biodiversity. For this reason, we propose to consider them also in STAR-ProBio's further work on its blueprint.

Eutrophication was highlighted by our interviewees as an additional criterion as well, mainly to be considered as an element of an assessment standard. The suggestion for an inclusion in a standard shows that this criterion is considered particularly relevant.

Specifying a criterion regarding the use of water was suggested clearly by our interviewees, for example from the automotive sector. The human health item toxicity was supported by this document as well, while D2.2's indicator mineral and fossil resources has its counterparts in our criteria bio-based content, energy requirement during production and biomass utilisation efficiency.

The importance of indicators on "wastes" is also stressed clearly in our study. Our eco-label list refers to "end-of-life" options in this regard while the interviewees provided various specific recommendations, not only for eco-labels, but also for the regulatory framework and standards. Regarding mulch films for example, this report highlighted the importance of the specific end-of-life option biodegradability in soil.

Air quality is also regarded as an important general indicator, not only relevant for bio-based products. As mentioned in chapter 9.3 regarding legislation for insulation material, air quality can be a key measure to support the health and well-being of building users. For this reason, STAR-ProBio's D2.2 support our findings regarding the importance of this indicator.

Two items of STAR-ProBio's D2.2 were not discussed in this report: Acidification is the first one. It is an item of the EU's Product Environmental Footprint Category Rules Guidance (European Commission, 2017) and applies to fossil-based products as well. Since this criterion is not very common in the eco-label landscape at the moment, STAR-ProBio will provide an additional contribution. The second item is the indicator climate change. It requires further specifications regarding an appropriate methodology according to STAR-ProBio D2.2, p. 17. If this is realised, this indicator can be a specific added value of STAR-ProBio's blueprint, which differentiates the project's results from the majority of eco-labels, by which this item is not considered.

Conclusions for specific sustainability assessment criteria

With specific regard to eco-labels, this report unveiled **sustainability assessment gaps** for specific products groups, which are also relevant information for the specification of application fields for STAR-ProBio's blueprint in the future. Furthermore, product-specific requirements for particular criteria and related indicators were unveiled. To give an example, this report not only promotes the findings of D2.2 regarding the relevance of the (human) toxicity topic but also shows the relevance of **product-specific sub-criteria**, which are, for example for food packaging issues such as vapour permeability, O_2 penetrability and the use of additives.

As already mentioned briefly above, specific findings also relate to **life cycle assessments**. Various interviewees expressed the need consider not only environmental issues in this regard, but also social LCA and life cycle costing. As described above, STAR-ProBio's D2.2 had a specific focus on environmental issues while social and economic issues and further product characteristics were not in the scope of this document. For this reason, the present report shows the importance of various **additional assessment issues**, for example regarding **social criteria, LCC and functionality requirements**. Furthermore, the relevance of criteria for specific product groups were presented, which shows that specific product-group solutions are needed.

The analyses of this report built on a set of case studies selected in STAR-ProBio's WP1 due to their relevance in the bio-economy. The characteristics of the case study products vary in many aspects, e.g. target groups, kinds of feedstock, product characteristics, application fields etc. Nevertheless, our analyses have shown that many eco-label criteria are important for all these products. For this reason, it is likely that the findings **apply to various other bio-based products** as well. With regard to the particular applicability for specific product groups, additional analyses are recommended. However, the discussion of the findings together with the findings of STAR-ProBio's D2.2 provide additional support for the relevance of the results of both deliverables.

With regard to recommendations to assess specific product groups, this report does not only specify eco-label criteria in general, but often also specifies, as mentioned, **criteria**

for different market segments, for B2C and B2B/B2G markets in particular. These pieces of information can support the specification of the STAR-ProBio blueprint as well.

In addition, the suggestions for standards and the specification of various standards items of this document do not only provide input for standardisation on European and international level in general, they can also be used for STAR-ProBio's intended creation of a CEN Workshop Agreement for the sustainability assessment of bio-based products.

The main focus of this report was on requirements to be considered by eco-labels, standards and legislation to support bio-based products better in the future. A key question regarding the realisation of a sustainable bio-based economy refers now to the reactions of the stakeholders, who are addressed by these requirements. An intrinsic motivation to promote sustainability and a fundamental change on the demand side of the market is needed, as stressed by our interviewees. As an example for a starting point, one interviewee described how their organisation organises a mandatory sustainability workshop once a year, involving all relevant staff members and specifying measures to improve the sustainability behaviour of the organisation. Options for similar measures are almost unlimited. The combination of suitable sustainability requirements and an intrinsic sustainability orientation on the side of all relevant stakeholders has the potential to become a cornerstone to make the sustainable bio-based economy a reality.

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Annex 1: Labels of the analysis

Table 15: Labels of the analysis

Analysed eco-labels	
• Cradle to Cradle Certified(CM) Products Programme • Roundtable on Sustainable Biomaterials • RSPO Certified Sustainable Palm Oil • PAS 100 certified • Blue Angel / Blauer Engel • Carbon Footprint of Products • Carbon Neutral Product Certification • Compost Label RAL • Compostability Mark of European Bioplastics • (Seedling) • Compostable: Biodegradable Products Institute Label • CSA Sustainable Forest Management • DGNB Certificate, developed by the German Sustainable Building Council • Earth Advantage, certification of high performance homes, remodels, sustainable communities etc., example: "Home" • EU Ecolabel • Ecocert • Effinature (biodiversity deterioration in the construction sector) • Fairtrade • Green Dot / Der Grüner Punkt / Grønt Punkt • GreenCircle • GreenPla • IMO Certified	• LEED Green Building Rating Systems • level mark • National Green Pages™ Seal of Approval • natureplus (quality for sustainable building and accommodation products) • Nordic Eco-label / "Swan" • NSF Sustainability Certified Product • OK biobased • OK biodegradable WATER • ÖkoControl • Recycled Content • SCS Recycled Content • SFC Member Seal (The Sustainable Furnishings Council (SFC) Member Seal) • SMaRT Consensus Sustainable Product Standards • Smart WaterMark • TerraCycle • UL Environment Multi-Attribute Certification • UL Environmental Claim Validation • UPS Eco Responsible Packaging Programme • USDA Certified BioBased • Verified Carbon Standard • VIBE (label for sustainable building and accommodation products)

Interview guide on the consideration of bio-based products by eco-labels

Introduction

STAR-ProBio is a three-year project (May 2017 - April 2020) and supports the European Commission in the full implementation of European policy initiatives, including the Lead Market Initiative in bio-based products, the industrial policy and the European Bio-economy Strategy. STAR-ProBio does so by developing sustainability assessment tools for bio-based products, and by developing credible cases for bio-based products with the highest actual market penetration and highest potential for the future markets. STAR-ProBio integrates scientific and engineering approaches with social sciences and humanities-based approaches to formulate guidelines for a common framework promoting the development of regulations and standards supporting the adoption of business innovation models in the bio-based products sector. The aim of STAR-ProBio is to fill gaps in the existing framework for sustainability assessment of bio-based products, and improve consumer acceptance for bio-based products by identifying critical sustainability issues in their value chains. This interview is part of STAR-ProBio's task "Analysis of regulations, (eco)labelling and policy initiatives" - "Assessing (eco)labels and Standards".

Questions

A Your background

1. Please specify your background and stakeholder group in the bio-based economy and the key product groups of your knowledge and activity briefly:

1.1 Product- or process-related background in the bio-based economy?

1.2 Stakeholder group?

□ Producer, retailer etc.
□ Consumer
□ Certification and standardization bodies
□ Public procurement
□ Other, please specify

1.3 Country?

2. Please select a product group to discuss the needs of bio-based products in the context of sustainability, regulatory support, ecolabels and standards.

B Framework conditions

Please describe the framework conditions for sustainable bio-based products in your selected area on a national, European and international level:

a) regarding the regulatory framework

b) regarding existing standards

c) regarding existing eco-labels

C Eco-labels

1. Please select one eco-label as foundation for the following questions.

2. How could this eco-label address the needs of the bio-based products of your selected product group better?

□ By doing nothing, the label addresses the needs of bio-based products appropriately

□ By the creation of a new product category

□ By a criterion requiring bio-based content

□ regarding the product

□ regarding the package

Do you suggest a specific percentage rate?

□ Yes □ No

If yes, please specify: _____

□ By criteria regarding specific characteristics

3. A few criteria, partly used in different eco-labels already, are listed below. Please discuss their usefulness to assess a product of your choice and explain your answer briefly.

3.1 Your selection

Bio-based product of my choice	

3.2 Discussion on assessment criteria in eco-labels

Assessment criteria	Relevant			
	Yes	No	Explanation	If yes, possible assessment methods and thresholds
Sustainable biomass				
CO_2 emissions				
Toxicity				
End-of-life options				
Fitness for use				
Social criterion corporate social responsibility				
Social criterion "fundamental principles and rights at work"				
Energy requirement during production				
Biomass utilisation efficiency				
Life cycle values				
Life cycle costing specifically				

3.3 Which additional criteria are important to assess the sustainability of the product of your selection appropriately and which assessment methods and thresholds are useful?

D Sustainability standards

Are you aware of needs for sustainability standards for the product of your selection:

1. Regarding sustainability assessment?

□ Yes, please specify

□ No

2. Regarding other issues?

□ Yes, please specify

□ No

E Regulatory framework conditions and policy gaps

1. Is there a need for new or updated policy documents regarding conformity assessments of bio-based products in your specific topic area?

□ Yes □ No

2. If yes: Please specify what is needed.

a) on the national level in Member States

b) on a European level

3. The European Directive on the promotion of the use of energy from renewable sources requires:

- To be considered sustainable, biofuels must achieve greenhouse gas savings of at least 50% in comparison to fossil fuels (since 2018 60% for new production plants). All life cycle emissions are taken into account when calculating these savings. This includes emissions from cultivation, processing, and transport.
- Biofuels cannot be grown in areas converted from land with previously high carbon stock such as wetlands or forests.
- Biofuels cannot be produced from raw materials obtained from land with high biodiversity such as primary forests or highly biodiverse grasslands.

Please describe your opinion to what extend these requirements could be a suitable option to promote bio-based products as well.

4. What could be done from the regulatory side regarding end-of-life options to support bio-based products better?

F Additional comments

1. Do you have additional comments or suggestions for our project?

□ Yes □ No

2. If yes: Please share your thoughts.

Thank you very much for your time!

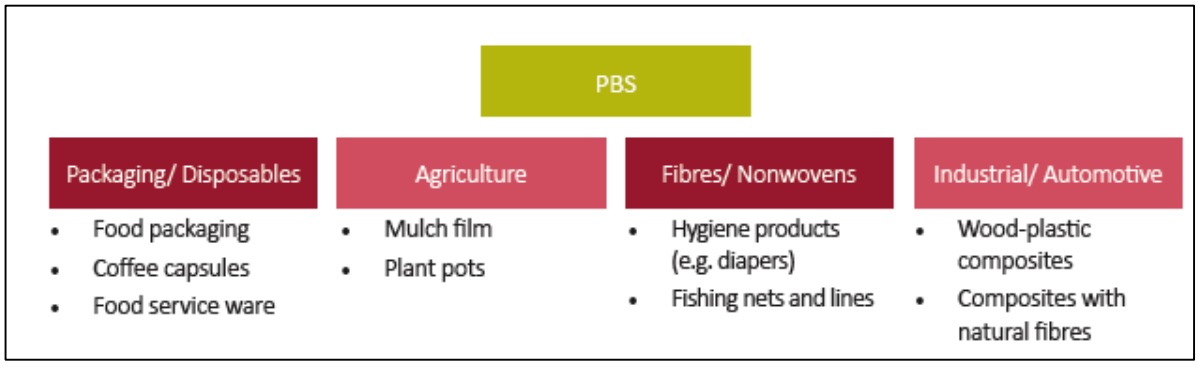
Annex 3: Information on PBS, PLA and their applications

Annex 3.1: Profile of PBS

Poly Butylene Succinate (PBS) is a combination of bio-based 1.4-butanediol (BDO) and bio-based succinic acid (SA). It is a thermoplastic and biodegradable polyester, used for blending with starch polymers to improve properties. PBS has previously been of fossil origin. However, significant industrial effort facilitated the production of bio-based PBS from bio-based succinic acid and bio-based 1,4-butanediol. Some of PBS' characteristics include:

- High flexibility and heat resistance.
- Suitable for extrusion, injection moulding, thermoforming, fibre spinning and film blowing.
- The physical properties and biodegradation rate can be tailored through composition control with different types and various contents of monomers.
- Compoundability to be used with other (bio)polymers to tune the performances of the material.
- Good binding to natural fibres without any additional bonding agent.
- Up to 100% bio-based (when using BBSA and BDO from renewable resources), enabling an improved material carbon footprint compared to alternatives based on fossil resources.
- Biodegradable and compostable under industrial conditions according to EN 13432.
- High Biomass Utilization Efficiency (BUE) (taken from Succinity, no date).

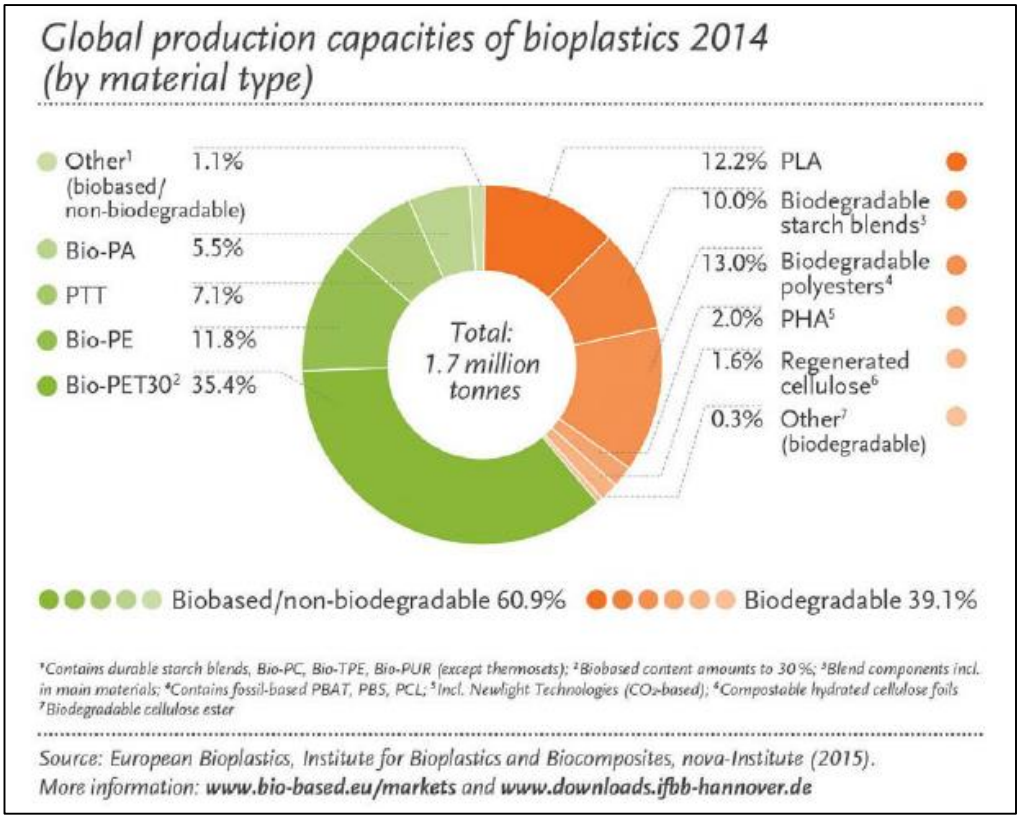
PBS has similar properties to polypropylene (PP), which demonstrates the enormous application potential (worldwide PP production is currently ca. 55 million t per year). The production capacity is expected to grow at a Compound Annual Growth Rate (CAGR) of 37%, reaching a demand of 82,000 t for bio-based succinic acid by 2020. The production of bio-based PBS is getting steadily more cost-effective compared to its petrochemical counterpart, which is directly linked to recent cost reductions in bio-based succinic acid and BDO. As indicated in the graph below, different applications for the use of PBS have been researched, including cutlery, packaging and application for the automotive sector.



Source: Succinity (no date)
Figure 8: PBS applications

Annex 3.2: Profile of PLA

Polylactic acid (PLA) is a compostable, biodegradable thermoplastic made from renewable sources, for example sugar cane, corn and beets. The transparent and brittle biomaterial is biocompatible, biodegradable and provides suitable physicochemical properties. Potential for use is broad, and ranges from packaging materials to medical applications including i) flexible packaging (as foil); ii) rigid packaging (as bottles and trays), iii) textiles; iv) consumer goods (as disposable cups); and v) electrics & electronics (See CE Delft, 2017, p. 81). PLA provides desirable properties such as high clarity, stiffness and printability combined with the ability to process PLA in conventional facilities (see Green and Kunnemann, D., 2006 for details). Depending on the specific application, PLA can replace different fossil-based plastics, for example PET in bottles.
As the following figure shows, it has a significant share in the global bio-plastics market.

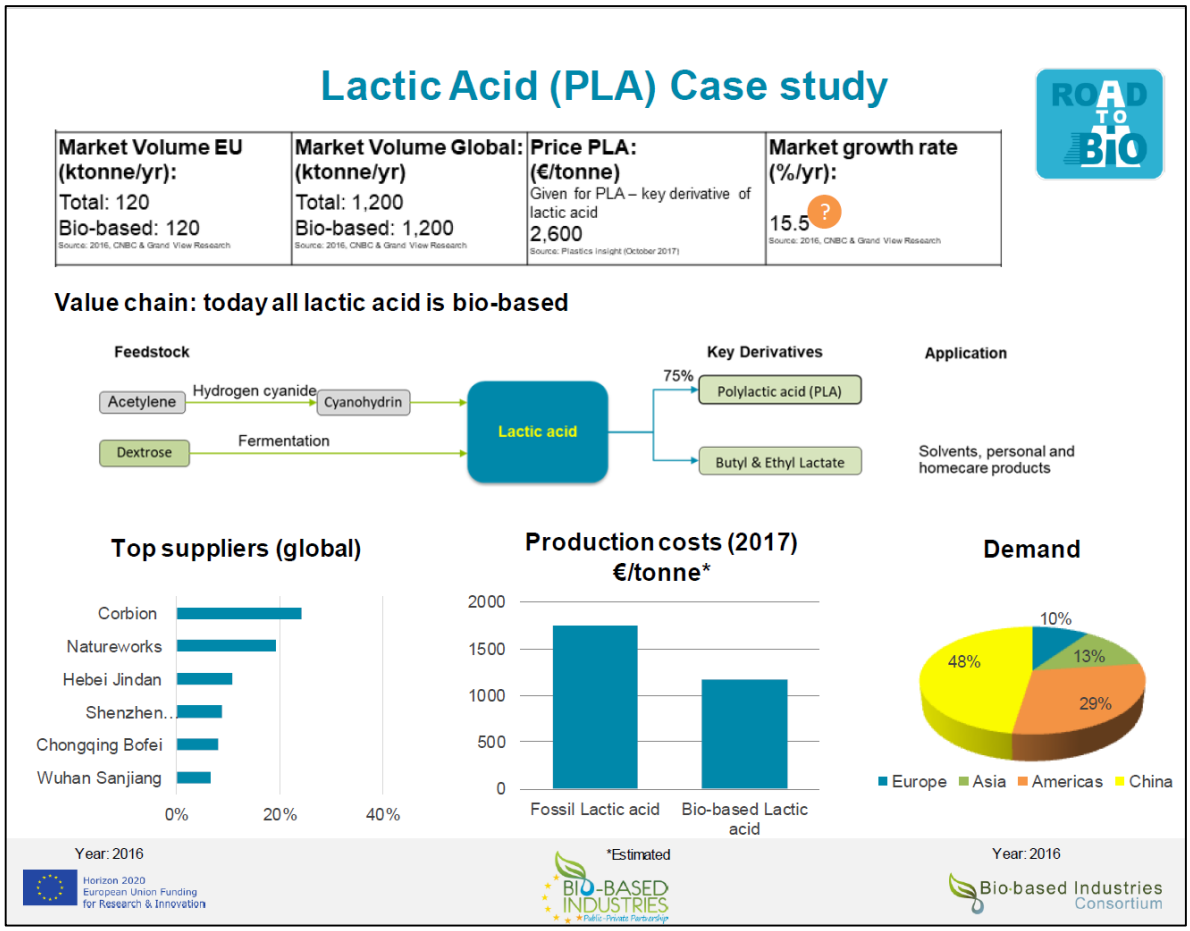


Source: European Bioplastics

Figure 9: Importance of PLA in the bio-plastics market

Based on its properties, PLA is one of the three most often used bio-based plastics in the market for rigid packaging, which represents the largest global share of production of bio-based plastics. Although it is from origin a rather brittle material, it can also be modified or used in blends to make it suitable for application as flexible packaging, addressing also the market for bio-based flexible packaging, which is the second largest application of bio-based plastics (See CE Delft, 2017, pp. 29, 30).

The following figure provides a short fact sheet on additional characteristics of the PLA market.



Source: RoadToBio (2018)

Figure 10: Factsheet on PLA

PLA's increased stiffness often allows article down-gauging in films and many rigid applications, which improves system cost and reduces waste. Besides industrial composting and biodegradation, PLA's end-of-life options also include mechanical and chemical recycling and traditional ones such as landfill and incineration. Key functional PLA properties are:

- Food safe
- Natural-based
- Excellent clarity and gloss
- Excellent resistance to food fats/oils
- Aroma barrier
- Good practical toughness
- Toughness and crystallinity increase with orientation
- Good printability
- Moisture breathability
- Wicking
- Low flammability
- Low soot
- Low smoke
- UV resistance
- Industrial compostability
- Readily recyclability

In summary, PLA is therefore regarded as an excellent choice in various fields. [29]

[29] See Green, R. and Kunnemann, D. (2006). PLA - A Renewable/Sustainable Packaging Option. http://www.tappi.org/content/enewsletters/eplace/2007/06PLA06.pdf

Annex 3.3: Food packaging applications

Packaging for food holds the first place of the packaging market with US$ 161 billion and a share of 38% (see Interpack, 2017). This report considers bio-based plastics specifically. Bio-based plastics are polymers, which are produced from renewable resources. Bio-based food packaging materials are mostly cellulose-based but research for new alternative products is ongoing. Innovative food packaging solutions based on other bio-based materials (e.g. starch-based) are expected to expand or new materials enter shortly the market. Starch-based packaging has been developed for various food packaging applications (e.g. pasta, PLA-based pots for yoghurts, PLA flexible film for fresh fruits etc.).

By the end of 2016 the very promising sector of biodegradable food packaging reached a global turnover of US$ 3,403.4 Mn. With an annual growth rate of 11.0% is expected to approach US$ 7,058.8 Mn by 2023.[30]

Life of packaging is undoubtedly short and that is the reason of being a major source of waste. The use of environmental friendly packaging that allows the preferred EOL options of reuse and secondly of recovery through recycling or composting is the only way for achieving sustainability of packaging. Therefore, special attention should be given to the extensive use of plastics in packaging applications because plastic waste causes severe pollution and can unfavourably affect lands, waterways and oceans. It is mentioned that 40% of the market applications for plastics are streamed to packaging industry. Bio-based food packaging properly designed by taking into account the targeted EOL options can provide viable solutions for many food packaging applications that are difficult to recycle (film laminates) and/or strongly contaminated (with green waste or sand).

[30] Biodegradable Food Packaging Market By Application (Dairy & Beverages, Fruits, Vegetables, Meat & Related Products, Others), By Material (Plastic, Paper, Aluminum, Steel, Others) - Growth, Future Prospects, Competitive Analysis, and Forecast 2016 – 2023, Credence Research, 2016 http://www.credenceresearch.com/report/biodegradable-food-packaging-market

Annex 3.4: Automotive applications

This section provides an overview on the current state on automotive applications for bio-based products based on PLA, PBS and other materials.

PLA

Various PLA applications are currently tested, for example in the project BioMAT-LCA (see e.g. IfBB, 2018a). As a disadvantage, an expert highlighted PLA's sensitivity to changes in temperature. At 60 degrees Celsius already it gets brittle. For this reason, pure PLA cannot be used for car applications, at least not for exterior parts. Instead, stabilised PLA (PLLA) can be used, mainly together with additives. Currently, PLA's main application field in the automotive industry is the interior, e.g. for central consoles and small injection-moulded components or astray devices. Another application field in the automotive industry includes bio-based textiles, which can also be made of PLA (see e.g. CE Delft, 2017).

PBS

Automotive applications may be made of PBS composite materials. In contrast to this, pure PBS is not regarded as an optimal material for the car industry. The reasons for this are the low melting point and the low resistance of the material. Other issues are that no injection molding applications are currently known[31] and that the mechanical properties of PBS are not optimal. The current role of PBS in the context of bio-based automotive applications is regarded as marginal. Nevertheless, an expert regards the creation of organo sheet metal with PLA/PBS blends as possible although he does not know examples for such products.

Other

Various other bio-based materials provide additional opportunities for applications in the automotive industry. They include, for example fibre-based materials for the interior, composite materials for the inner sides of the side doors and mirror covers made of bio-based polyamides/PPT. Biobased plastics can also be used in textile products for automotive parts (see CE Delft, 2017, p. 29).

Looking into the future

With the Bioconcept-Car, the future of sustainable mobility was presented at the Hanover Fair in April 2018. The Bioconcept-Car is a race car and the result of a feasibility study in which various traditional components were replaced by those made of bio-composite materials. The car has been successfully tested during ongoing racing operations. Converted for racing use and powered by a low-emission rapeseed biodiesel, this VW Scirocco 2.0 TDI combines innovative approaches to lightweight construction in the mobility sector based on resource-saving materials, such as natural fibre reinforced composites, bio-based resins and bio-based plastics (see IfBB, 2018b).

[31] E-Mail communication with an expert on August 24, 2018.

Annex 4: Eco-labels, standards and regulation for packaging

Eco-labels

Forty-three eco-labels on packaging were identified in the Eco-label index, of which 29 are relevant for physical products in Europe (see the following table).

Table 16: Eco-labels on packaging

Source: Eco-labelindex, modified for Europe and physical products

Eco-labels on packaging	
• B Corporation • Blue Angel • CarbonCare • CarbonFree® Certified • Carbon Neutral Certification • Carbon Neutral Product Certification • Compostability Mark of European Bioplastics • Compostable: Biodegradable Products Institute Label • ECOLOGO • Ekologicky setrny vyrobek Environmental Product Declaration • Etichetta ambientale • Forest Stewardship Council (FSC) Chain of Custody Certification • Global Recycle Standard • GreenCircle	• Green Products Standard • Green Range • LowCO2 Certification • NoCO2 • NSF Sustainability Certified Product • OK biobased • OK biodegradable SOIL • OK biodegradable WATER • OK Compost • OK Compost HOME • On-Pack Recycling Label • Programme for the Endorsement of Forest Certification (PEFC) schemes • TerraCycle • UL Environmental Claim Validation • EU Ecolabel (added based on additional analyses)

According to further analyses, labels for the packaged products and the packaging itself have to be distinguished.

As an example for the first group, the Blue Angel label on recycled plastics was tested but it does not refer to bio-based content. In addition, the Blue Angel labels for three packaged products "Shampoos, shower gels and soaps and other so-called "rinse-off" cosmetic products", "Cleaners" and "Monitors" were tested with the result that they do not refer to packaging.

The EU Ecolabel, which provides relevant content regarding packaging, considers bio-based packaging and/or the characteristics "biodegradable" or "compostable" by the label for four product categories with the following formulations:

- Wooden floor coverings and wooden furniture: packaging materials taken from renewable resources
- Footwear and portable computers: Packaging of 75% recycled material or they shall be biodegradable or compostable

As mentioned in Annex 5.1, PBS and PLA are biodegradable and compostable under industrial conditions, which makes such criteria very interesting for such materials.

Legislation

Key European documents on packaging are the Directive on packaging and packaging waste and its amendment:

- European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste
- Directive 2005/20/EC of the European Parliament and of the Council of 9 March 2005 amending Directive 94/62/EC on packaging and packaging waste

Several harmonised standards were created under these directives, see next section.

Based on their general nature, both directives are also relevant for food packaging.

An important measure in favor of biodegradable plastics was adopted in August 2016 in France. This is the ban on single-use plastic bags as part of the new law on Energy Transition and Green Growth. The implementation decree setting out the requirements and conditions applies in particular to single-use bags other than cash register bags that are below a thickness of 50 microns, which will have to meet the requirements of the French standard for home composting and feature a bio-based content of at least 30 percent. The minimum bio-based content will increase progressively to 40 percent in 2018, 50 percent in 2020, and 60 percent in 2025 (European Bioplastics, 2017).

Standards

As mentioned in chapter 6, several harmonized standards were created based on Directive 94/62/EC, in particular the packaging standards EN 13427– EN 13432:

- EN 13427:2004 Packaging - Requirements for the use of European Standards in the field of packaging and packaging waste
- EN 13428:2004 Packaging - Requirements specific to manufacturing and composition - Prevention by source reduction
- EN 13429:2004 Packaging - Reuse
- EN 13430:2004 Packaging - Requirements for packaging recoverable by material recycling
- EN 13431:2004 Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value
- EN 13432:2000 Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging.

Annex 5: Example information on PLA food packaging given by the Biokunststofftool

Table 17: Example information on PLA food packaging given by the Biokunststofftool

Ecology dimension
Information on the farming stage: Environmentally friendly farming refers, for example, to the reduction or avoidance of pesticides and the use of water. Regarding certified farming, AöL informs about the following certificates used by important players in the market: i) ISCC PLUS, ii) membership at Bonsucro, an international organisation supporting sustainable sugar cane and iii) SEDEX, a global sustainable sourcing initiative. A specific characteristic of Bonsucro is the provision of measures for greenhouse gas emissions. Therefore, it is recognized by the EU as a certification scheme to demonstrate compliance with the RED. Regarding GMOs, examples are provided to guarantee the supply of non-gene modified feedstocks. **Information on the EOL stage:** Regulatory gaps regarding composting are highlighted. Besides this, the open question is described up to what percentage bioplastics can be added to conventional plastics without causing any problems in the recycling processes.
Social dimension
Information on the farming stage: this is provided, for example, by NatureWorks' ISCC PLUS certification, Bonsucra and SEDEX, applied by Corbion Purac. **Information on the processing stage:** the application of social assessments varies. Although SEDEX considers this issue, vendors often use their own code of conduct.
Safety and technology dimension
Information on migration and interaction: the packaging of the U.S. American company NatureWorks are approved by the U.S. Food and Drug Administration. Furthermore, the company provides information requested by the EU regulation 10/2011. **Information on additives:** providing such information is regarded as important. **Information on barrier properties:** PLA has specific barrier properties, which can be optimized by suitable treatment techniques. Normally, the water vapour permeability is 20-80g/m2d according to DIN 53122. Furthermore, there is an oxygen permeability of 500-600 cm3/(m2*d*bar) and a carbon dioxide permeability of 2500-3500 cm3/(m2*d*bar). **Information on other issues:** PLA is sensitive to water and heat. Therefore, the suitability of the different PLA variations for the use on traditional production machines has to be analysed separately.
Quality dimension (synonymous with this report's fitness for use criterion)
Information on general requirements: The tool mentions, for example, the German Federal Institute for Risk Assessment (BfR)'s specification which requirements various packaging materials must meet. These requirements also include important criteria concerning ecology and environment, especially for bio-based packaging materials. **Information on product-specific requirements:** AöL highlights that the packaged product also sets requirements on the packaging material. It is very important to define these requirements as precisely and practically as possible, e.g. according to ISO 18602:2003 (Packaging and the environment). **Information on additional requirements:** Stability tests are sometimes required. PLA is suitable for products having a minimum shelf life of less than six months.

Source: AÖL (2018)

Analysis of the basic criteria and the specific award criteria for "Blown-in, Cellulose-based Insulation", which build on the basic criteria

The following overview discusses the following assessment dimensions particular:

- Raw material sourcing, production of preliminary products, production
- Ecological Parameters
- Recycling/Disposal
- Social requirements
- Composition, Forbidden Substances, Substance Restrictions
- Packaging
- Laboratory Tests
- Declaration

Raw material sourcing, production of preliminary products, production

The basic criteria document begins with a descriptive section mentioning natural resources, particularly the **maximisation of the proportion of renewable and/or 'environmentally-friendly' mineral raw materials**: **a minimum proportion of renewable and mineral raw materials is clearly stated at not less than 85% of the mass of the product**. Minimisation of the use of petrochemical 'input substances' are also mentioned: the criteria explicitly exclude from certification products using petrochemical substances to deliver their functions. Finally, further details are provided on raw materials: 'environmentally friendly' secondary raw materials should replace materials limited in their availability or which are very difficult or cost-intensive to harvest/extract. In general, substances should be excluded when a more ecological, economically viable alternative exists (natureplus, 2011).

Considerable requirements on materials are also addressed in a section of the basic criteria. The criteria document clearly positions the natureplus® eco-label on environmental performance setting out as a fundamental principle the conservation of natural resources and energy efficiency in the harvesting or extraction of resources and the production process.

This section sets out specific requirements on use of renewable and non-renewable resources, such as **consumption of renewable resources not exceeding their annual net production levels**.

The basic criteria also set out requirements on **sourcing of raw materials**: which extend to protecting the natural environment and biodiversity, compliance with CITES[32], and re-cultivation or renaturation of extraction sites.

The **sustainable harvesting of renewable raw materials** is described and includes: avoiding the use of pesticides, chemicals and chemical fertilizers; avoiding raw materials from non-sustainably managed plantations and from intensive cultivation and destructive exploitation such as non-certified tropical timber; and maximum use of organic agriculture and sustainable forestry management.

For **raw material sourcing and production processes**, the level of energy efficiency and environmental compatibility must be proven in terms of the ecological effectiveness

[32] The Basic Criteria document requires compliance with the Washington Wildlife Protection Agreement which is also known as CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora

indicators. More detailed information is contained within the award guidelines for specific products and these must be complied with.

For the specific criteria, as cellulose-based insulation is made of recycled paper, some of the above criteria – notably consumption of renewable resources and their sustainable harvesting - are less *immediately* relevant. Nonetheless, the sourcing of recycled paper (for example, European manufacturers using only paper recycled in Europe) could be an interesting criterion.

Production of cellulose should use only **recycled/recovered paper** as a means of protecting resources and ensuring the use of secondary raw materials. The manufacturer must ensure that the recycled/recovered paper does not contain heavy metals or other harmful substances, and must demonstrate that employee protection is assured through hazardous substance management according to national standards and regulations.

Further employee protection measures address general dust limit values and the use of personal protective equipment to minimise avoidable burdens of the employees.

Ecological Parameters

The specific criteria set out a number of ecological parameters that products must comply with, including **primary energy input** (of non-renewable total resources and of non-renewable and renewable total resources). Other ecological parameters include potentials of photochemical ozone creation, acidification, eutrophication, global warming and abiotic depletion.

Recycling/Disposal

The basic criteria document sets out a set of 'basic rules of a recycling-compatible, material design in the manufacture of certified products'. This is further detailed and includes: the minimisation of the number of input substances; the building materials should be suitable for processing into recycled products of a comparable value; avoidance of material composites; where composite materials are used substances which may be problematic for recycling should be labelled and removable. The criteria also address the lifetime of a building stating that this should be maximised by a durable, basic construction and flexible fixtures, and the possible removal/disassembly of the building materials and components employed must be related to their predicted life-span.

The specific criteria add that the product must be suitable for safe disposal in a waste incineration facility.

Social requirements

The basic criteria state that compliance with the minimum standards of the International Labour Organisation (ILO) may be taken as an indication of the social compatibility of the production process. Eight conventions of the ILO[33] that defined fundamental principles and labour rights are to be complied with and a number of points must be guaranteed: the freedom of association and the right to organise; the recognition of collective bargaining; the prohibition of any form of forced or compulsory labour; the effective abolition of child labour and the elimination of discrimination in terms of employment and occupation.

[33] ILO 29, 87, 98, 100, 105, 111, 138 and 182

Composition, Forbidden Substances, Substance Restrictions

The specific criteria states that at least 85% of the product based upon its dry weight must be made from a specific type of recycled newspaper[34]. Acceptable flame retardant substances are detailed along with a maximum percentage in the final product.

Packaging

The basic criteria document addresses product packaging, stating that it should have the lowest possible impact upon the environment. This is further detailed with different requirements including use of reusable packaging. On specific packaging materials: paper and cardboard should be made predominantly from recycled paper or paper from FSC or PEFC certified plantations; wood packaging should also be from the same type of certified plantations. Packaging should not contain biocides, and if this is unavoidable, then they must be declared and the declaration clearly visible on the packaging.

In the specific criteria, the packaging must be recyclable and the manufacturer must participate in a recycling system if there is one for the corresponding material. The Basic Criteria award criteria are restated, particularly for paper and cardboard, wood, and plastic materials. Additionally, packaging made from PVC is generally not permitted.

Laboratory Tests

Various test parameters with limits and units are provided for different "**harmful substances** and undesirable ancillary ingredients" including: VOCs, formaldehyde, acetaldehyde, and separate element analyses with limit values and units for (e.g. arsenic, cadmium, chromium, mercury, lead, antimony, and zinc). "Other analyses" set out test parameters, limit values, units and methods for: halogenic organic compounds (AOX, EOX), PAH (polycyclic aromatic hydrocarbons) as well as odour.

Declaration

The specific criteria set out requirements on messages on the packaging of the product. They require the full declaration of the input materials used, as per the EU Cosmetics Regulations requiring individual ingredients to be listed in declining order of the mass percentage. When such detailed declaration is not possible, the information should be provided with the product in a technical datasheet or sales leaflet. Details are also provided for those intermediate/preliminary products or formulations used as input substances present in the final product at >0.1% of the mass of the product. Finally, **information on the country of origin of the main components must also be made available to the consumer or user** (e.g. online).

[34] Group 2.01 according to EN 643 "Paper and board – European list of standard grades of recovered paper and board". Group 2.01 is medium grade paper, lightly printed white shavings without glue.

Annex 7: Detailed information on selected eco-label criteria in the case studies

Table 18: Details on eco-label criteria in the case study on car components

Assessment criteria	Relevance according to the interviews						
	C1 on car interiors of Polypropylene	C2	C3/4 on various components	C5 on various components	C6 on interior linings of car doors of composite materials	C6 on mirror covers	Summary
Sustainable biomass	x	x	x	No	x	x	5 of 6
CO_2 emissions	x	x	x	x	x	x	6 of 6
Toxicity	N.A.	x	No	No	x	x	3 of 5 (1x N.A.)
End-of-life options	x	x	x	x	x	x	6 of 6
Fitness for use	No	No	x	x	No	No	2 of 6
Social criterion corporate social responsibility	x	x	x[35]	x	No ("interesting but difficult to quantify")		4 of 6
Social criterion "fundamental principles and rights at work"	No (merge with previous one)	x	x[36]	x	No ("interesting but difficult to quantify")		3 of 6
Energy requirement during production	No	x	No[37]	x	x	No	3 of 6
Biomass utilisation efficiency	No	x	x[38]	No	x	No	3 of 6
Life cycle values	x	x	(No)[39]	x[40]	x[41]	x[42]	5 of 6
Life cycle costing specifically	No	No					3 of 6

Legend: relevant in > 50% of the interviews | relevant in 50% of the interviews | not relevant in > 50% of the interviews

[35] provided by ISCC PLUS
[36] provided by ISCC PLUS
[37] because not included in ISCC PLUS
[38] provided by ISCC PLUS
[39] "Is important but should be conducted in a broader context, meaning for the whole car"
[40] Interviewees' response: "Depends on the context. It's possible in general but the cars of (the interviewees' company) have unique life times."
[41] for BTB markets
[42] for BTB markets

Table 19: Details on eco-label criteria in the case study on food packaging

Assessment criteria	Relevance according to the interviews[43]					
	F1	F2	F3	F4	F5	Summary
Sustainable biomass/ bio-based content	x[44]	x	x	x	x	all
CO_2 emissions	x	x	x	x	x	all
Toxicity	x	x	x	x	x	all
End-of-life options	x	x	x	(No)[45]	x	4 of 5 (1x suggesting a related criterion instead)
Fitness for use	x	x	x	x	x	all
Social criterion corporate social responsibility	x	x	ILO	x	x	4 of 5 (1x referring to a company-wide criterion instead
Social criterion "fundamental principles and rights at work"	x	x		x	x	4 of 5 (1x referring to a company-wide criterion instead
Energy requirement during production	NA	x	x	x	x	4 of 5 (1x NA)
Biomass utilisation efficiency	NA	x	x	x	x	4 of 5 (1x NA)
Life cycle values	NA	x	x	No	x	3 of 5 (1x N.A., 1x No)
LCC specifically	NA	x	x	No	x	3 of 5 (1x N.A., 1x No)

Legend: relevant in > 50% of the interviews; relevant in 50% of the interviews; not relevant in > 50% of the interviews

[43] Interviewee F6 did not discuss the eco-label criteria.
[44] Bio-based content discussed only
[45] Referring to additional suitable criteria, the interviewee explained later that Information on end-of-life options should be given, e.g. suggestions where the packages could be left etc.

Table 20: Details on eco-label criteria in the case study on mulch films

Assessment criteria	Relevance according to the interviews							
	M1	M2	M3	M4	M5	M6	M7	Summary
Sustainable biomass / bio-based content	x[46]	x	x	x	x	N.A.	N.A.	Support for both when asked 2x N.A.
CO_2 emissions	x	No	x	No	x	x	x	5 of 7
Toxicity	x	x	x	No	x	No	x	5 of 7
End-of-life options	x	x	x	x	x	x	x	all
Fitness for use	x	x	x	x	x	x	N.A.	6 of 7
Social criterion corporate social responsibility	(x) Indirectly	N.A.	x	x	x	No	x	5 of 7 (1x N.A.)
Social criterion "fundamental principles and rights at work"	(x) Indirectly	N.A.	N.A.	x	x	No	x	4 of 7 (2x N.A.)
Energy requirement during production	No "Maybe not directly"	x	N.A.	x	x	x	N.A.	4 of 7 (2x N.A.)
Biomass utilisation efficiency	N.A.	N.A.	N.A.	N.A.	x	x	x	3 of 7 (4x no answer)[47]
Life cycle values	x	N.A.	x	N.A.	x	x	x	5 of 7 (2x N.A.)
Life cycle costing specifically	x	N.A.	x	N.A.	x	No	N.A.	3 of 7 (3x N.A.)[48]

Legend: relevant in > 50% of the interviews; not relevant in > 50% of the interviews; relevant in 50% of the interviews

[46] M1 and M2 discussed bio-based content only

[47] Shown in yellow because of the low number of answers although most people who discussed this criterion were in favor of it.

[48] Shown in yellow because of the low number of answers although most people who discussed this criterion were in favor of it.

Table 21: Details on eco-label criteria in the case study on insulation material

Assessment criteria	Relevance according to the interviews			
	I1	I2	I3	Summary
Sustainable biomass / bio-based content	x	x	x	all
CO_2 emissions	x	x	x	all
Toxicity	x	x	x	all
End-of-life options	x	x	x	all
Fitness for use	x	x	x	all
Social criterion corporate social responsibility	x	x	Less priority	2 of 3
Social criterion "fundamental principles and rights at work"	x	x	Less priority	2 of 3
Energy requirement during production	x	x	x	2 of 3
Biomass utilisation efficiency	x	x	x	2 of 3
Life cycle values	No	No	No	0 of 3
Life cycle costing specifically	No	No	No	0 of 3

Legend: relevant in > 50% of the interviews; relevant in 50% of the interviews; not relevant in > 50% of the interviews