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Bio-based products –

Guide to standards and claims

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Foreword

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Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

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0 Introduction

0.1 General

Bio-based products are products which are wholly or partly derived from biomass and include intermediates, materials and semi-finished or final products. They range from high-value added fine chemicals, such as pharmaceuticals, cosmetics and food additives, to high volume materials such as bio-polymers or chemical feedstocks.

Examples of bio-based products include:

- amino acids;
- chemical and pharmaceutical building blocks;
- composite materials based on natural fibres;
- cosmetics;
- enzymes;
- lubricants;
- organic acids;
- paints;
- plastics and polymers;
- solvents;
- surfactants; and
- textiles made from natural fibres.

Bio-based products have a shorter carbon cycle compared to products made from fossil-based resources (Figure 1). Carbon captured in biomass can be replenished within a relatively short period of time, for example, with plant oils or timber this period ranges from a few years to a few decades. Carbon dioxide emitted during the manufacture, use or disposal of bio-based products can be used by plants, as part of photosynthesis, and converted into new biomass.

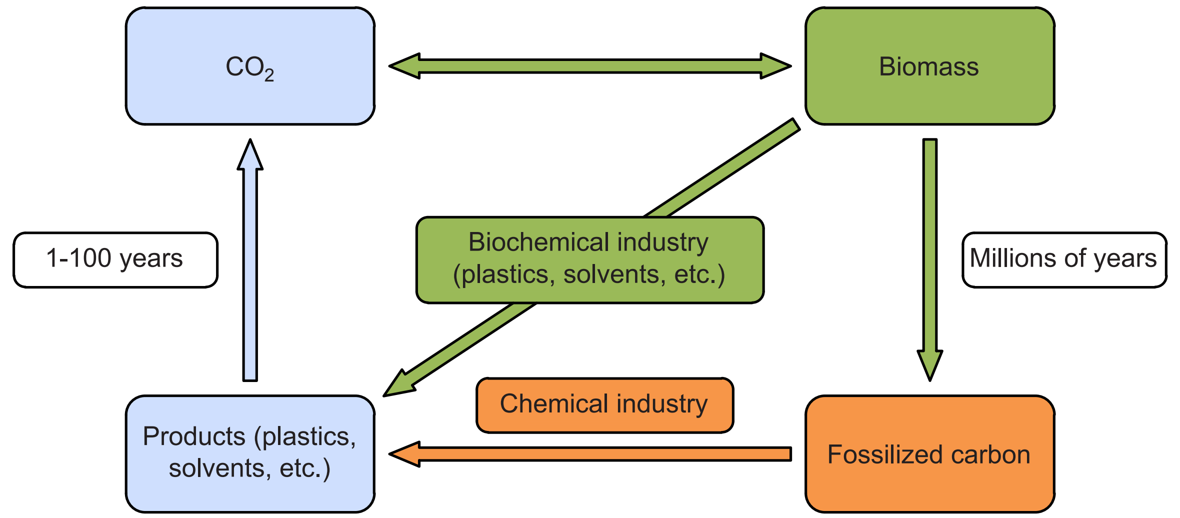
Carbon locked in petroleum originates from fossilized organic materials, such as zooplankton and algae that undergo anaerobic decomposition accompanied by high levels of heat and pressure causing the organic matter to alter chemically and form liquid and gaseous hydrocarbons. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years [1]. Therefore the rate of carbon dioxide fixation is much slower than the rate at which carbon dioxide is released from fossil-based materials. Bio-based products are themselves "carbon sinks" (i.e. they can lock away carbon). Biomass, such as plants or algae, capture CO_2 from the atmosphere to produce carbohydrates and other compounds that are used for the production of bio-based products. For some products that are degradable and have a short life, this carbon sink offers very little, however for products such as durable plastics or construction materials, this can be a substantial sink of carbon.

Use of bio-based products has grown at a steady pace in the last decade. In 2005, they accounted for 7% of global sales and around US$77 billion (£49 billion) in value within the chemicals sector, with the EU industry accounting for approximately 30% of this value [2].

One estimate is that by 2020 the global market for bio-based products will grow to US$250 billion (£158 billion) and that by 2030, one-third of chemicals and materials will be produced from biological sources, including bio-polymers and bio-plastics [3]. This lies broadly within the range of the estimate of industrial biotechnology market size, which is predicted to be between £150 billion and

£360 billion by 2025, with the UK share of this market being between £4 billion and £12 billion [4].

Figure 1 **Carbon cycle of bio-based and fossil-based products**



NOTE This figure is adapted from Narayan (2001) [5].

Use of bio-based raw materials could enable UK companies to diversify on raw materials and promote an efficient and sustainable use of natural resources. In addition, bio-based products can contribute to companies' corporate and social responsibility programmes, sustainability agendas and aid the development of new consumer markets.

Bio-based products have potentially high societal and economic value due to several factors, the main ones being the use of renewable and scalable resources and the potential to reduce greenhouse gas emissions. Some bio-based products offer improved recovery and recycling options due to biodegradability or compostability. In some cases, bio-based products enable the use of less resource-intensive production methods (e.g. in terms of water and energy use) [6].

0.2 Production of bio-based materials

There are multiple steps in the production of bio-based materials and products (Figure 2 and Figure 3 give an overview of these steps for two bio-based product types), each of them having an impact on the overall environmental performance of a finished product or product system.

For example, numerous parts of plants can be used to produce bio-based products. In the case of plants such as flax, different parts of the plant can be used to make numerous different products. The other example in Figure 3 provides a schematic outline for production of PLA from corn or other plant material. Table 1 summarizes the steps in the production process and how they can affect the environmental impact of the product.

Figure 2 **Production of bio-based materials and products from flax plant**

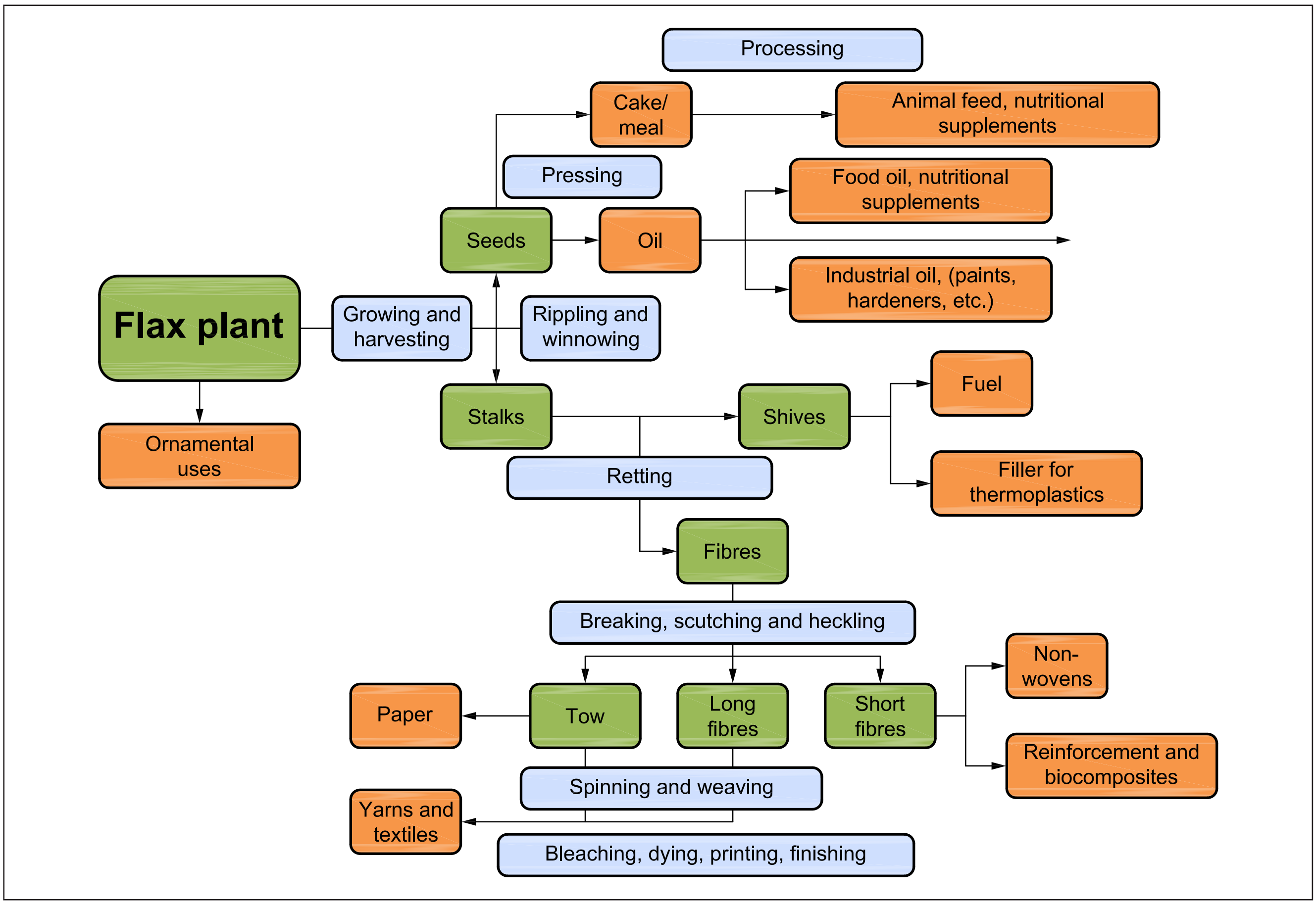


Figure 3 **Production of PLA and PLA-based products from plant material**

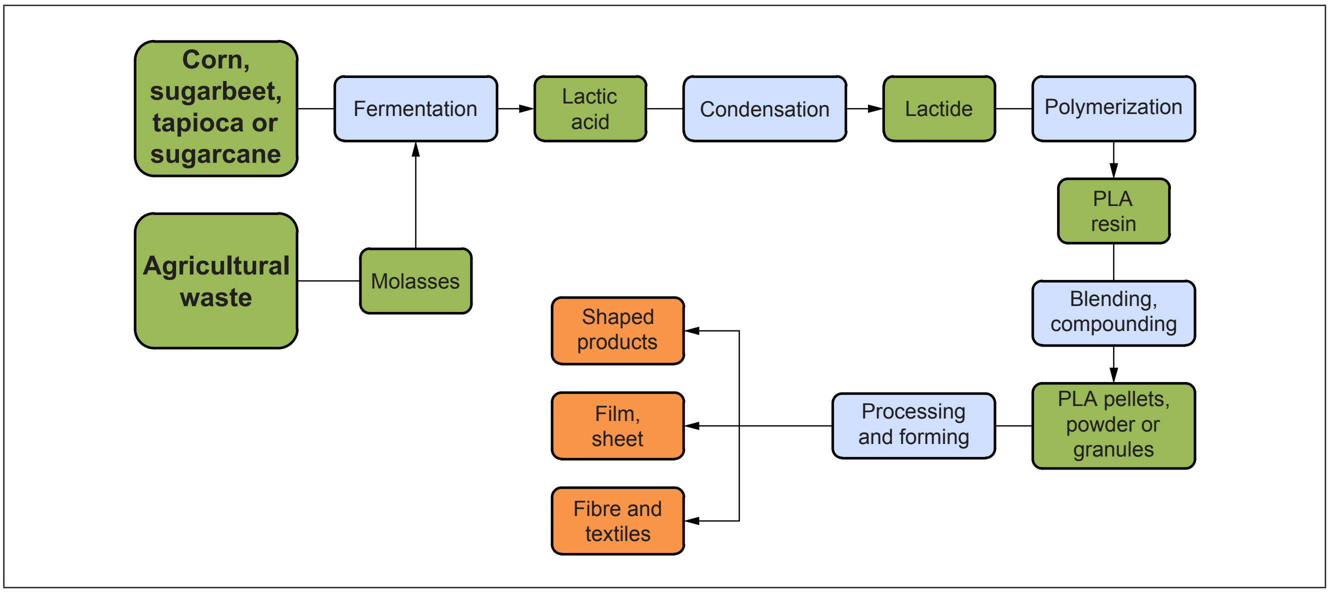


Table 1 **Plant-derived bio-based product production steps and their environmental impacts**

Production stage	What the stage can involve	Environmental impact considerations	Comparison with non-bio-based products
Growth and harvesting	Raw material harvesting and pre-processing	Fertilizer use, harvesting method, transportation	Mining the materials, oil drilling, cracking and refining; transportation
Processing	Processing of plant-derived materials can involve mechanical (e.g. hackling or weaving), chemical and enzymatic breakdown steps	Use of energy, water, chemicals and additives, e.g. solvents	In some cases, processing of non-bio-based products requires more energy and water
Formulation and blending	Physical and chemical properties of bio-based products are modified by the addition of other chemicals or materials, e.g. biocomposites where fibres are blended with plastics	Use of energy, water, chemicals and additives, e.g. plastics. Disposal of waste. Use and disposal of by-products.	Similar to bio-based products
Transportation		Mode of transport, distance	Similar to bio-based products
Consumer use	Consumption and care	Water and energy use associated with consumption (i.e. washing or repair)	Similar to bio-based products
	Reuse and remanufacture	Potential waste reduction and materials reuse if products are designed for deconstruction and materials reuse	Similar to bio-based products
Disposal		Recycling, landfilling, compostability, and biodegradability	Recycling or landfilling. Some non-bio-based products are biodegradable and compostable if they conform to the relevant standards
		Generation of renewable energy through incineration	Energy generated through incineration is not renewable

The principle of a biorefinery can underlie the industrial production of bio-based products. Efficient use of biomass requires integration of several value chains that make use of all components of the biomass. Biorefining is similar to petroleum refining and based on the principle of cascading use of biomass, driven by the need to use biomass in the most efficient way. Biomass is refined to separate complex materials into different valuable components, which then undergo further processing. During biorefining renewable feedstocks are converted into a wide range of valuable products such as fuels, building blocks for chemicals, including bio-plastics, bio-lubricants, bio-solvents and bio-surfactants, fine chemicals, including ingredients for pharmaceuticals and enzymes for bioprocessing.

In order to make biorefining economically viable, technologies used to separate and process biomass need to be optimized and work on a large scale, and the whole model needs to be integrated into more complex industrial systems, such as chemical industry, construction or automotive industry. The outputs from a biorefinery are linked to the feedstock used and the processing technology.

When establishing an industrial production of bio-based products, it is important to ensure a consistent supply of feedstock, to evaluate energy and water requirements, as well as to assess the indirect impact of the land use change.

0.3 Drivers

The main factors driving future markets and demand for bio-based products in the UK and EU are:

a) limited availability and increasing cost for fossil-based raw materials;

b) policy developments aimed at mitigation of climate change and supporting sustainable development and economic growth;

c) increasing consumer demand for products with lower environmental impact [6].

Bio-based materials can complement or substitute for a proportion of petroleum and gas-based raw materials, as well as metals and mineral-based materials. Bio-based products can also offer new functionalities and specific innovative properties that can have advantages over other products. For example, in sensitive environments, hydraulic equipment and chainsaws can use biodegradable lubricants that are non-toxic in soil and water (see Annex A, Case Study 1). The main driver for use of bio-lubricants is lower environmental risks associated with unintended disposal in environmentally-sensitive industrial applications, such as in agricultural machinery or machines used in close proximity to water. In packaging, bio-based compostable materials can offer a significant advantage to disposable packaging in conjunction with responsible waste disposal.

Another key advantage of renewable feedstock is its short reproduction cycle, which ranges between several days for algae and several years for trees, compared to the much longer reproduction cycle of fossil feedstock. A proportion of CO_2 emissions released during the manufacturing and consumption of bio-based products can be counterbalanced by the CO_2 captured during the growth of the biomass used for their production.

Policies supporting the mitigation of climate change and energy efficiency (namely EU "20-20-20" targets [7]) support the development of markets for bio-based products, alongside those for renewable energies. The EU "Europe 2020 Strategy" for smart, sustainable and inclusive growth [8] recognizes that tackling the climate and energy challenge contributes to the creation of jobs, the generation of "green" growth and a strengthening of Europe's competitiveness. The UK Government supports the EU 2020 Strategy by encouraging investment in low carbon power, supporting infrastructure development, promoting the development of new markets in green goods and services and capping the costs of policies funded through energy bills. Further details on legislation supporting the development of the market for bio-based products are given in Clause **6**.

Governments can play an important role in developing market for bio-based products. In 2002, the US federal government set up its BioPreferred programme [9] to increase the purchasing of bio-based products. This programme has two major initiatives:

a) certify and award labels to qualifying bio-based products; and

b) designate categories of bio-based products that are afforded preference by federal agencies when making purchase decisions.

In this programme, any bio-based product that can be proven to match its conventional alternative on cost and performance is listed to have preferential consideration in purchasing by federal agencies and their contractors. By 2013, 9 000 designated bio-based products in 89 different categories were made available for preferred federal purchasing, and about 3 000 of these are currently listed in the BioPreferred catalogue [10]. The US Department of Agriculture (USDA)-certified bio-based products are also listed in the BioPreferred catalogue. However, due to an absence of funding in the Farm Bill extension legislation [11], the USDA has had to suspend the processing of applications for voluntary certification of bio-based products [12]. According to the USDA [13], federal agencies and the US Department of Defence spent approximately US$500 billion (£316 billion) on bio-based products by 2012. The impact of the BioPreferred programme has been to increase awareness about bio-based products that are available and their manufacturers. The USDA BioPreferred programme was the first example of a government procurement programme for bio-based products, which influenced the European strategies in the area of bioeconomy, such as the Lead Market Initiative [14].

On a company level, corporate social responsibility (CSR) programmes can drive the development of environmentally sustainable solutions. Organizations that have a CSR policy have self-regulatory mechanisms integrated into a business model, whereby a business monitors and ensures its active compliance with the law, ethical standards and international norms. Environmental sustainability issues can represent one of the elements of an organization’s CSR programme. Under such a programme, an organization ensures its compliance with environmental regulation and acts responsibly on a variety of levels, for example, from purchasing materials and products, to use of energy and water, and disposal of waste, all in an effort to minimize any negative environmental impact of its activities.

In other cases, like for bio-plastics, the adoption of bio-based products is stimulated by the availability of commercial quantities of bio-based resins at prices acceptable to the market, as in case of bio-based polyethylene (PE) and polyethylene terephthalate (PET) becoming commercially available in 2010. Bio-based materials can contribute, in some instances, to raw material security, both in the sense of availability and the affordability. Biomass is a renewable source of industrial raw materials, especially in production of chemicals which depends on carbon-based-materials. Fluctuation of crude oil prices and their increase represent a significant threat to industries relying on this resource.

Bio-based products can offer additional or different end-of-life options. For example, some bio-plastics can be organically recycled via composting or anaerobic digestion.

0.4 Barriers

Although there are a number of factors driving the development and commercialization of bio-based products, currently only a small portion of bio-based products are available on the market. A number of factors limit the demand for bio-based products. Bio-based materials generally have higher costs. For example, bio-plastics on average are currently two to four times more expensive than conventional plastics, although some bio-plastics are already cost competitive.

Bio-based materials generally have complex value and production chains starting with agricultural resources, branching out in different intermediates and processing steps, resulting in numerous co-products and final products ranging from fuels to fine chemicals, with an end use in different markets. In order to develop the market for bio-based products, these value chains need to be established, linking raw material producers to manufacturers (chemical and other industries), retailers and end users.

Availability of land and how it is used can be considered as a barrier to adoption of bio-based products on a large scale. This is as a result of a perception that crops used for the manufacture of bio-based product take up land that can be used to grow food and feed. However, figures suggest that, currently, this is not the case. For example, in 2011, bio-plastics required 0.006% of the global agricultural area of 5 billion hectares, compared with the area used to grow crops for food and feed (27%), or biofuels (1%) [15].

According to the Food and Agriculture Organization (FAO) and the Organization for Economic Co-operation and Development (OECD), currently there is enough land to support both bio-plastic, bioenergy and biofuel crops, food crops for a growing population, and use for conservation and biodiversity protection. However, with the growing global economy the demands for bio-based products, bioenergy and biofuels are set to increase. Some estimates predict that by 2050, more than 730 million hectares of land would be required to meet demands for bio-plastics, biofuels and bioenergy, which could test the limits of the amount of land sustainably available for crops [16]. Competition for land is forcing material developers, designers and product manufacturers to use scarce resources, such as land, energy and water, more efficiently by driving innovation (for example, by utilizing crops that can be grown on marginal or degraded land, such as that lignocellulosic crops, algae, as well as using agricultural residues and wastes).

Due to higher costs, fluctuations in prices and, in some cases, due to risks associated with reliability of supply and quality of bio-based raw materials, demand for bio-based products has not been sufficient to achieve economies of scale because producers and users choose cheaper alternatives. In most cases bio-based materials have to compete against petroleum-based materials, which are being manufactured and distributed in well-established value chains.

Like any other products, bio-based products face some technical barriers to achieve the same properties and performance offered by petroleum-based products, for example, some bio-plastics have a low melting temperature or low transparency and some are brittle. In addition, different processing and manufacturing properties of bio-plastics can require adaptations in the manufacturing plant or a complete refit in order to function efficiently. Although this is a barrier, most of the bio-polymer manufacturers adapt their products so that they can be run on traditional moulding/extruding equipment with few setup alterations. Also, a lack of practical knowledge on how to design for, and manufacture with, bio-based materials, which often have different processing and performance characteristics, presents a further barrier. This could be overcome with time as more experience accumulates in handling bio-based products.

The performance and functionalities of bio-based materials are improving. For example, one of the first commercially available bio-plastic materials, PLA, has undergone a significant improvement since it was first developed, which has enabled its use in a wide range of applications. Although the range of available bio-based materials is still limited compared with the range of non-bio-based materials, the bio-based industry is an evolving sector with new materials and products being developed.

Financing large-scale demonstrators that allows an up-scaling of bio-based production and new bio-based product innovations represents a significant problem, especially for SMEs. Funding for research and development (R&D) and product innovation are of particular importance for bio-based materials as this area represents a new field and new technologies and processes need to be developed to address the functionality, feedstock availability, cost and environmental performance of bio-based products.

Potential contamination of plastic recycling streams has posed a significant barrier for wider adoption of bio-plastics, especially for packaging such as bottles and household waste. This barrier can be overcome with adoption of a clear labelling system used at collection point, and communication across the product manufacturers, waste recycling industry, and local authorities.

Lack of clear and unambiguous standards and sustainability criteria for bio-based products represent a significant barrier. A relative lack of awareness is another barrier to wider adoption of bio-based products, especially among small and medium-sized enterprises.

0.5 Funding for R&D and demonstration projects

Information on grants and other funding opportunities can be obtained from various sources, including business support organizations and Local Enterprise Partnerships. In addition, information on funding and partnering can be found via Knowledge Transfer Networks (KTNs).

NOTE A KTN is a national network in a specific field of technology or business application, which brings together people from businesses, universities, research, finance and technology organizations to stimulate innovation through knowledge transfer and sharing of ideas. For example, the KTN for Energy Generation and Supply hosts a low carbon funding landscape navigator (www.lowcarbonfunding.org.uk), a database of funding providers in the low carbon sector.

In the UK funding for bio-based products can be given by various governments departments (in particular, DEFRA, DECC, BIS), and government funding bodies such as the Technology Strategy Board (TSB). The TSB is a business-led, government-funded organization that promotes and invests in technology-enabled innovation to boost UK business and prosperity. TSB has identified a number of technology areas and application areas where its efforts are focused, including biosciences, high-value manufacturing, advanced materials, environmental sustainability, energy generation and supply, and built environment. TSB invests in projects involving business and researchers working together to deliver successful new technology-based products and services. In addition, TSB champions the Small Business Research Initiative (SBRI), a programme that brings innovative solutions to specific public sector needs by funding short-term development contracts.

In the EU, Horizon 2020 [17] is the financial instrument that will support research and innovation with a budget of €80 billion (£67 billion), of which €4.7 billion (£4 billion) has been proposed for the tacking challenges of food security, sustainable agriculture, marine and maritime research, and the bioeconomy [18].

Small- and medium-sized enterprises (SMEs) will be encouraged to participate across Horizon 2020 programmes through a new dedicated SME instrument. It aims to fill gaps in funding for early-stage, high-risk research and innovation by SMEs as well as stimulating breakthrough innovations. It is expected that through this integrated strategy around 15%, or €6.8 billion (£6 billion), of the total combined budgets of the "Tackling societal challenges" Specific Programme and the "Leadership in enabling and industrial technologies" objective will be devoted to SMEs [19]. The first calls from Horizon 2020 are expected to be issued in early 2014.

In 2012, the UK Government launched the UK Green Investment Bank [20], which is dedicated solely to supporting the development of a "green" economy. Its mission is to provide financial solutions to accelerate private sector investment in the green economy. One of its aims is to increase growth capital for innovative green technology. Bio-based products will form a key part of the bio-based economy and so could receive support from the Green Investment Bank. This initiative was operational from October 2012.

0.6 The role of standardization in creating a market for bio-based products

The lack of product quality standards and data on environmental performance for new bio-based products can present a significant barrier for wider adoption of bio-based products. Without clear standardization and labelling, the acceptance and commercialization of bio-based products could be difficult to achieve. Standards and certification can give assurance as to a bio-based product's quality, its performance, as well as its bio-based content. This assurance can in turn result in an increased uptake of bio-based products.

Standards and certification can help to:

a) define a market for bio-based products;

b) ensure that environmental declarations are understood and are based on objective evidence;

c) enable consumers to make an informed choice.

While bio-based products might offer economic, environmental and social benefits, these can vary significantly between bio-based products. Life cycle assessment (LCA) standards can provide a means of comparing a product's environmental impact. Manufacturers and end users wanting to minimize their environmental impact can then make an informed choice between bio-based and non-bio-based products.

LCA takes into account all stages of product life cycle from raw materials to intermediate and final products, considering the impacts associated with use, disposal or re-use on the environment, as well as economic and societal impacts. For manufacturers it is important to communicate objectively and clearly, the benefits of bio-based products in manufacture, use and disposal.

However, caution needs to be applied when comparing products based on their LCA, as parameters and methodologies can vary. For example, one LCA could take into account the impact of the products from cradle-to-gate (from resource extraction, "cradle", to the factory gate, i.e. before it is transported to the consumer), while another LCA might take into account the impact from cradle-to-grave (from resource extraction to use phase and disposal phase, "grave"). These two LCA variants will produce different results. In addition, different methodologies or reference data could be used, thereby adding to the variability of the end result (see **4.4**).

1 Scope

This PAS provides a signpost to key standards, codes of practice and guidance that can be adopted in the production, use and disposal phases of bio-based products. Guidance is also provided on the communication of the benefits of bio-based products in a way that is accurate, verifiable, relevant and not misleading. It covers:

a) standards that are relevant to the life cycle of a product;

b) labelling;

c) future areas for standards development;

d) existing and potential future regulatory impacts.

Standards coverage is limited to the UK and EN/ISO standards, where adopted by the UK. Other highly relevant international standards are also included.

Bio-based products described in this PAS refer to non-food products derived from biomass (plants, algae, crops, trees, marine organisms, wool, silk, and biological waste from households and food production).

For the purposes of this PAS, biomass as an energy source, such as biofuel, traditional bio-based products (such as wood, paper and pulp) and pharmaceuticals are excluded.

The PAS is principally, but not exclusively, aimed at the SME base in the UK that either holds significant IP in this technology or is considering adopting it, and SMEs manufacturing bio-based products on contract.

2 Terms and definitions

For the purposes of this PAS, the following terms and definitions apply.

2.1 bio-based
derived from biomass

2.2 bio-based content
proportion of a product that is derived from biomass

NOTE 1 Normally expressed as a percentage of the total mass of the product.

NOTE 2 If oxygen (O) and/or hydrogen (H) atoms are bound to a biomass carbon structure, they are considered to be part of the bio-based content.

*NOTE 3 For the methodology to determine bio-based content, see **3.2**.*

2.3 bio-based material
material wholly or partly derived from biomass

2.4 bio-based plastic
plastic in which constitutional units are totally or in part from biomass origin

2.5 bio-based polymer
polymer in which constitutional units are totally or in part from biomass origin

[SOURCE: PD CEN/TR 15932:2010, **3.1.2.11**]

NOTE 1 Bio-based polymers are not identical to bio-polymers. Bio-based polymers can be made synthetically from monomers derived from biomass, while bio-polymers are made entirely by the living organisms.

NOTE 2 Bio-polymers can be of animal (such as collagen, chitin or spider silk), plant (such as starch and cellulose), algal (alginates) or bacterial origin (polyhydroxyalcanoates). An example of a synthetic bio-based polymer is polylactadie, produced from lactic acid.

NOTE 3 A bio-based polymer similar to a petrochemically based one does not imply any superiority with respect to the environment unless the comparison of respective life cycle assessments is favourable.

2.6 bio-based product
product wholly or partly derived from biomass

NOTE 1 The bio-based product is normally characterized by the bio-based carbon content or the bio-based content. For the determination and declaration of the bio-based content and the bio-based carbon content, see the relevant standards of CEN/TC 411.

NOTE 2 Product can be an intermediate, material, semifinished or final product.

NOTE 3 "Bio-based product" is often used to refer to a product which is partly bio-based. In those cases the claim should be accompanied by a quantification of the bio-based content.

[SOURCE: prEN 16575:2013 [1)], **2.5**]

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1) In preparation.

2.7 biocomposite material
composite material where at least one of the constituents is derived from biomass origin

[SOURCE: PD CEN/TR 15932:2010, **3.1.2.12**]

2.8 biodegradable plastic
plastic whose degradation results from the action of microorganisms such as bacteria, fungi and algae

2.9 biodegradation
degradation caused by biological activity leading to a significant change in the chemical structure of a product

[SOURCE: prEN 16575:2013 [2)], **2.6**]

2.10 bio-lubricant
lubricant derived wholly or partly from biomass

*NOTE According to PD CEN/TR 16227:2011, **4.3.1**, the term "bio-lubricant" covers several materials:*

a) bio-based lubricants, when referring to raw material sourcing, which can be partially or wholly bio-based;

b) biodegradable lubricants, when referring to functionality; and

c) biocompatible lubricants, when referring to compatibility with human or animal body (non-toxic properties).

For the purposes of this PAS, the term "bio-lubricant" is used to refer to "bio-based lubricants".

2.11 biomass
material of biological origin excluding material embedded in geological formations and/or fossilized

NOTE 1 Biomass can have undergone physical, chemical or biological treatment(s).

*NOTE 2 This definition refers to the well-known short-cycle of carbon, i.e. the life cycle of biological materials (e.g. plants, algae, marine organisms, forestry, microorganisms, animals, and biological waste from households, agriculture, animals and food/feed production), as defined by the working group CEN/BT/WG 209 "Bio-based Products" which was established for the execution of Mandate M/42 (see Clause **5**).*

[SOURCE: CEN/BT/WG 209]

2.12 biomass content
see "bio-based content"

2.13 biorefinery
facility that uses mechanical, thermal, chemical and/or biochemical processes to convert biomass into bio-based products or key intermediates for the production of chemicals and other materials

2.14 bio-solvent
solvent derived wholly or partly from biomass

NOTE 1 The term "bio-solvent" is interchangeable with the term "bio-based solvent".

NOTE 2 Bio-solvents have no criteria or relation to biodegradability.

[SOURCE: CEN/TC411, WG2]

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2) In preparation.

2.15 bio-surfactant

surfactant derived wholly or partly from biomass

NOTE For the purposes of this PAS, the term "bio-surfactant" is interchangeable with the term "bio-based surfactant".

2.16 carbon footprint

absolute sum of all emissions of greenhouse gases caused directly and indirectly by a subject either over a defined period or in relation to a specified unit of product or instance of service and calculated in accordance with a recognized methodology

[SOURCE: PAS 2060:2010, **3.4**]

NOTE In more precise terms, a carbon footprint is a measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions, of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO_2e) using the relevant 100-year global warming potential (GWP100) [21].

2.17 composite

solid product consisting of two or more distinct phases, including a binding material (matrix) and a particulate or fibrous material

NOTE A composite can consist of two of more layers of different materials with or without adhesive interlayers.

[SOURCE: BS EN ISO 472:2013, **2.182.1**]

2.18 compostability

property of a material to be biodegraded in a composting process

NOTE 1 To claim compostability, a material biodegrades and disintegrates in a composting system (as shown by standard test methods) and completes its biodegradation during the end-use of the compost. The compost meets the relevant quality criteria, which include low content of regulated metals, no ecotoxicity, no obviously distinguishable residues.

NOTE 2 For the purposes of this PAS, composting refers to industrial composting processes.

NOTE 3 Attention is drawn to PAS 100, which specifies requirements for the process of composting.

2.19 compostable plastic

plastic that can degrade by biological processes during composting to yield CO_2, water, inorganic compounds and biomass at a rate consistent with other known compostable materials and leave no visible, distinguishable or toxic residue

NOTE Compostable plastic fulfils the requirements of biodegradability and compostability set by existing international standards, such as ASTM D6400-12 and BS EN 13432.

2.20 composting

managed process that controls the biological decomposition and transformation of biodegradable materials into a humus-like substance called compost:

a) the aerobic mesophilic and thermophilic degradation of organic matter to make compost;

b) the transformation of biologically decomposable material through a controlled process of bio-oxidation that proceed through mesophilic and thermophilic phases and results in the production of CO_2, water, minerals and stabilized organic matter (compost or humus)

2.21 cradle-to-cradle
continuous cycle of material use and reuse by nature and humankind

2.22 cradle-to-gate
assessment of a partial product life cycle from resource extraction (“cradle”) to the factory gate (i.e. before transportation to the consumer)

NOTE The use phase and disposal phase of the product are omitted in this case. Cradle-to-gate assessments are sometimes the basis for environmental product declarations (EPD) termed business-to-business EPDs.

2.23 cradle-to-grave
full assessment of environmental impacts from resource extraction (“cradle“) to use phase and disposal phase (“grave“)

NOTE Cradle-to-grave assessments will normally model the typical end-of-life scenario for a product – this might be landfill but in many cases it can include recycling or energy recovery. Benefits of recycling and recovery can also be included within a cradle-to-grave assessment.

2.24 degradation
irreversible process leading to a significant change in the structure of a product, typically characterized by a change of properties (e.g. integrity, molecular mass or structure, mechanical strength) and/or by fragmentation, affected by environmental conditions, proceeding over a period of time and comprising one or more steps

[SOURCE: prEN 16575:2013 3), **2.10**]

2.25 end-of-life
end of a product’s useful life

NOTE End of life ultimately leads to the concept of disposal, i.e. what is done with the end product after its useful life is over.

2.26 feedstock
material to supply or fuel an industrial process

2.27 green washing
marketing used deceptively to create an impression that a product or process is environmentally friendly

2.28 life cycle assessment (LCA)
compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

[SOURCE: prEN 16575:2013 4), **2.12**]

2.29 natural fibre
bio-based fibres or fibres from vegetable and animal origin, including all natural cellulosic fibres (such as cotton, jute, sisal, coir, flax, hemp, abaca, ramie, etc.) and protein based fibres such as wool and silk

NOTE 1 Excluded here are mineral fibres, such as asbestos, that occur naturally but are not bio-based. Also excluded are dietary fibres or supplements.

NOTE 2 Fibre can be taken from three parts of a plant: the stem, the seed and the leaf. Natural fibres are mainly composed of cellulose, hemicellulose and lignin.

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3) In preparation.

4) In preparation.

2.30 organic material
material containing carbon-based compounds in which the element carbon is attached to other carbon atoms, hydrogen, oxygen, or other elements in a chain, ring, or three-dimensional structure

NOTE Not to be confused with the term "organic" when used in the context of food or produce, which implies that the food was produced using methods of organic farming *(i.e. without the use of synthetic pesticides and chemical fertilizers, and processed without using irradiation, industrial solvents or chemical food additives).*

2.31 plastic
material that contains, as an essential ingredient, one or more organic polymeric substances of large molecular weight, is solid in its finished state and mouldable

NOTE During product manufacturing plastics can be processed into finished articles and shaped by flow, such as injection moulding or blow moulding.

2.32 product
substance, mixture of substances, material or object resulting from a production process

NOTE Product can be an intermediate, material, semi-finished or a final product.

2.33 recycling
processing of waste materials for the original purpose or for other purposes, excluding energy recovery

[SOURCE: BS EN ISO 472:2013, **2.1706**]

2.34 renewable resource
resource with the ability to be continually replenished by natural processes

NOTE For example, resources can include biomass, water, geothermal heat, wind, solar radiation, etc.

2.35 resin
predominantly amorphous macromolecular material that ranges from the solid to the liquid state, has a relatively low molecular mass and is capable of hardening permanently

NOTE 1 Synthetic resin is produced by chemical reactions such as polyaddition, polycondensation or polymerization.

NOTE 2 Properties of synthetic resins are similar to natural plant resins but their chemical structure is very different from the various resinous compounds secreted by plants.

2.36 sink (carbon sink)
natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period

NOTE The main natural sinks are absorption of carbon dioxide by the oceans via physicochemical and biological processes, photosynthesis by plants. The main artificial sinks are landfills and carbon capture and storage technologies.

2.37 solvent
liquids that possess the ability to dissolve, dilute or extract other substances without modifying the chemical composition of the extracted substances or of the solvent itself

2.38 SPI code
resin identification coding system comprising a set of symbols placed on plastics to identify the polymer type

2.39 surfactant

compound that lowers the surface tension of a liquid, the interfacial tension between two liquids, or between a liquid and a solid

NOTE Surfactants can act as detergents, wetting agents, emulsifiers, foaming agents and dispersants.

2.40 waste

any substance, material or object which the holder discards or intends/is required to discard

[SOURCE: prEN 16575:2013 [5)], **2.19**]

3 Standards relevant to bio-based products

3.1 General

This section describes standards related to:

a) bio-based content and the amount of renewable raw materials in the products;

b) standards related to specific product groups, their functionality and technical performance (specifications);

c) end-of-life options for bio-based products.

Typically standards can be divided into horizontal standards that can apply across industry or address several characteristics, or vertical standards that apply to specific industries or product categories. Horizontal standards are of particular importance for the introduction of new types of products that can be used across industry.

In general, the main types of standard are: specifications, methods of test, guidance and codes of practice. Specifications are normally product or process specific and provide requirements that must be fulfilled in order to claim compliance. In order to determine compliance with a particular specification, a product can undergo a conformity assessment.

Methods of test describe a test methodology that a product could undergo in order to determine a specific characteristic, e.g. bio-based content, but do not contain any pass/fail thresholds.

The development of standards relevant to bio-based products is undertaken by CEN (European Committee for Standardisation) and is overseen by CEN/TC 411 "Bio-based Products" (see more on future standards in Clause **5**). The overview of existing standards on bio-based products was published by CEN as a technical report (PD CEN/TR 16208) in 2011. The UK contributes to this committee through its own technical committee, MI/2 "Bio-based Products", which is run by BSI.

3.2 Standards related to bio-based content and biomass content

3.2.1 General

Currently, there is no single method for determining bio-based content across all types of products. Testing services are offered by specialized testing houses or organizations.

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5) In preparation.

In the UK, testing and measurement services can be accredited by the United Kingdom Accreditation Service (UKAS), which is the sole national accreditation body recognized by government to assess, against internationally agreed standards, organizations that provide certification, testing, inspection and calibration services.

Several testing houses provide conformity testing for bio-based products in the EU and USA. To find an accredited testing house, it is recommended to look for organizations that are accredited as testing and calibration laboratories that conform to BS EN ISO/IEC 17025.

NOTE UKAS has searchable listings of all of the companies in the UK that have been accredited by UKAS to provide testing or calibration services (http://www.ukas.org/).

3.2.2 Testing for bio-based content

ASTM D6866 is the main standard used for testing products for bio-based content. The testing method is based on ^{14}C analysis and determines the carbon content derived from biomass.

It uses a ratio equation, by comparing the unknown sample with a standard of "modern carbon". The ratio is expressed as percentage of modern carbon (pMC), and this is the ratio between the amount of modern carbon (representing carbon obtained from biomass) and fossilized carbon (representing carbon from fossil fuels). Therefore this ratio can compare directly to the amount of carbon from biomass. The whole test relies on the assumption that the biomass in the product has a pMC of 105 and that the fossilized carbon in the product has a pMC of 0.

ASTM D6866 is used as a standard for bio-based content internationally and is the basis of several certification schemes.

The result of the test includes a percentage of bio-based content, which refers to the percentage of carbon that is bio-based in reference to the total organic carbon content, not to the total mass or molecular weight. This standard only measures the bio-based content and provides no information on the biodegradability of a product.

NOTE Carbon-14 (^{14}C) is a naturally occurring isotope of carbon. In different stores of carbon, the proportion of carbon that is ^{14}C varies for numerous reasons. For bio-based content, two stores of carbon are relevant: biomass and fossilized. Parts per modern carbon is set at the amount of ^{14}C in 1950. Due to the creation of ^{14}C in the following decades by nuclear bomb testing, this number almost doubled. However since test ban treaties, this number has declined. The current approximate value for pMC is 105, therefore all biomass is assumed to have a pMC of 105. Fossilized carbon is assumed to have a pMC of 0, as a result of the processes that have caused its production.

3.2.3 Sampling methods for testing on bio-based content

ASTM D7026 provides a framework for collecting and handling samples for determination of bio-based content of materials by means of the carbon isotope method similar to ASTM D6866. ASTM D7026 also describes the reporting of results, sampling techniques, handling procedures and discusses chain-of-custody issues.

Bio-based materials often present sampling problems, such as heterogeneity, therefore material-specific sampling methods are required. The method states that if there is a standard sampling technique for the material to be tested that is widely accepted by the industry, such a procedure may be used and the details of sampling recorded in sufficient detail to allow critical assessment of the techniques used. This standard is significant in that it highlights the importance of representative sampling.

3.2.4 Bio-based content in solid recovered fuels

BS EN 15440 is used to determine bio-based content in solid recovered fuels. It is also based on the ^{14}C method described by ASTM D6866 (in this document, see **3.2.2**), and describes two additional sorting and calculation techniques. BS EN 15440 enables the bio-based content to be expressed by:

a) weight;

b) energy content (gross or net calorific value);

c) carbon content.

3.2.5 Bio-based content in plastics

CEN/TS 16137 is a standard for measuring the bio-based content of plastics including in monomers, polymers, other plastics and composites. This technical specification provides reference test and calculation methods for determining the bio-based carbon content of plastics and other polymers that contain organic carbon. Under CEN/TS 16137, a material's bio-based carbon content is the amount of carbon in a sample that is of recent origin as evidenced by its ^{14}C isotope content. The method used to determine bio-based content is the same method as for BS EN 15440 (in this document, see **3.2.4**) and based on ASTM D6866 (in this document, see **3.2.2**). CEN/TS 16137 results are reported as the percentage of renewable carbon relative to the total carbon and not to the total mass of the sample or molecular weight.

It uses the same methods as ASTM D6866 for determining the amount of carbon from biomass. The amount of bio-based carbon from CEN/TS 16137 can be presented in three ways:

a) as a fraction of the total sample mass;

b) as a fraction of the total carbon content;

c) as a fraction of the total organic carbon content.

3.3 Specifications

3.3.1 General

Product functionality is strongly dependent on the product and application. Criteria for performance (and measurement methods) are the same for bio-based and non-bio-based products and therefore covered by the same standards. For example, any lubricant used in internal combustion engines, regardless of its origin, should conform to BS ISO 13738.

Often the product is only part of a system, and the environmental impact of the system could be greater than the impact of the product itself. The overall environmental impact of a product is expressed through product functionality. However, the relevance of specific product functionalities is dependent on application and product use, and therefore some standards exist for specific bio-based product groups.

Specifications give a coherent set of objectively verifiable requirements. The result is a non-negotiable set of criteria for products, services or systems. They are particularly suited to giving the performance criteria demanded of a product (e.g. biodegradation, environmental safety, bio-based content, performance, etc.).

3.3.2 Lubricants, hydraulic liquids and industrial oils

3.3.2.1 PD CEN/TR 16227 on bio-lubricants and related terminology

PD CEN/TR 16227 is a technical report that gives information about bio-lubricants and recommendations for bio-lubricant (and bio-based lubricant) related terminology.

There is no European-wide standardized definition for bio-lubricant and bio-based lubricant. However, PD CEN/TR 16227 recommends considering the following when defining "bio-lubricants" or "bio-based lubricants":

a) renewability: bio-lubricants and bio-based lubricants are required to have renewable raw material content at 25% according to ASTM D 6866. There is no equivalent CEN version to date;

b) biodegradability:

   1) ≥ 60% according to OECD 301 B, C, D or F (or adequate ISO or EN standards) for oils [22];

   2) ≥ 50% according to OECD 301 B, C, D or F (or adequate ISO or EN Standards) for lubricating greases [23];

c) toxicity: not to be labelled as "Dangerous to the environment" (Symbol N) according to CLP Directive EC 1272/2008 (Classification, Labelling, and Packaging) [23];

d) performance: the product needs to be "fit for purpose" or "fit for use". The lubricant manufacturer and the customer using the product both need to ensure that the recommended lubricant is suitable for a specific application.

PD CEN/TR 16227 also briefly describes the current test methods in relation to the characterization of bio-lubricants.

It presents recommendations for related standards on:

a) biodegradability;

b) product functionality;

c) impact on greenhouse gas emissions; and

d) amount of different renewable raw materials and/or different bio-based contents, used during the manufacturing of such bio-lubricants.

3.3.2.2 BS ISO 15380 on lubricants, industrial oils and related products

BS ISO 15380 specifies requirements for environmentally acceptable hydraulic fluids at the time of delivery and provides product performance requirements for a number of lubricating and hydraulic oils. It focuses on non-toxic biodegradable hydraulic fluids. It is intended for hydraulic systems, particularly hydraulic fluid power systems, but does not cover other product categories, such as automotive lubricating oils.

BS ISO 15380 forms the basis of many certification and labelling schemes for bio-lubricants. It does not specify the origin of the products and so can apply to both bio-based and non-bio-based products.

3.3.2.3 BS ISO 22621 series for plastics piping from polyamide

The BS ISO 22621 series of standards covers PA 11 material, which is a performance polyamide (PA) derived from castor oil (*Ricinus communis*). BS ISO 22621-1 specifies the general properties of PA (PA 11 and PA 12) compounds for the manufacture of pipes and fittings made from these compounds, intended to be buried and used for the supply of gaseous fuels at maximum operating pressures (MOP) up to and including 20 bar.

It also specifies the test parameters for the test methods to which it refers.

BS ISO 22621-2 specifies the physical and mechanical properties of pipes made from PA, jointed typically by using mechanical, electro fusion or butt fusion techniques, but not by solvent cement jointing. BS ISO 22621-3 specifies the physical and mechanical properties of fittings made from PA.

3.3.3 Plastic waste bags for waste collection

For biodegradable plastic bags that are intended for collection of waste that will undergo organic recycling (anaerobic digestion and/or composting), such as food waste collected by businesses and councils for anaerobic treatment or garden waste, two standards are relevant:

a) BS EN 13432 (see **3.4.3.3.2**);

b) BS EN 14995 (see **3.4.3.3.3**).

3.3.4 Fibre-based products

The use of natural fibres is covered by a number of existing international and UK standards relevant to wool, cotton, flax, and synthetic fibres such as cellulose and rayon.

Different types of standards include those that define:

a) properties of fibres, such as length, thickness, tensile strength, oils, fats, and waxes (wool); sugar content; moisture content, etc. (e.g. BS 3183);

b) properties of fabrics, such as density;

c) sampling and testing methods (e.g. ASTM D1441–12);

d) product specific standards, i.e. for beddings and staffing (e.g. BS 2F **5**2);

e) processing and treatment of natural fibres and products made from them (e.g. BS 5689-3.1:1996, IEC 60394-3-1:1976).

Natural fibre-based composite materials have applications in the automotive and construction industries. BS EN 15534-5 is a standard in development, which is expected to include requirements for natural fibre composites (NFC).

3.4 Standards related to the end of life

3.4.1 General

According to the Waste Framework Directive (2008/98/EC) [24], manufacturers should, in the first instance, seek to prevent the production of waste at source. Products may also be produced with the intention for reuse. Reusable bio-based products should conform to BS EN 13429 and one or more of the standards related to material/organic recycling and energy recovery given in this sub-clause.

The Waste Framework Directive lists the following waste hierarchy in order of priority:

a) prevention;

b) preparing for reuse;

c) recycling;

d) other recovery, notably energy;

e) disposal.

Accordingly, bio-based products could have one of the following end-of-life routes:

- recovery, including materials recycling, organic recycling, and recovery of energy from waste;
- disposal (intended or unintended).

Standards on reuse, recycling, energy recovery, organic recovery are only available for packaging. Depending on the product, these standards may also be applied to non-packaging products.

3.4.2 Material recycling

Some bio-based products can be recycled, depending on their composition and local recycling facilities.

Separation of materials and products that are generally not compatible with each other is important in order to avoid cross-contamination. Accordingly, bio-based products should be identified. Means of identification are provided by: BS EN ISO 1043-1 (which defines abbreviated terms for the basic polymers used in plastics, symbols for components of these terms, symbols for special characteristics of plastics, and SPI code for resin identification); and the European Commission decision 97/129/EC [25] establishing the identification system for packaging materials [26].

For packaging, significant work has been done to standardize requirements for recycling (see BS EN 13427 and BS EN 13430). However, the evaluation criteria for recyclability are independent of the origin of the product and can apply to both bio-based and non-bio-based products.

Clear labelling of bio-based products can improve the rate of recycling or composting. However, biodegradable and non-biodegradable bio-plastics need to be very clearly labelled at collection point, since each is considered as a contaminant if it enters the wrong waste recycling stream.

Clear labelling and communication is important to ensure that materials reach the correct disposal facility and avoid contamination.

3.4.3 Organic recyclability, biodegradability and compostability

3.4.3.1 General

Bio-based products' suitability for organic recycling is dependent on their biodegradability and compostability.

Biodegradation is carried out by microorganisms, and can occur either aerobically (in the presence of oxygen) or anaerobically (without oxygen). The length of time it takes for a material to break down varies.

There are important differences between "biodegradable" and "compostable", which affect waste management options (see **3.4.3.2** and **3.4.3.3**).

3.4.3.2 Biodegradation

3.4.3.2.1 General

Biodegradation is dependent on environmental conditions and is a process comprising one or more steps. A material should only be called biodegradable with respect to specific environmental conditions: if it undergoes biodegradation to a specified extent within a given time, measured by standard test methods in a specific environment.

The applications or end-of-life options of a product determine the environmental conditions of the test method and further requirements, such as extent of conversion and the time frame in which it occurs. Therefore, there are numerous standards specifying the test methods for different applications or end-of-life scenarios.

These test methods are designed to measure biodegradation in specific environmental conditions (related to a specific application), regardless of the origin of the product. They are applicable to bio-based and non-bio-based products. The biodegradability of a product is dependent on the chemical structure of the polymer and is independent of the origin of the material. There is no direct link between bio-based content and biodegradability. For example, some petroleum-derived plastics can easily biodegrade, while some bio-based plastics are non-biodegradable.

In the EU, biodegradability is defined by standards related to:

a) packaging;

b) plastics;

c) biodegradation in water;

d) biodegradation in soil.

Standards relevant to biodegradation and ecotoxicity are described in detail in the KBBPPS report [27], which reviews the current biodegradation test methods in different environments (fresh water, marine environment, anaerobic environment, soil and compost) and the existing test procedures for evaluating environmental safety. The most significant test methods for biodegradation of lubricants and plastics are described below.

3.4.3.2.2 Biodegradation of lubricants

Described in **3.3.2.1**, PD CEN/TR 16227 gives information about bio-lubricants and recommendations for bio-lubricant (and bio-based lubricant) related terminology, and describes the current test methods in relation to the characterization of bio-lubricants.

ASTM D7373 describes the method for predicting the biodegradability of lubricants using a biokinetic model. It allows predictions to be made in one day and correlates well with a conventional laboratory biodegradation approach.

ASTM D5864 describes the method for determining the degree of aerobic aquatic biodegradation of fully formulated lubricants or their components on exposure to an inoculum under laboratory conditions. This test method is intended to address specifically the difficulties associated with testing water-insoluble materials and complex mixtures, such as those found in many lubricants. ASTM D5864 is designed to be applicable to all lubricants that are not volatile and do not inhibit, at the test concentration, the organisms present in the inoculum.

ASTM D6731 is a test method for determining the degree of biodegradability of lubricants or their components in an aerobic aqueous medium on exposure to an inoculum under controlled laboratory conditions. This test method is an ultimate biodegradation test that measures oxygen demand in a closed respirometer. This test method is suitable for evaluating the biodegradation of volatile as well as non-volatile lubricants or lubricant components, and applicable to lubricants and lubricant components which are not toxic and do not inhibit the test microorganisms at the test concentration. Test results are stated in SI units.

3.4.3.2.3 Biodegradation of plastics

BS EN ISO 14855-1 is a test method for biodegradability and composting of plastic materials. The method is based on measurement of the amount of CO_2 evolved and the degree of disintegration of the plastic at the end of the test. It is not specific to materials of biological origin. This method is designed to simulate typical aerobic composting conditions for the organic fraction of solid mixed municipal waste. The test material is exposed to an inoculum which is derived from compost. The composting takes place in an environment in which temperature, aeration and humidity are closely monitored and controlled. The test method is designed to yield the percentage conversion of the carbon in the test material to evolved carbon dioxide as well as the rate of conversion. BS EN ISO 14855 is relevant only for solid materials. Although specified for plastic materials, its application area can be further extended to any type of solid material. There are also standards defining the methods of preparation of samples for biodegradability testing, such as ISO 10210.

BS EN ISO 17556 specifies a method for determining biodegradability of plastic materials in soil by measuring the oxygen demand in a closed respirometer or the amount of carbon dioxide evolved. This method applies to natural and/or synthetic polymers, co-polymers or mixtures of these; plastic materials which contain additives such as plasticizers or colorants; water-soluble polymers. It does not necessarily apply to materials which, under the test conditions, inhibit the activity of the microorganisms present in the soil. If the test material inhibits the microorganisms in the soil, a lower test material concentration, another type of soil or a pre-exposed soil can be used.

BS ISO 15985 specifies a method for the evaluation of the ultimate anaerobic biodegradability of plastics based on organic compounds under high-solids anaerobic-digestion conditions by measurement of evolved biogas and the degree of disintegration at the end of the test. This method is designed to simulate typical anaerobic digestion conditions for the organic fraction of mixed municipal solid waste. The anaerobic decomposition takes place under high-solids (more than 20% total solids) and static non-mixed conditions. The test method is designed to yield the percentage of carbon in the test material and its rate of conversion to evolved carbon dioxide and methane (biogas).

Other standards relevant to biodegradation of plastics are listed below:

- BS EN ISO 14851 describes the method for determination of the ultimate aerobic biodegradability of plastics materials in an aqueous medium using respirometer.
- BS EN ISO 14852 describes the method for determination of the ultimate aerobic biodegradability of plastics materials in an aqueous medium using analysis of the evolved carbon dioxide.
- BS ISO 14853 describes the method for determination of the ultimate anaerobic biodegradation of plastic materials in an aqueous system by measurement of biogas production.
- BS ISO 16929 describes test method to determine the degree of disintegration of plastic materials in a pilot-scale aerobic composting test (in anaerobic conditions) and can also be used to determine the influence of the test material on the composting process and the quality.
- BS ISO 13975 describes a method for determination of the ultimate anaerobic biodegradation of plastic materials in controlled slurry digestion systems by measuring biogas production.

3.4.3.3 Compostability

3.4.3.3.1 General

Besides demonstrating inherent ultimate biodegradability, materials should be able to disintegrate completely in an industrial composting process, without having adverse effects on the composting process, or on the quality of the resulting compost. It is important to note that compostability of the item depends on its thickness. Another important difference between biodegradability and compostability is that compostability is defined by time.

There are several international standards related to compostability, such as BS EN 13432, ISO 17088 and ASTM D6400. However, they are harmonized and follow exactly the same methodology. Minor variations exist in, for example, maximum tolerated amounts of heavy metals, or the allowed duration of biodegradability assessments.

Packaging items that conform to BS EN 13432 and plastic items that conform to BS EN 14995 are acceptable inputs to those commercial composting systems with appropriate waste codes in their permits, licences or registered exemptions. Those composters who produce compost that conforms to the PAS 100 specification for composted materials can only accept packaging items if they also conform to BS EN 13432, and can only accept plastic items if they also conform to BS EN 14995.

3.4.3.3.2 Compostability and anaerobic treatability of packaging

BS EN 13432 covers compostability of packaging itself and how to deal with multi-component packaging. It specifies requirements and procedures to determine the compostability and anaerobic treatability of packaging and packaging materials by addressing four characteristics:

a) biodegradability;

b) disintegration during biological treatment;

c) effect on the biological treatment process;

d) effect on the quality of the resulting compost.

BS EN 13432 requires the chemical breakdown of the material into water, CO_2 and minerals. Proof is required to show that after six months, 90% has degraded through biological processes, including that after 90 days 90% has been disintegrated under the set temperature of 58°C (±2°C). The conditions of degradation are those maintained in industrial composting units. The minerals that are released are also limited in quantity, so as not to harm the compost.

The requirements are specific for organic recovery or composting of packaging materials. The criteria are not material specific but can be applied to any type of packaging, regardless of its origin (bio-based or non-bio-based). The application area can be extended even further to any type of solid material or single/multi-component product. This standard has been widely adopted by the major degradable plastic producers on a voluntary basis.

3.4.3.3.3 Plastics suitable for composting or anaerobic treatment

BS EN 14995 specifies requirements and procedures to determine the compostability or anaerobic treatability of plastic materials by addressing four characteristics:

a) biodegradability;

b) disintegration during biological treatment;

c) effect on the biological treatment process;

d) effect on the quality of the resulting compost.

The requirements and evaluation criteria are derived from those in BS EN 13432 (for example, the tests and pass/fail criteria are exactly the same as those in BS EN 13432, the only difference being that BS EN 14995 applies to any plastic material or product which is not packaging). This standard takes into account the physical–chemical parameters of plastic products, such as the thickness. The requirements are specific for organic recovery or composting. The criteria are not material specific but can be applied to any type of plastic, regardless of the origin (bio-based or non-bio-based).

3.4.3.3.4 Plastics suitable for municipal and industrial aerobic composting facilities

ASTM D6400 is a US standard equivalent to BS EN 13432 and specifies the biodegradability of plastics and products made from plastics (including packaging) that are designed to be composted in municipal and industrial aerobic composting facilities.

It sets out the requirements for the labelling of materials and products, including packaging, made from plastics as "compostable in municipal and industrial composting facilities". It seeks to determine whether plastics and products made from plastics will compost satisfactorily. It includes requirements for biodegrading at a rate comparable to known compostable materials. The requirements also ensure that the degradation of these materials will not diminish the value or utility of the compost resulting from the composting process.

ASTM D6400 sets out the requirements to demonstrate a satisfactory rate of biodegradation.

Biodegradability is determined by measuring the amount of CO_2 produced over a certain period by the test material. ASTM D6400 does not specify the origin of the material, which could be bio-based or derived from non-bio-based feedstocks.

Various international standards set out different requirements for the percentage of biodegradation. ASTM D6400 and ISO 17088 (see **3.4.3.3.6**) require both that 90% absolute or relative biodegradation of the whole item or for each organic constituent, which is present in the material at a concentration of more than 1% (by dry mass) within 180 days. Moreover, all organic constituents present at levels between 1% and 10% are required to meet the 90% biodegradation criteria. BS EN 13432 is less strict as organic constituents present at levels between 1% and 10% do not need to be tested separately. Furthermore, there are ongoing discussions on revising the BS EN 13432 so that it requires 90% biodegradation within 90 days instead of 180 days [27]. This is issue is also under discussion at ISO level.

3.4.3.3.5 ASTM D6868 for products that include plastics or polymers

ASTM D 6868-11 specification covers end items that include plastics or polymers where plastic film/sheet or polymers are incorporated (either through lamination, extrusion or mixing) to paper and other substrates (such as coatings or binders) and the entire end item is designed to be composted under aerobic conditions in municipal and industrial composting facilities.

The composting specifications refer to requirements and criteria towards biodegradability, disintegration and environmental safety. ASTM D6868 is based on ASTM D6400 and requires the same biodegradation thresholds.

3.4.3.3.6 Plastics suitable for recovery through aerobic composting

ISO 17088 specifies procedures and requirements for the identification and labelling of plastics, and products made from plastics, that are suitable for recovery through aerobic composting. There are four main aspects covered within this standard:

a) biodegradation;

b) disintegration during composting;

c) negative effects on the composting process and facility;

d) negative effects on the quality of the resulting compost, including the presence of high levels of regulated metals and other harmful components.

This specification establishes the requirements for labelling of materials and products, including packaging, made from plastics as "compostable", "compostable in municipal and industrial composting facilities", and "biodegradable during composting". Industrial and municipal composting plants have optimized conditions with respect to water content, aerobic conditions, the carbon-to-nitrogen ratio, and the processing conditions are optimized to enable disintegration and biodegradation of compostable plastics at rates comparable to yard trimmings, kraft paper, bags and scraps.

3.4.3.3.7 Biodegradable plastics used on and in soil

PD CEN/TR 15822 is a technical report that summarizes the current state of knowledge in the field of biodegradable plastics that are used on soil or end up in soil. This document addresses the application of plastics and end-of-life options in soil environments and provides a basis for the development of future standards.

It is not material specific but can be applied to any type of plastic, regardless of the origin (bio-based or non-bio-based).

3.4.3.3.8 Packaging suitable for organic recycling

ISO 18606 specifies requirements for packaging to ensure that it is suitable for organic recycling. The scope of ISO 18606 is the same as that of BS EN 13432 and so it has not been adopted by CEN or published as a British Standard. According to ISO 18606, packaging is considered as recoverable by organic recycling only if all the individual components meet the requirements of ISO 18606. Therefore, packaging is not considered recoverable by organic recycling if only some of the components meet the requirements of ISO 18606. However, if the components can be easily physically separated before disposal, then the physically separated components can be individually considered for organic recycling.

ISO 18606 is applicable to organic recycling of used packaging but does not address regulations regarding the recoverability of any residual packaged goods. ISO 18606 does not provide information on the requirements of the biodegradability of used packaging which ends up in the soil environment as litter, because littering is not considered as a recovery option. It is also not applicable to biological treatment undertaken in small installations by householders.

For each of the packaging components, the following four aspects are addressed:

a) biodegradation;

b) disintegration during biological waste treatment process (i.e. composting);

c) negative effects on the biological process;

d) negative effects on the quality of the resulting compost, including the presence of high levels of regulated metals and other substances hazardous to the environment.

3.4.4 Recoverability in the form of energy

Bio-based products can be incinerated, while energy generated in this process can be renewable. Bio-based content of the product can be wholly or partly considered as a source of renewable energy.

BS EN 13431 specifies the requirements for packaging to be classified as recoverable in the form of energy and sets out procedures for assessment of conformity with those requirements. The scope is limited to factors under the control of the supplier. This standard can be extended to any item within the scope to determine the inferior calorific value (q_{net}; MJ/kg). According to BS EN 13431, to claim energy recovery q_{net} shall be equal to or greater than 5 MJ/kg.

3.5 Standards relevant to sustainable sourcing

BS 8905 provides a framework for the assessment of social, economic and environmental issues in the sustainable use of materials. The framework can be applied to all parts of the supply chain and is intended to support decision making about the sustainable use of any type of material.

Although this standard is not specific to bio-based materials, it can help manufacturers to select materials that maximize social, environmental and economic contributions, minimize negative impacts and encourage the use of renewable materials.

4 Labels, declarations and certification

4.1 General

Environmental claims enable consumers to make informed choices and allow industry to declare the environmental benefits of their products and services. To do this effectively, it is important that claims and labels are clear, accurate and do not mislead. Product specifications are designed to form the basic principle for certification schemes and labelling systems.

Declarations of bio-based content and other characteristics impacting on environmental performance (such as compostability) can be a key marketing advantage for a product. There are a number of ways in which these declarations can be expressed. Different types of labelling programmes exist, from single issue labels, to independent or private labels, and national and international labels.

The BS EN ISO 14000 series of environmental standards includes the BS EN ISO 14020 family of standards, which specifically cover environmental labelling. Principles of environmental labelling are set out in BS EN ISO 14020, and three types of labelling schemes are introduced:

a) type I is a multi-attribute label developed by a third party and verified by external parties. Type I labels are developed to conform to BS EN ISO 14024, which provides guidance on developing programmes that verify the environmental attributes of a product;

b) type II is a single-attribute label developed by the producer. These environmental claims are made about goods and services and are not independently verified. These declarations conform to BS EN ISO 14021, which describes terms and definitions for self-declared environmental claims;

c) type III is a label based on a full life-cycle assessment (LCA). These declarations are verified by an independent expert. The declarations should conform to BS EN ISO 14025 (see **4.4** for further details).

4.2 Type I declarations: Environmental labelling

BS EN ISO 14024 sets out the principles and procedures for establishing Type I environmental declarations for organizations developing certification and labelling schemes. Type I declarations are based on multiple pre-determined environmental performance criteria against which products can be evaluated. The assessment criteria are set by an independent body with input from a range of stakeholders, and advisory and expert committees. The criteria are defined as "a set of quantitative and qualitative technical requirements that the applicant, product or product category shall meet to be awarded an environmental label". The claims can range from broader criteria such as "natural", "organic/organic certified" and "lower environmental impact", to narrower criteria such as bio-based content and compostability. Product manufacturers can self-declare compliance and/or verify it through external parties who possess the appropriate competence.

Some of the labels are used only for particular product categories and set the requirements that take into account the specific product application or use. Such a label would be widely recognized within the particular industry, and could best meet the requirements of this industry for products with reduced environmental impact. Further information about these labels could be found via the relevant professional or trade association. Some of the labels have European applicability. The Global Ecolabelling Network (GEN) provides information on many of the programme operators and schemes compliant with and conforming to BS EN ISO 14024 (see www.globalecolabelling.net).

4.3 Type II declarations: Self-declared environmental claims

Type II environmental claims (or declarations) are made about products by their manufacturers, importers or distributors, based on a single attribute. They are not independently verified, do not use predetermined and accepted criteria for reference, and do not include as much information as types I and III labels.

These types of claims are often regulated by Government through consumer protection legislation. The general guidelines prohibit misleading, false and vague declarations, such as "sustainable", "environmentally friendly" or "nature's friend".

BS EN ISO 14021 sets out guidance on self-declared environmental claims (including the use of symbols), specific requirements for selected claims, and requirements for the evaluation and verification of claims. In the UK, BS EN ISO 14021 is recommended for use by the UK Code of Non-Broadcast Advertising, Sales Promotion and Direct Marketing (CAP code) and Code of Broadcast Advertising (BCAP), and by the UK Advertising Standards Authority. In the EU, EN ISO 14021 is recommended for use by the European Commission *Guidance for making and assessing environmental claims* [28].

BS EN ISO 14021 recommends conditions for using certain self-declared statements (such as recyclable, degradable, compostable, etc.), symbols and logos. It also describes a general evaluation and verification process for making or checking claims. BS EN ISO 14021 forms the basis of the UK Governments' *Code of practice on green claims* [29].

Self-declarations of environmental benefits offer the simplest type of declaration. However, such declarations are not made by an independent party and so can be problematic since there is a perceived conflict of interest. Self-declarations are often used in marketing campaigns as a tool for demonstrating competitive advantage. In other cases, Type II declarations are developed by industry to counteract "green washing" within a particular industry and aim to develop a preliminary benchmark before any specific standards that are developed covering their product types.

4.4 Type III declarations: Life cycle assessment

4.4.1 General

Type III environmental declarations present quantified information about the life cycle of a product, which enable manufacturers or end users to make direct comparisons between products fulfilling the same function.

Such declarations are:

a) based on independently verified life cycle assessment (LCA) data, life cycle inventory analysis (LCI) data or information modules in accordance with the BS EN ISO 14040 series of standards and, where relevant, additional environmental information;

b) developed using predetermined parameters; and

c) subject to the administration of a programme operator, such as a company or a group of companies, industrial sector or trade association, public authorities or agencies, or an independent scientific body or other organization.

Type III environmental declarations as described in BS EN ISO 14025 are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication is not precluded.

Unlike type I labels, they do not judge products, but enable consumers to make their own choice. The output report is known as an environmental product declaration (EPD). EPDs are constituted in accordance with sets of standard product category rules and utilize the same scope of data and metrics for each functional use category. EPDs developed by organizations are subject to major stakeholder review processes and then published in the public domain by country-based registrars.

EPDs allow consistency within an industry and enable comparison of products. They are the most rigorous form of environmental declaration because of the PCR process, the use of LCA to BS EN ISO 14040 and independent verification to BS EN ISO 14025.

4.4.2 What is a life cycle assessment?

Life cycle assessment (or LCA) is an environmental impact auditing method detailing the energy requirements, carbon footprint, waste and useful co-product output that a particular product or process has. LCAs provide a way of benchmarking and comparing the environmental credentials that products have. LCAs may encompass a number of stages in the lifetime of a product, but a clear definition of the system boundaries (stages included in the study) and standards used (e.g. the BS EN ISO 14040 series) is required to ensure comparisons between products are valid. Common terms used in LCAs include "cradle-to-gate" or "cradle-to-grave".

Life cycle assessment usually focuses on the environmental impacts of a process, such as the production, use, reuse and end-of-life of a product. LCAs are performed to assess the environmental impact of a process fully and to highlight where there is an opportunity for improvement in reducing a product's environmental impact.

For bio-based products, LCAs offer an opportunity to highlight the environmental credentials of a product. The use of renewable materials, carbon capture, recyclability and compostability can all be included in an LCA.

An LCA can be carried out for the whole process or a part of a process. Because of this, the scope of an LCA can vary. LCA relevance depends on the "boundary conditions", which define the calculation basis for different types of products.

The variance in scope of LCAs and differences in the measurement and weighting of different factors can render comparison of two different products problematic. To minimize such variability in LCAs and so enable direct comparisons, data used for LCAs need to be compiled to obtain a relevant calculation base. Reference datasets such as the International Reference Life Cycle Data System (ILCD) [30] and the European Reference Life Cycle Database (ELCD) [31] provide important methodology and guidance, which allow harmonization of LCAs. This not only allows direct comparisons of processes but also decreases the costs of carrying out LCAs since information already collected can be available for different LCAs.

The ILCD covers a set of technical guidance documents, supporting tools and documents, data sets, and other resources in support of good practice in LCA. The ILCD supports the implementation of a number of policies, decision support systems and voluntary private initiatives, such as European Sustainable Consumption and Production Policies [32], EU Ecolabel [33], the Waste Framework Directive [24], the Eco-design of Energy-using Products Directive (EuP) [34], Green Public and Procurement (GPP) activities and guidance [35], Environmental Product Declaration (EPD) schemes, carbon footprint calculations and declarations, the Eco-innovation Action Plan (EcoAP) [36], and Environmental Technology Verification (ETV) [37].

The ELCD also looks at the quality, consistency and applicability of the data. Both databases are based on the criteria set out in BS EN ISO 14040 and BS EN ISO 14044.

For bio-based products these databases can ensure consistency across LCAs. They allow comparisons of bio-based products to be made with non-bio-based alternatives, which can highlight any environmental advantages.

Currently, there is a lack of harmonized LCA methodologies for bio-based products that meet the essential requirements of relevant legislation, since different methodologies produce different results. For the construction industry, there is now BS EN 15804, a consistent LCA methodology, expressed as core product category rules for construction product – this will allow the comparability of EPDs produced using BS EN 15804 within building level assessment across Europe.

EPDs enable comparison of products based on the sets of standard product category rules and peer-reviewed LCA data developed based on the BS EN ISO 14040 methodology. The construction products regulations 2011 (CPR) [38] propose the use of EPDs, where available, for the assessment of the sustainable use of resources and the impact of construction works on the environment.

4.4.3 Relevant standards for LCA

4.4.3.1 BS EN ISO 14025 for environmental declarations in business-to-business communication

BS EN ISO 14025 establishes the principles and specifies the procedures for developing type III environmental declarations. It specifically establishes the use of the BS EN ISO 14040 series of standards in the development of type III environmental declarations. Type III environmental declarations as described in BS EN ISO 14025 are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication under certain conditions is not precluded. BS EN ISO 14025 enables comparisons between products fulfilling the same function. This standard does not include sector-specific provisions, which are dealt with in other ISO documents. BS EN ISO 14025 forms a basis when developing labels and certification schemes and is not specific for bio-based products.

4.4.3.2 BS EN ISO 14040 and BS EN ISO 14044 principles and framework for LCAs

BS EN ISO 14040 and BS EN ISO14044 are part of the BS EN ISO 14000 family of standards that deals with environmental management, but have no specific provisions for bio-based products. These two standards describe the principles and framework for LCAs and cover all ranges of LCAs for all different systems. However, they do not specify methodologies or LCA techniques.

BS EN ISO 14040 describes the principles and framework for LCA while BS EN ISO 14044 specifies requirements and provides guidelines. Both standards include the definition of the goal and scope of the LCA, LCI phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements.

PD ISO/TR 14047, and PD ISO/TR 14049 provide examples of how to apply BS EN ISO 14044 to various stages of an LCA.

4.4.3.3 BS EN 15804 EPDs for construction products

BS EN 15804 is part of a suite of standards that consider the sustainability of construction. It provides the core product category rules for construction product EPDs, allowing for LCA data to be provided in a consistent manner for all construction products, and uses the information module approach over the full life cycle, and allows product level data to be combined to provide scenario-based cradle-to-grave building level assessments.

CEN TCs, such as TC 88 for Insulation, are now in the process of drafting product category rules based on BS EN 15804, which would cover bio-based insulation material.

4.4.3.4 BS EN ISO 14064 for greenhouse gas emissions

BS EN ISO 14064 provides governments, businesses, regions and other organizations with an integrated set of tools for programmes aimed at measuring, quantifying and reducing greenhouse gas emissions. The three parts of this standard allow organizations to take part in emissions trading schemes using an internationally recognized standard. The three parts comprising BS EN ISO 14064 are:

a) Part 1: quantification and reporting of greenhouse gas emissions and removals at organization level;

b) Part 2: guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements;

c) Part 3: validation and verification of greenhouse gas assertions.

4.4.3.5 BS ISO 14067 requirements and guidance for LCAs, under development

BS ISO 14067 is under development. The standard will provide much more specific guidance than the underlying BS EN ISO 14044. BS ISO 14067 calls for specific product category rules, including not only the specifications of BS EN ISO 14025 for type III environmental declarations, but also other sector-specific standards or internationally agreed guidance documents related to materials and product categories. The standard will offer a range of communication options, including carbon footprint declarations, labels, reporting and performance tracking. The requirements on verification and the need for specific product category rules are partly dependent upon whether the communication is business-to-business or business-to-consumer.

4.4.3.6 PAS 2050 greenhouse gas emissions in product life cycle

PAS 2050 provides a method for assessing the life cycle greenhouse gas (GHG) emissions of goods and services. The PAS 2050 LCA covers either GHG emissions of the whole life cycle of a product (business-to-consumer) or the life cycle of a product up to the point where it forms an input to a second business (business-to-business). PAS 2050 also incorporates an assessment of GHGs released by direct land use change related to agricultural feedstock production. PAS 2050 has been formulated for communication purposes and to allow the comparison of GHG emissions between products. However, PAS 2050 does not require communication of results, though it does allow reporting of GHG emissions of supply chains to stakeholders and consumers as part of company CSR commitments.

PAS 2050 is a tool that can help organizations to:

a) carry out internal assessment of the existing life cycle GHG emissions of products to identify “hotspots” and related cost/energy saving opportunities;

b) evaluate alternative product configurations, sourcing and manufacturing methods, raw material choices and supplier selection;

c) devise ongoing programmes aimed at reducing GHG emissions;

d) report on corporate responsibility.

PAS 2050 is the only standard that takes into account the ability of a product to sequester carbon (i.e. to be a "carbon sink"). This standard looks at the impact of greenhouse gas emissions and does not take into account any other environmental impacts and so cannot be used solely to describe the full life cycle impact of a product.

An accompanying guide to PAS 2050 [39] describes how to carbon footprint products, identify hotspots and reduce emissions in your supply chain.

4.4.3.7 Standards relevant for life cycle assessment of packaging

There is significant potential for use of bio-based products in the packaging industry. In addition, for many products, packaging should be included in the LCAs. The technical report PD CEN/TR 13910 describes criteria and LCA methodologies for packaging. The report uses BS EN ISO 14040's criteria to set best practice guidelines. This includes material extraction, manufacture of packaging, service performed to the packaged product (e.g. reducing damage in transportation, reducing product waste), post-use collection and recovery or disposal. The report includes comments on what should be included within the scope of packaging, how the product influences the packaging and how the packaging can influence the product. PD CEN/TR 13910 gives guidance on the use of life cycle inventory analysis, impact assessment, and interpretation in the case of packaging (BS EN ISO 14044). However, no specific provision for bio-based products is made in this report.

In addition to PD CEN/TR 13910, PD 6607 (CR12340) contains recommendations on conducting life cycle inventory analysis of packaging systems.

5 Future standards and guides within the EU

5.1 General

The EU has set mandates through the European Committee for Standardization (CEN) for technical reports and standards for bio-based products to assist in the development of this industry. CEN collaborate with standards bodies throughout the EU to create these documents. In addition to general standards for bio-based products, CEN is developing standards in the areas of bio-lubricants, bio-polymers, bio-surfactants and bio-solvents.

The major driver for policies underpinning the development of the bio-based products market was the Lead Market Initiative (LMI) [40]. The LMI, launched in 2008, is an innovation policy initiative where European member states, companies, NGOs, public organizations, other stakeholders, and the European Commission work together to reduce time-to-market of new products and services.

Under the LMI, specific goals and activities were prioritised covering legislation and regulatory measurements, public procurement, development of more consistent standardization, labelling standardization and certification, and supporting actions including business and innovation support services or financial support instruments for supply side activities [14].

As a result of the LMI, the EU Government issued four mandates related to the development of standards for bio-based products:

a) M/429 for a standardization programme for bio-based products [41];

b) M/430 on bio-polymers and bio-lubricants [42];

c) M/491 on bio-solvents and bio-surfactants [43];

d) M/492 for the development of horizontal standards for bio-based products [44].

5.2 Standardization work carried out by CEN/TC 411

Following the acceptance by CEN of M/491 and M/492, a new CEN technical committee, CEN/TC 411 "Bio-based products", was created.

The priorities for CEN/TC 411 are:

a) development of standards concerning terminology, methods, criteria, guidance and tools, applicable to bio-based products, taking into account (but not necessary limiting to) the CEN/BT/WG 209 report *Bio-based products*;

b) accelerating the development of the European market for bio-based products by developing a consistent terminology for bio-based products;

c) development of standards for aspects including sampling, bio-based content, application of LCA, sustainability criteria for biomass;

d) developing certification scheme(s) for bio-based products, identifying which characteristics can/should be assessed and how they should be reported.

Under this TC, five working groups have been established to undertake specific activities set out by the mandates M/491 and M/492:

1) WG1, "Terminology";
2) WG2, "Biosolvents";
3) WG3, "Bio-based Content";
4) WG4, "Sustainability and LCA";
5) WG5, "Certification and Declaration Tools".

It is anticipated that the standards development work will take five years to complete and aims to be completed in 2016.

5.3 Mandate for the development of standards for bio-lubricants and bio-based lubricants

Within the framework of mandate M/430, technical committees CEN/TC 19, "Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin", and CEN/TC 249, "Plastics", are developing standards on bio-lubricants and bio-polymers.

CEN/TR 16227 provides information on bio-lubricants and gives recommendations on the terminology used around bio-lubricants and bio-based lubricants. It also makes recommendations for future standards. These standards relate not only to the bio-based content of the lubricants, but also to the biodegradability of the product and its performance. The report recommends that an international standard should be developed specifically for bio-lubricants. Since some lubricants, in the course of their use, are exposed to the environment, the report recommends that use of the prefix "bio-" should be limited to those lubricants not only having a bio-based content of 25% or more but also following biodegradability EN standards for oils and greases.

5.4 Mandate M/491 for bio-surfactants and bio-solvents

Mandate M/491 for bio-surfactants and bio-solvents [43] calls for the development of a European standard for bio-surfactants and bio-solvents that will take into account biodegradability, product functionality, greenhouse gas emissions and renewable raw material content and/or bio-based content used during manufacturing. It will also take make provision for potential specific technical performance and descriptive standards for bio-based products as well as related measurement, testing and LCA procedures needed to prove specially required technical performance criteria. The standards are scheduled to be available by 2014, and progress can be monitored via the CEN website [45], under the work of committee CEN/TC 411. The work on bio-surfactants was allocated to the technical committee for surface active agents (CEN/TC 276).

CEN/TC 411 will carry out the work requested by mandate M/491 on bio-solvents, under WG2 (see **5.2**).

5.5 Development of UK standardization for bio-based products

In the UK, BSI is the national standards body (NSB) representing UK economic and social interests across all European and international standards organizations. The standardization work in the area of bio-based products is undertaken by the BSI committee MI/2, Bio-based Products, which is working under the guidance of the committee MI/1, Materials Industries.

MI/2 is mirroring work of the CEN/BT/WG 209, Bio-based products, which is developing standards concerning terminology, methods, criteria, guidance and tools, applicable to bio-based products. MI/2 is leading the UK's contribution to the European work programme and the UK strategy for standards in support of bio-based products, including the development of domestic standards. MI/2 is represented by a wide range of stakeholders, including industry, policy, academia and government.

5.6 EU Environmental Technology Verification

EU Environmental Technology Verification (ETV) is a new tool to help innovative environmental technologies reach the market. The ETV pilot programme was launched in 2011 by the European Commission. It validates the performance claims put forward by technology manufacturers, on a voluntary basis, by qualified third parties. This should help manufacturers prove the reliability of their claims, and help technology purchasers identify innovations that suit their needs.

The ETV pilot programme aims to cover three technology fields:

a) water treatment and monitoring;

b) energy technologies;

c) materials, waste and resources.

The ETV pilot programme is to be implemented by verification bodies specifically accredited for this purpose by national accreditation bodies, such as UKAS, in the member states. Verification bodies act, effectively, as a one-stop-shop for companies using ETV.

By issuing a statement of verification, which is the product of a successful ETV process, ETV provides information on the new technology, such as actual performance of the verified technology as well as the results of the tests performed. With proof of performance independently assured, along with information about the design of the tests, innovations can expect a larger market share.

6 Legislation and regulation

6.1 General

Currently there is no specific legislation in the UK (or the EU) to support bio-based products. As a result, there is a lack of tax incentives or other supporting regulations. In response to the LMI, the Ad-hoc Advisory Group for Bio-based Products has developed a series of recommendations to stimulate market uptake and development, which are yet to be implemented. These recommendations encourage the development of legislation promoting market development of bio-based products (such as setting indicative or binding targets for bio-based content in products), legislation that would enable renewable raw materials for industrial use to be available in sufficient quantity of good and guaranteed quality and at competitive price, and enabling the development of infrastructures and logistics for an optimal use of all available biomass (including waste).

A number of European policies can benefit bio-based products directly or indirectly, such as

a) Common Agricultural Policy (CAP), which is due for revision in 2013 [46], has an impact on availability and price of feedstock and also for industrial (non-food) use;

b) European strategy for the development of key enabling technologies (KETs), where industrial biotechnology is one of the six technologies being selected by the European Commission as a KET;

c) European legislation on waste, such as EU Directive 2008/98/EC on waste [24], which establishes a legal framework for the treatment of waste and enforces waste prevention, reuse, recycling and other recovery, notably energy recovery;

d) legislation concerning packaging waste (EU Directive 2005/20/EC, 94/62/EC [47]);

e) European regulation on chemicals and especially regulatory framework for the management of chemicals (REACH), under which naturally occurring substances are exempted from REACH registration when the following two criteria are fulfilled: "a substance that occurs in nature" [according to the definition in Article 3(39)] and "not chemically modified" [according to the definition in Article 3(40)] [48];

f) European legislation on energy, such as EU Renewable Energy Directive 2009/28/EC [49], that sets mandatory targets for proportion of energy from renewable resources.

In addition, Europe 2020 strategy [8] for smart, sustainable and inclusive growth is a policy framework that sets out ambitious economic, social and environmental goals which need to be achieved by 2020. The strategy recognizes that tackling the climate and energy challenge contributes to the creation of jobs, the generation of "green" growth and a strengthening of Europe's competitiveness. Under the strategy, sustainable growth means efficient, sustainable use of resources, developing new green technologies and production methods and helping consumers make well-informed choices.

Specific EU targets [7] for sustainable growth include:

1) reducing greenhouse gas emissions by 20% compared to 1990 levels by 2020;

2) increasing the share of renewables in final energy consumption to 20%;

3) moving towards a 20% increase in energy efficiency.

The EU "20-20-20" targets support the development of markets for bio-based products, alongside those for renewable energies.

The UK Government supports the EU 2020 Strategy by encouraging investment in low carbon power, supporting infrastructure development, promoting the development of new markets in green goods and services and capping the costs of policies funded through energy bills.

6.2 Climate Change Act and carbon reduction commitments

In the UK, the Climate Change Act 2008 [50] establishes a long-term framework to tackle climate change. The Act aims to encourage the transition to a low-carbon economy in the UK through unilateral, legally binding emissions reduction targets.

This means a reduction of at least 34% in GHG emissions by 2020 and at least 80% by 2050.

UK Low Carbon Transition Plan [51], published in 2009, presents a strategy for how the targets for cutting down GHG emissions by 2020, set out by the Climate Change Act, will be met. The Plan shows how reductions in the power sector and heavy industry; transport; homes and communities; workplaces and jobs; and farming, land and waste sectors could enable carbon budgets to be met.

The UK Government *Plan for growth* [52] and *Carbon plan* [53] underpin the EU 2020 Strategy by focusing efforts on encouraging investment in low carbon power, supporting infrastructure development, promoting the development of new markets in green goods and services, and capping the costs of policies funded through energy bills.

6.3 Waste Framework Directive

6.3.1 General

Waste Framework Directive (WFD) (2008/98/EC) [24] is the primary European legislation for the management of waste. It provides the overarching legislative framework for the collection, transport, recovery and disposal of waste and is implemented in the UK through the waste regulations 2011 [54]. The aim of the revised WFD is to promote waste prevention, increase recycling and ensure better use of resources, while protecting human health and the environment. The waste hierarchy is designed to encourage reduction and reuse as a priority over recycling, energy from waste, and other forms of energy and materials recovery.

Under the WFD, packaging and packaging waste regulations as well as landfill regulations are the most relevant for bio-based products.

6.3.2 Packaging and Packaging Waste Directive

In Europe Packaging and Packaging Waste Directive (96/62/EC, amended by 2004/12/EC) [25] encourages the reduction of packaging, as well as recovery and recycling of materials. In the UK the 94/62/EC Packaging Directive is implemented through the Packaging (Essential Requirements) Regulations 2003 [55] and the Producer Responsibility Obligations (Packaging Waste) Regulations 2005 [56]. Companies falling under this regulation can demonstrate their compliance by presenting Packaging (waste) Recovery Notes (PRNs) or Packaging (waste) Export Recovery Notes (PERNs). The use of recyclable bio-plastics will help earn PRN or PERN certificates for companies that meet their recycling targets.

6.3.3 European Landfill Directive and landfill tax

The European Landfill Directive (1999/31/EC) [57], among other objectives, aims to reduce biodegradable municipal waste in landfill. Bio-based products can be recycled, composted (industrially or home composted), or used for energy recovery (for example via anaerobic digestion, gasification or pyrolysis), whereby positively contributing to the reduction of landfilled waste.

Landfill tax (LAX) was introduced in 1996 and is an important financial factor in waste disposal to landfill. The standard rate is currently (2013) pitched at £72 per tonne and set to increase to £80 per tonne in 2014 (after which time it will not fall below £80 per tonne). Importantly, LAX can provide an indirect driver for bio-based products since they can be composted or recycled and, therefore, do not incur the extra LAX charge upon disposal (see Annex A, Case Study 2).

6.3.4 EU Renewable Energy Directive

Biorefinery concept makes a link between bio-based products and biofuels, whereby one feedstock (a crop or a microorganism) can be used for production of both, the materials and the energy. Co-products of biofuels are often utilized for making bio-based materials and vice versa. Therefore, regulations supporting energy from renewable resources indirectly also support bio-based materials.

EU Renewable Energy Directive 2009/28/EC [49] sets a mandatory target of 20% share of energy consumption from renewable sources by 2020 (15% in the UK) and a mandatory 10% minimum target to be achieved by all member states for the share of transport fuels.

Delivering 15% renewable energy by 2020 is feasible with the following proportion of energy consumption in each sector coming from renewables:

a) 30% of electricity demand, including 2% from small-scale sources;

b) 2% of heat demand;

c) 10% of transport demand.

6.3.5 Product-specific regulations

Regulations supporting the market for bio-based products exist within some industries, such as construction industry, which can have a high environmental impact. In order to improve environmental performance of buildings, the "embodied carbon" of building materials is considered, such as in the *BRE green guide* [58]. Bio-based products might generally have lower embodied carbon and their use in buildings could improve their rating. Other examples of highly regulated industries where bio-based products can offer advantage are the paints industry with regulations concerning the volatile organic compounds (VOC) or forestry where use of bio-lubricants in the machinery working in the forest is mandatory.

Annex A (informative) Case studies

A.1 Case study 1: Bio-based lubricants

Bio-based lubricants can offer a valuable alternative to non-bio-based products in environmentally-sensitive industrial applications where the risk of disposal via water and soil is high, such as in agricultural machinery or machines used in close proximity to water. Bio-based lubricants are used in these applications because they are non-toxic and can biodegrade, creating a smaller disturbance to the ecosystem.

They are generally derived from vegetable oils. By PD CEN/TR 16227 definition, bio-based lubricants should have a high content of renewable raw materials (at least 25%), high biodegradation rates (60% for oils or 50% for greases), and not carry a "dangerous to the environment" label.

Bio-based lubricants are also used by bicycle owners. Use of bio-lubricants can also positively contribute to the overall environmental profile of an operator or a land owner, which is especially important for organizations that directly work with, or for, the public.

Although bio-lubricants have a number of drawbacks and can be more expensive, vegetable oil-derived bio-lubricants have some useful physical properties, such as higher lubricity and thus a much lower coefficient of friction when compared to petrochemically based lubricants. Bio-based lubricants typically have high flash points, which makes them effective in high temperature environments to minimize evaporation or dissipation. In addition, they have relatively stable viscosity indexes, so that they are useful over a large range of temperatures.

A.2 Case study 2: Compostable catering products

Several UK companies use bio-polymers to produce compostable catering products such as disposables and food service packaging. These companies have developed new formulations of compostable bio-polymers that combine compostability with high performance characteristics, such as high-heat resistance. Careful product design makes these products compostable and conform to BS EN 13432 and ASTM D6400.

Compostable disposables can contribute significantly to the reduction of waste sent to landfill from public institutions and events (such as festivals), etc. by diverting waste from an unrecyclable waste-stream to organic waste recycling through composting or anaerobic digestion.

Compostable disposables enable food service operators to dispose of food together with compostable packaging and containers via a single waste stream, with no need for waste segregation. For busy catering outlets, this results in a more simplified waste management process, along with financial savings as the waste would no longer be liable for landfill tax (in 2012, food waste recycling was over £40 less expensive than landfilling per tonne of waste).

Exclusive use of compostable disposables also benefits waste management operators, since they would not need to segregate waste coming from their food operator customers, so saving time and resources.

For example, in a large hospital's catering department, the use of a full range of compostable disposables led to a 50% reduction in waste going to landfill and enabled the hospital to meet the NHS carbon reduction targets. The switch to compostable serviceware was cost neutral for the hospital.

The number of schemes offering the collection of food waste and facilities that can treat it is growing. The main method of treatment is in-vessel composting. Many of these facilities permit compostable disposables. As the result, the number of food service operators disposing of their waste via such facilities is growing.

A.3 Case study 3: Bio-based insulation

The built environment accounts for 40–50% of natural resource use, 20% of water use, 30 – 40% of energy use and around a third of CO_2 emissions. The Climate Change Act 2008 [50] sets a target to reduce to greenhouse gas emissions in the UK by at least 80% from 1990 levels by 2050. According to the UK Government's "zero carbon" policy, all non-domestic buildings, such as schools and offices, need to be "zero carbon" from 2019.

Ways to reduce the carbon footprint of buildings can be achieved by making buildings more energy efficient, reducing the amount of "embodied carbon" materials used in the original building constructions and by recycling materials at the end of a building's life. Studies show that an average low energy new house made with conventional materials contains the equivalent of 50t CO_2 as embodied carbon. This could be significantly reduced with greater use of renewable bio-based materials [59].

Examples of bio-based materials in construction include thatch, cob (a mixture of clay and straw), flax, hemp and straw bale. Renewable materials offer low embodied carbon properties as the emissions from manufacturing and construction are partially offset by the sequestered carbon dioxide from the atmosphere. Increased use of insulation materials could mean increased amount of embodied carbon. Therefore, insulation made from bio-based materials is an attractive solution. Some bio-based insulation offers additional benefits, such as breathability and moisture buffering. Insulation can be made from renewable sources such as cellulose, cork, wood fibre, hemp, flax and sheep wool. These materials have lower embodied carbon than some of the traditional insulation materials such as fibreglass, cellulose, polystyrene and rock wool.

A.4 Case study 4: Biocomposites for automotive parts

The UK automotive industry is a vital part of the UK economy and typically generates more than £55 billion in annual turnover, delivering around £12 billion in net value. It generated £27 billion of revenue for the UK in 2011, which accounted for around 11% of total UK exports. The UK has several car manufacturers and more than 100 specialist brands. Around 2 350 component manufacturers, ranging from large companies competing globally to small and medium-sized businesses (SMEs) are actively involved in the UK supply chain.

UK automotive industry is at the forefront of the low carbon agenda, investing in R&D and new technologies. An example of this is the reduction of an average new car's CO_2 emissions to a new low of 133.1g/km in 2012, which is a 20% reduction in the last ten years. The five strategic technologies identified by the industry are [60]:

a) energy storage and management;

b) electric motors and power electronics;

c) internal combustion engines;

d) lightweight vehicle and powertrain structures; and

e) intelligent mobility.

Bio-based materials can offer significant opportunities for achieving some of these goals. The main applications here are natural fibre-reinforced plastics (NFRP) and wood plastic composites (WPC). These are composites that are typically filled or reinforced with plant fibres and wood flour respectively, as well as plastics such as polypropylene (PP), polyethylene (PE) or recently, even bio-based plastics. NFRP and WPC are used in a large variety of products and applications, including the automotive industry. Natural fibres that find use in NFRP include bagasse, cellulose, cotton, flax, hemp, jute, and sisal. Use of 100% bio-based resins together with natural fibres can provide a fully bio-based composite material.

The main application for NFRP in the automotive industry is in compression moulding with natural fibre-reinforced thermosets, which can be used as door and floor panels, or as dash boards, and insertions in non-structural components. Between 7kg and 30kg of natural fibre composite material can be used in a single vehicle.

The main advantages of using natural fibres in automotive industry include:

a) lower environmental impact (neutral in terms of CO_2 emissions, renewable);

b) specific mechanical properties (high tensile strength and low density, thus contributing to the light weighting of structures);

c) price stability for the raw material supply;

d) lower energy costs for the production compared with glass fibres.

The disadvantages of using natural fibres and their composites are their poor impact properties, inferior flame retardancy compared to glass fibre or other synthetic fibre systems, biodegradability of fibres and odour formation. However, it is possible to address these drawbacks, for example by modifying the fibre surface, coating or adding into the matrix agents that provide significant performance improvement. This is an active area of research and development. The knowledge gained through automotive industry applications can enable use of natural fibres in other applications, including marine and aerospace industries.

Natural fibre suppliers have recognized the emergence of this market for their materials, and are now starting to supply the automotive industry. For example, with the decline in the use of flax in textiles, and the general decline of textile industry in Europe for the last ten years, flax is being now supplied to make materials for the automobile industry.

There are several UK companies developing and manufacturing natural fibre composite materials for a wide range of uses. The main innovations include new chemical and enzymatic fibre treatments to improve the natural fibre-matrix interface, new treatment of the fibres and yarns to obtain optimum performance, new technical textile production methods with innovative fibre alignment, adaptation of production techniques to improve impregnation and improved compatibility with bio-based resins, and improvements of processing methods including vacuum consolidation, vacuum infusion, resin transfer moulding, compression moulding and continuous compression moulding, as well as development of joining and coating techniques.

Currently, the automotive industry is unwilling to pay a premium for products that have better green credentials or environmental claims. Therefore products made from natural fibre need to have other advantages when compared to non-bio-based alternatives to compete in the market. For example, flax biocomposites can deliver high strength while being lightweight, which is a very important property for automotive applications.

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