Open-Bio

Opening bio-based markets via standards, labelling and procurement

Work package 1

Project Management

Deliverable N° 1.2:

Publishable final report

Public

Version: 1

Delft, 16 January 2017
prepared by:

NEN

Ortwin Costenoble

Netherlands Standardization Institute
NEN Energy Resources
Vlinderweg 6, 2623 AX Delft, the Netherlands
Tel.: +31 (15) 2690 326
Fax: +31 (15) 2690 207
Email: energy@nen.nl
Partner website : www.nen.nl
Project website : www.open-bio.eu

Table of contents

1 Summary

The Open-Bio project aims at increasing the uptake speed of standards, certification systems, labels and data sheets for bio-based products. Public acceptance of bio-based products is increased through ensuring, verifying and visualizing the sustainable sourcing of raw materials, the effective bio-content, the end-of-life options and clear indication of their (comparative) functionality in relation to the regular products. These positive effects will indirectly result in faster growth of the bio-based product industry and increased share of bio-based in the total use of final (consumer) products and intermediates. The Open-bio project promotes these positive effects by facilitating the development and optimization of standards, (ecological) labels and product information databases.

This Seventh Framework Programme project commenced in November 2013. It is partially a follow-up on a pending pre-normative project (KBBPPS), which had initiated the development of standardised methods to test bio-based products for various properties. The current project took these proposed standards forward and elaborated a number of new ones, considering aspects as diverse as the determination of the total bio-based content of a product, its likely biodegradation in sea water, its compostability and the extent to which it can be recycled. Standardised methods help manufacturers to substantiate their claims about the bio-based content and related properties of their products. Several of those proposed by the two successive projects have been submitted to the European Committee for Standardization (CEN) and the International Standardization Organisation (ISO). Four have been adopted, and several more are being finalised in cooperation with these bodies.

In addition to that, it is important that all properties and applications are clearly communicated to the users of bio-based products. Open-Bio has established guidelines for ecological labelling of and for the product information supplied together with bio-based products. A socio-economical investigation towards bio-based products acceptance in six EU Member States complements the work. In the end, the result is intended to lead to standards and policy rules at European level.

2 Objectives and basic concepts

2.1 General objectives

The project aims at increasing the uptake speed of standards, certification systems, labels and data sheets for bio-based products. The application of these by a large number of players in the European bio-based product industry has positive long-term effects on the overall development of bio-based product markets. Trade barriers are reduced and the development of a pan-European market for bio-based products is promoted. Higher quality, recognition and sustainability of bio-based products increase the satisfaction of end-users at all levels and the economic viability of bio-based products' utilisation, e.g. through increased awareness of the life cycle advantages. Finally, public acceptance of bio-based products is increased through ensuring, verifying and visualizing the sustainable sourcing of raw materials, the effective bio-content, the end-of-life options and clear indication of their (comparative) functionality in relation to the regular products. These positive effects will indirectly result in faster growth of the bio-based product industry and increased share of bio-based in the total use of final (consumer) products and intermediates up to 2020 and beyond. The proposed programme will promote these positive effects by facilitating the development and improvement of standards, labels, product information lists and their related certification systems.

The specific objectives of the project are:

1) Development of a standard test method and test data for completion into a generally applicable European Standard for bio-based content measurement in bio-based products.
2) Development of a complete set of standard test methodologies for mechanical, chemical, thermal and other functionalities of the major bio-based products, i.e. bio-polymers, -lubricants, -surfactants, and –solvents.
3) Development of standard test methods, including validation data, for the testing of the biodegradability of bio-based products in soil, fresh water and marine environments.
4) Development of draft horizontal test method standards, including validation, for centralized composting, for home and farm composting and for biogasification of bio-based products.
5) Define further improvements of the Ecolabel criteria as to make them compatible with bio-based product criteria in accordance with the developed standards on functionality and sustainability criteria.
6) Development of the adequate interaction tool for business-to-business and business-to-consumer information exchange.

2.2 Partners and advisors

The following partners worked in Open-Bio (with their abbreviations and country of origin indicated as well):

1. Netherlands Standardization Institute (NEN, NL)
2. Stichting Energieonderzoek Centrum Nederland (ECN, NL)
3. Green Chemistry Centre of Excellence at the University of York (UoY, UK)
4. nova-Institut GmbH (NOVA, DE)
5. Organic Waste Systems (OWS, BE)

6. Stichting Dienst Landbouwkundig Onderzoek, Wageningen UR (DLO)[1]
7. Agricultural University of Athens (AUA, GR)
8. Biomass Technology Group (BTG, NL)
9. Fachagentur Nachwachsende Rohstoffe (FNR, DE)
10. Centre National de la Recherche Scientifique, Institute of Analytical Science. Central Analysis Service (ISA, FR)
11. Technische Universität Berlin, Chair for Innovation Economics (TUB, DE)
12. HYDRA Institut für Meereswissenschaften (Hydra, DE)
13. Novamont S.p.A. (Novamont, IT)
14. LeAF BV (LEAF, NL)

In addition the following organizations acted as advisory partners and participated in discussion, investigations, research and workshops: Beta Analytics Inc. (US), EuropaBio (BE), Scion research Institute (NZ), Prof R. Narayan from Michigan State University (US), European Bioplastics (BE), Pôle de compétitivité à vocation mondiale Industries & Agro-Ressources (IAR-POLE, FR) and BASF (DE).

2.3 Bio-based content and sustainability

Methods to directly determine the biological content of bio-based products are complemented with indirect determinations. In additions definitions for the circular economy have been prepared and assessed. Also whether and how sustainability of the products itself and its feedstock can be determined and implemented (via a certification scheme) is part of the work.

A further exercise was to check whether isotopes of elements other than carbon could be used to check for biological origin. Multi isotopic investigations have been applied in various scopes: bio-plastics, bio-rubbers, biofuels, bio-solvents, bio-surfactants, etc. A wide range of components from raw-materials, to semi-finished product and commercial components have been taken into account, and the isotopic data were collected and evaluated. On the whole, the variation of the botanical origins and the overlap among biomass and non-biomass isotopic values are significant drawbacks for the development of isotopic method to be used as biobased automation method. Investigations show that isotopic values can be connected to the origins of biomass. These measurements might be relevant a criteria for sustainable or economic issues. They can then be used to check a claim on the sourcing of the biomass.

Other bio-based content determinations or the use of methods in combination with other processes, like renewability and other sustainability aspects, were studied without becoming a standard. For linking the content with sustainability, definitions for renewable elements and molecules (as components of bio-based products) were laid down. This to assist the Open-Bio consortium when preparing sustainability criteria for the indirect assessments of bio-based products, were laid down. A single overarching definition of renewability was not seen as appropriate for use horizontally across all bio-based products and chemical articles in general. This approach is helpful when considering the life cycle of an article, because the

[1] This partner had a change of name in 2016 into Wageningen Research. For consistency reasons in the deliverables of the project this is not reflected in this report.

complete article will not necessarily remain whole as its constituent parts are recirculated. Biodegradation is an example of this.

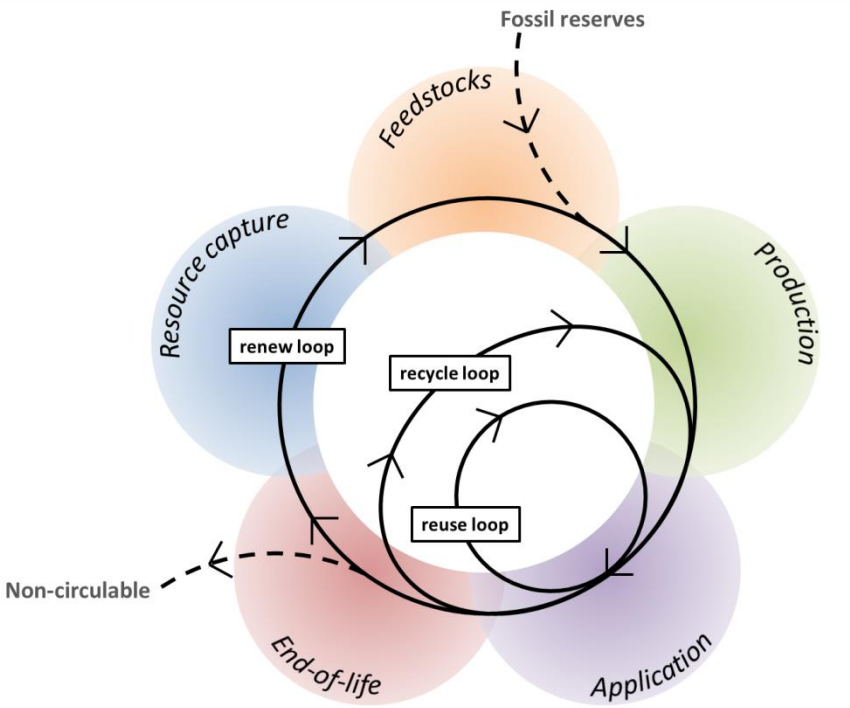


Figure 1 – The terms and concepts defined and their internal relationships

An indirect method for the assessment of bio-based product recirculation has been studied. The test method has been developed to improve the design features of bio-based products so that they are made of the most appropriate renewable feedstocks, and are easily and effectively treated at end-of-life. The test method is constructed in such a way to make it complimentary to standardisation on-going in CEN/TC 411. Future standardisation committees in the area of eco-design and resource efficiency may also find the results of this work helpful.

2.4 Bio-based product functionality

Here the project had to focus due to the variety of bio-based products and the limitation of test methods available to the partners. The earlier investigation under KBBPPS has delivered a limited set of possible horizontal test procedures, so through the advisory workshop and partners, a selection needed to be made. Some advices towards ISO and CEN came forward but the amount of available test specimen – and the fact that only a couple of partner labs could assess procedure updates - limited the conclusions. The standardization community now needs to discuss the suggestions and check feasibility of revisions.

Work on standardised methods for the testing of bio-based products will continue in a follow-on project started in September 2016. Instead of focusing on the specificities of the final product, this project, named Star4BBI, will look into various steps in the production of bio-based goods. The aim is to examine any regulatory or standardisation issues that might be an obstacle to successful commercialisation.

2.5 Bio-based product biodegradability

Work consisted on further progressing draft standards developed in KBBPPS concerning biodegradability of products in (surface) fresh water and soil. The testing schemes for biodegradation in soil and freshwater developed by Open-Bio address a broad range of bio-based products including solids (e.g. plastics) and liquids (e.g. lubricants) and represent so-called “horizontal” testing methods. The validity of the optimised test methods for measuring biodegradation of plastics in soil and freshwater was investigated by inter-laboratory tests conducted by three partners. Some specific work on lubricants was executed under CEN. Besides the performed work on biodegradation in soil and freshwater, additional work was performed on environmental safety of biodegradation residuals of polymers. This on request of CEN. The toxicity test with higher plants and the toxicity test with earthworms were found suitable for the evaluation of toxicity of biodegradation residuals of polymers.

The second part concerned the development of new methods for testing biodegradation in the marine environment. Here three environments were defined and testing methodologies developed. The three years of the project however appeared to be too short to draw sufficient comparison conclusions as the degradation in marine environment is a long and difficult to control process. Three lab tests and a couple of (semi) field test procedures are developed and the results reported to ISO. The three interconnected test schemes provide a toolset to assess the biodegradation and disintegration of bio-based and other materials in an environmentally relevant manner under marine conditions. The field tests for all three habitats were technically developed to a stage that they can be now universally applied, and evaluated in a RR test, and finally approved to become a standardised set of methods. Some aspects still need further development and investigation. However, ISO and ASTM have already taken some of the Open-Bio work forward.

2.6 Bio-based product compostability, digestibility and recyclability

Already initiated investigations for degradability are completed by tests supplying other comparison factors; the level at which a product degrades in seawater, is compostable (also through home-composting in your own garden) or can be digested to biogas in an industrial installation. These 'end-of-life applications’ are important in order to compare bio-based products (also in terms of sustainability) and develop applicable policies.

Draft standard specifications for products suitable for home composting and anaerobic digestion were prepared. Moreover, a test methodology for the simultaneous evaluation of the disintegration and the biodegradation of test materials under anaerobic conditions was prepared and a list with improvements for the current standards for industrial compostable products. Furthermore, two test methods related to chemical recycling were prepared. The developed test methods and standard specifications can be used as starting point for the development of a European standard specification.

2.7 Bio-based product labelling and certification

In Open-Bio looked into ways of presenting key qualities to the consumer. The objective was to assess the suitability of ecolabel criteria for bio-based products, or in other words, to find

out whether the existing criteria of ecolabels can be applied to bio-based products, whether there are conflicts of harmonization and whether additional criteria can or have to be added in order to adequately label bio-based products. During the research it quickly became clear that the research agenda of developing a combined “bio-based and ecolabel” as set out in the description of work was not possible to do in a general form, but rather required the work on several exemplary cases. This is both due to the structure of a multi-issue label that considers different environmental impacts and requirements per product group and also due to the complexity of the group of “bio-based products”. From intermediates and building blocks to complex end products, covering all kinds of materials from wood over plastics to lubricants, solvents, surfactants and others, it is impossible to create one ecolabel for all of them.

The consortium concluded that yes, indeed, it was possible to design the criteria of a multi-issue ecolabel in a way that they give credit to the advantages of bio-based products and provide them in an advantage. It was decided not to design a completely new label, but to suggest changes to the existing EU Ecolabel. The EU’s Ecolabel system could be refined to additionally convey information about the bio-based content and related aspects. The conclusion was that the criteria would have to differ for individual categories of products, as it would be difficult to define a set of requirements that is relevant to all. The project has developed a manageable, user-friendly approach.

From a more strategic point of view, however, it is indeed possible to phrase some general reasons why bio-based products should be given preference also from an environmental perspective. First of all, there is already a lot of information showing that many single bio-based materials perform better than their conventional counterparts e.g. in terms of GHG emissions, toxicity or end of life options. And this is despite the fact that most bio-based solutions are much younger than their conventional (fossil) counterparts and consequently have a lot of development potential to improve their performance. Second of all, renewability of resources in itself is an advantage that is not included in the recognized catalogue of environmental impacts of the LCA methodology. Several other aspects relevant to bio-based products are not included in current LCA methodology, either, which is why the researchers suggest to allow for some flexibility in reasoning when developing labelling criteria, too. The EU Ecolabel requires LCA evidence that bio-based products perform better than comparable conventional products in order to promote them. It is possible to provide this evidence in some cases, but not in all. However, the researchers argue that while LCA evidence is important, it is also not the be-all and end-all to evaluate environmental impacts, and there are overarching environmental reasons to promote bio-based products.

2.8 Bio-based product information for all markets

Open-Bio developed a database designed to support public procurement decisions. This application, which was trialled internally within the project and externally with several companies producing and procuring biobased products, enables manufacturers to list the properties and qualities of their products for consideration by potential public sector customers. It will be developed more fully in InnProBio, a new Horizon2020 coordination and support project launched in March 2015.

The Open-Bio project aimed to formulate a strategy for the development of a European label for bio-based products. Such a label represents a potential vehicle for promoting the market uptake of bio-based products by consumers, businesses as well as in public procurement. To ensure the effectiveness of measures that support the demand of bio-based products, work package 9 of the Open-Bio project on “Social Acceptance” was tasked with the identification of key criteria for the acceptance of bio-based products and related standards and information systems, including labelling options for bio-based products.

Figure 2 – The consortium partners at a project meeting in Berlin

3 Work executed and results achieved

3.1 Bio-based content determination and sustainability impacts

3.1.1 Bio-based (carbon) content determination

Execution of round robin assessments and definition of performance characteristics for bio-based carbon content and total bio-based content, as well as evaluation of applicable techniques for the determination of bio-based content were performed in order to obtain full standards.

The bio-based carbon content determination was introduced and described in CEN/TS 16640. In order to investigate the influence of parameters which may vary between individual laboratories and to determine the performance characteristics of the method, a round robin assessment was organised as part of the project. The assessment involved 11 independent laboratories to whom in total 132 samples were delivered (11 equivalent sets of samples, 12 samples each set). Since the requirement was that the method described in CEN/TS 16640 shall be applicable to any products, the selection of samples for the round robin tests was done to cover as much as possible different and challenging products.

Based on the performed validation of the method during the round robin testing, it was recommended to set 1,5% as the overall absolute standard deviation for the bio-based carbon content determination The final draft is accepted and the EN 16640 will be published at the beginning of 2017.

Having approved the procedure for bio-based carbon content determination, the next question of having a horizontal standard for total bio-based content was addressed. Total bio-based content is not restricted only to the bio-based carbon content and can involve contribution from bio-based oxygen and/or hydrogen and/or nitrogen. For the determination of total bio-based content of a product, the knowledge of all its constituents that derived from biomass, are needed. However, in practice the claimed values can be over- or underestimated. Therefore a separate procedure for the validation of the bio-based content was proposed by the draft standard prEN 16785.

A round robin assessment devoted to the validation of the bio-based content of various samples that was stated by the producers of these samples. Validation of stated total bio-based content of several various products was the ultimate goal of initiated round robin assessment. The assessment involved 11 independent laboratories to whom in total 66 samples were delivered (11 equivalent sets of samples, 6 samples each set). Together with the samples, the so-called statements were provided by samples suppliers. Every statement included information about composition of a given sample, its bio-based carbon content and its total bio-based content. The information mentioned in the statements was checked by the measurements by each of participating laboratories. Then the stated values were validated or not, depending how big was the difference between stated and measured value for each of involved parameters. The results were carefully analysed and resulted in a number of im-

provement to the initial version of EN 16785-1. Correspondingly, a number of suggestions and recommendations were included in EN 16785-1 that became the official European standard in December 2015.

3.1.2 Isotopes

Next to the procedure described in EN 16785-1 (that is based on the radiocarbon analysis), a possibility to use stable isotope analysis for the determination of total bio-based content is also considered. Multi isotopic investigations have been applied in various scopes: bio-plastics, bio-rubbers, biofuels and bio-solvents, bio-surfactants, etc. A wide range of components from raw-materials, to semi-finished product and commercial components have been taken into ac-count, and the isotopic data were collected and evaluated. On the whole, the variation of the botanical origins and the overlap among biomass and non-biomass isotopic values are significant drawbacks for the development of isotopic method to be used as biobased automation method. However our study presents interesting starting points for determination purposes when some conditions are fulfilled. In all cases isotopic databases must be monitored and regularly updated with the knowledge of isotopic limits. These data are necessary to furnish the better uncertainty given to the biobased content assessment.

There is also another methodology which can be used to check products on production lines. When the raw-materials incorporated in an industrial process are always the same and isotopic values of every component and amount of components well known, the biobased content of the final product can be directly connected to isotopic values. This approach permits the manufacturers to check the biobased content. In this case no database needs to be monitored.

Investigations also show that isotopic values can be connected to the (botanical) origins of biomass. These measurements might be relevant a criteria for sustainable or economic issues. They can then be used to check a claim on the sourcing of the biomass. The complete possibilities with respect to the use of stable isotopes, e.g. sustainability aspects like origin, are described and became starting point for a Technical Report under CEN/TC 411. Other possibilities to be considered are the material balance method and the possible use of other radio-active isotopes, especially tritium.

3.1.3 Sustainability

An attempt to produce definitions for renewable elements and molecules (as components of bio-based products), was undertaken. The purpose of these definitions is to assist the Open-Bio consortium when preparing sustainability criteria for the indirect assessments of bio-based products. Definitions were prepared and proposed to bio-based product stakeholders as part of a consortium led workshop, as well as to members to the Green Chemistry Centre of Excellence (University of York, UK), Open-BIO advisory partners, and delegates at the 7th International Conference on Bio-Based Materials. After these discussions it was decided to generate a family of definitions addressing specific aspects of the recirculation of elements and molecules as they are returned to use. A single overarching definition of renewability was not seen as appropriate for use horizontally across all bio-based products and chemical articles in general.

This approach is helpful when considering the life cycle of an article, because the complete article will not necessarily remain whole as its constituent parts are recirculated. Biodegradation is an example of this.

Recirculated. Returned to use within a certain timeframe by an anthropogenic process and/or a natural process. Any element that is not returned to use is considered in an 'uncontrolled' framework. Recirculated includes the terms renewable, reusable and recyclable.

Renewable. Comes from renewable resources and is returned to use within a certain timeframe by a natural process.

Recyclable. Returned to use within a certain timeframe by an anthropogenic process. Reusable.

An indirect method for the assessment of bio-based product recirculation has been developed has been developed to improve the design features of bio-based products; so that they are made of the most appropriate renewable feedstocks, and are easily and effectively treated at end-of-life. This has the potential to lessen the environmental impact of plastics and other chemical products, building materials etc. Requirements are established as clauses, adapted from over 30 standards. These are complimented with original clauses that help establish the concept of recirculation in the design phase of a bio-based product. The test method is constructed in such a way to make it complimentary to standardisation on-going in CEN/TC 411. Future standardisation committees in the area of eco-design and resource efficiency may also find the results of this work helpful. Alternatively, the format of the design requirements lends itself to development into a certification scheme for bio-based products, or a series of recommendations that might form a reference document on Best Available Techniques (BAT) for material eco-design.

3.1.4 Sustainability

The definitions as presented before are used to generate sustainability criteria (in terms of components and used elements/molecules) for bio-based products. General use of these definitions is also encouraged when describing the renewability of bio-based products, including bio-plastics, bio-lubricants, bio-based solvents and bio-based surfactants.

The sustainability of the production of biomass is not different whether the biomass is produced for energy, fuels or bio-based products. It will strongly depend on the type of biomass. Because all processes are related to LCAs and the use of LCAs is not exactly defined (what should and what must be incorporated), it is still not exactly clear what should be used and what shouldn't be used. However, a report has been drafted that gives a thorough introduction in all possibilities and is the starting point for discussions. Both the owners of sustainability schemes and the other parties involved should be aware that the incorporation of bio-based content in a sustainability scheme is only a starting point.

3.2 Functionality testing

3.2.1 General

The aim of this work package is to carry out a series of tests on commercial bio-based products and develop test data related to functionalities. Work is a follow-up on the KBBPPS result to check functionality tests for the products of major importance. Focus is on special functionalities of bio-based products and test methodologies are developed for these. One report delivered describes the selection of specific products within these product categories and outlines the most important properties that determine the functionality of the product with respect to mechanical testing, chemical and thermal testing and additional functionalities. A next deliverable reports the results of testing and includes recommendations. For each of the selected product categories the key properties were defined in a way that they ensure the functionality of the product in the specific application and during the entire lifetime.
The aim was to select 5 to 7 product categories and to test 1 or 2 products for each categories. Fossil based references were added for each category. A broad variety of test have been performed (mechanical, thermal, chemical, etc.) and the most important findings (highlights) for each product category are listed below.

3.2.2 Packaging films

Main recommendation is to add properties at frozen conditions and very wet conditions to the MDS (material data sheet) since the properties of most bio-based films deteriorate under these conditions. Another addition could be the CO_2 transmission rate values as this is a critical property for Modified Atmosphere packaging of food products. Reproducibility of Elmendorf tear propagation and the WVTR (water vapour transmission rate) between two labs appeared to be poor. Information of the applicability of the test method and further working instructions are recommended.

3.2.3 Disposable cups and plates

Main hurdle is that there are no standards to proof the functionality of a disposable cup that could be referred to when new products are marketed. Therefore evaluation was done by using adaptations of standards developed either for paper and board or for plastics. The different testing conditions after use (coffee, and several times pouring hot water) show that cups can deal with high temperature liquids, the functionality of the coating in paperboard based cups is sufficient to reuse the cup up to three times. An adopted method to determine leakage of seals reveals that all cups show some leakage at the seals including the traditional PE coated cup.

Figure 3 - Leakage at the seals for the different coated cups, from left to right: PLA coated, Ecovio coated and PE coated cups.

3.2.4 WPC-decking

Wood-plastic composite decking replaces solid wood in outdoor applications and testing is directed towards properties where WPC decking behaves differently from solid wood. There is a harmonized European standard for WPC-decking (EN 15534) and various properties listed in this standard were studied in detail. It is recommended to use more demanding conditions both for testing high temperature creep (longer creep periods and higher loads) and low temperature impact (increase dropping height). More over an approach to develop a cleanability test method has been drafted.

3.2.5 Mulching films

The biodegradable mulch films are susceptible for ageing resulting in a decrease of mechanical properties. This may not hinder the functionality in the application but still it is recommended to include a section on the artificial weathering exposure of bio-based films also in the draft European standard prEN 17033. Moreover, it is advised to measure the relative light transmission over the whole visible spectrum (380-780 nm) and not over the only a portion of the visible radiation spectrum like suggested by prEN 17033.

3.2.6 Adhesives and binders.

A bio-based paint and a traditional oil based paint with the same colour and for the same application were tested for mechanical and physical properties. A general observation is that most tests require very specific (and expensive) test set-ups. In most of the tests the bio-based paint results are comparable to the oil-based paint. Scrub tests show that bio-based paint has good adhesion to the glass plate and scrubs less than the oil-based paint.

3.2.7 Solvents

For bio-based solvents that aim to replace existent, well known petro-based solvents, a set of characteristics to determine its functionality can be crucial in its successful introduction in the market. As a start Hansen solubility parameters can be helpful to use as a first guide on applicability (also part of the just accepted EN 16766 standard). There are several ways of characterizing thermal properties of solvents. TGA curves give a first impression on the volatility of the solvents and the temperatures of complete and 50% evaporation. This is certainly a valuable method that is highly accessible for most laboratories.

3.2.8 Pre-manufactured components/isolation

Work on the product category was limited to a desk study because of the complexity of the material. The advantages of biofibre based insulation mats cannot be marketed effectively due to standard test methods which are not based on practically most relevant testing conditions. It is proposed that the testing method specifies analysis of the thermal conductivity performance of insulation materials at typical winter conditions, and at typical summer conditions using direct measurements (rather than calculations). The advantageous sound insulation properties could be demonstrated by testing of sound absorption at different frequencies according to EAD 040005-00-12.01. Just analysing the insulation material alone (not in a construction) will give a good first indication of its performance.

3.3 In situ biodegradation

3.3.1 Horizontal testing schemes for biodegradation in soil and freshwater

This part of the work was aiming to extend the testing methods for the biodegradation of lubricants in soil and freshwater which were developed in the framework of the previous KBBPPS project to testing methods also suitable for plastics. Additionally, inter-laboratory tests were organized among the project participants in order to collect data for confirming the reproducibility and the validity of the proposed testing methods. The testing schemes for biodegradation in soil and freshwater developed by Open-Bio address a broad range of bio-based products including solids (e.g. plastics) and liquids (e.g. lubricants) and represent so-called “horizontal” testing methods for soil and freshwater (i.e. are they are valid for all categories of materials). The development of the methods simplifies the standardisation framework and the certification processes and concern both bio-based and fossil-based materials.

The soil biodegradation test methodology used in the Open-Bio inter-laboratory test was based on carbon dioxide production in closed flask bioreactors, even though oxygen consumption methods and continuously aerated systems are also suitable. Provisions for improving the reproducibility of the test results were developed. In particular refinements with respect to sample quantity, addition of nutrients, and selection of soil, which improved the quality of the measurements.

Two methodologies were used for the biodegradation test in freshwater, both based on combining the best of existing ISO, CEN, ASTM2 and OECD3 standards. The tests were further developed in Open-Bio with some improvements in order to increase the repeatability of the test methodologies: e.g. only one inoculum source is allowed instead of several inoculum sources. In the test methodology based on oxygen consumption an extra option is added to determine simultaneously the carbon dioxide production by measuring the carbon dioxide captured in the absorbent as a kind of double-check.

The results of the inter-laboratory tests showed that the reproducibility of the testing methods was satisfactory both for soil and freshwater. Regarding biodegradation in soil all participating laboratories found comparable biodegradation rates for the four test materials despite the

[2] American Society for Testing and Materials
[3] Organisation for Economic Cooperation and Development

different inocula used, namely natural soils of various compositions and origin. Similarly, no substantial differences or abnormal behaviour were observed in the freshwater inter-laboratory tests. For the major part of the performed tests no substantial overproduction of carbon dioxide was observed.

Besides the performed work on biodegradation in soil and freshwater, additional work was performed on environmental safety of biodegradation residuals of polymers (obtained after a biodegradation phase in soil) on request of CEN/TC 249. An additional deliverable was written that contains the results of (1) biodegradation tests in soil on the different polymers, (2) a disintegration test in soil on the different polymers and (3) toxicity tests with plants, earthworms and micro-organisms on the biodegradation residuals of the polymers.

All draft test methods and improvement steps for the soil biodegradation, fresh water tests and the eco-toxicity in soil have been shared with CEN and ISO groups. Advices on the correct limits to be specified have also been shared. Apart from adoption by the bio-lubricants experts in EN 16807, published in 2016, discussions on taking the results forward in horizontal test methods under CEN/TC 444 or specifically for plastics in ISO/TC 61 are still not yet concluded.

3.3.2 Marine biodegradation

The second section of work concerned the development of new methods for testing biodegradation in the marine environment. First a review of current methods and standards relevant to marine degradation was prepared. This review started with a short analysis of the environmental threat due to the accumulation of large quantities of plastic waste in the seas. The task to find a compromise between the need to transfer a complex ecological system as the ocean into a small bottle, i.e. a standardised easy-to-use small-volume laboratory test, and at the same time keep the test environmentally relevant was critically assessed. Currently, seven test methods for the biodegradation in the marine environment are available: one from OECD, three from ISO and three from ASTM. No European test method has been developed so far. The available biodegradation tests for polymers in the marine environment were limited, too specific and poorly standardised.

As compared to freshwater, soil and compost conditions, the marine environment is considered less aggressive from an aerobic biodegradation point of view because the density of microorganisms in seawater is relatively low. The conclusive recommendation of the review was to develop a three-scale test scheme (lab, mesocosm, field) (figure 1) covering relevant habitats and conditions of the marine environment, starting with three representative shallow-water habitats.

Laboratory methodologies and dedicated testing schemes for marine biodegradation of plastics were developed for three distinct marine environments: eulittoral (beach scenario: intertidal sandy sediment), sublittoral resp. benthic (seafloor scenario: interface sandy sediment/seawater), and pelagic (seawater scenario: shallow-water nearshore water column). Five laboratories carried out the biodegradation tests measuring the CO_2 production or the O_2 consumption using seawater and sediment coming from Salamis Island (Greece) and Elba Island (Italy). The tests were repeated for two consecutive years.

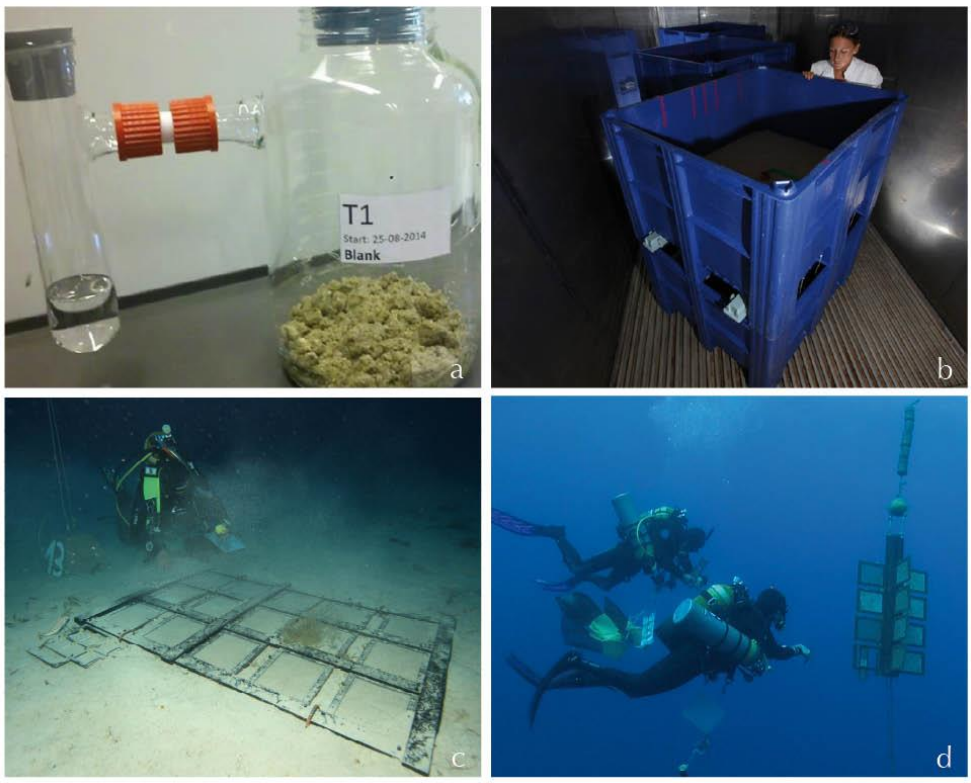


Figure 4 - (a) The lab test system. (b) The mesocosm test system with all three habitats (eulittoral, benthic, pelagic). (c) The field tests system with benthic samples (sublittoral seafloor scenario). (d) The field tests system with pelagic samples.

The sublittoral method was characterized, in some laboratories, as giving not clear and confusing results due to CO2 overproduction. Progress was made during these two years to improve this test method with respect to reproducibility and biodegradation rate, but the test methodology still needs further improvement. Regarding the eulittoral method fewer refinements are needed. The main problem observed was attributed to the low biodegradation rate. The use of powdered test samples in combination with additional nutrients appeared to result in a higher biodegradation rate, but this also needs to be further investigated. The pelagic test method also was promising as similar biodegradation trends were obtained in both years. The final versions of the three test methods were reported and can be submitted to the relevant standardization bodies.

A stand-alone *mescocosm test* was developed to assess the degradation of polymers under partially controlled marine conditions, and to link the lab tests to the field tests. A closed-circuit tank system, independent from the access to the ocean, which mimicked the same three shallow-water habitats as in the laboratory tests, was placed in a climate chamber where light, temperature, water movement, tides and water quality could be controlled.

The disintegration of polymer samples was estimated by the determination of lost area % over time. To assess the polymer degradation independently from eventual fragmentation analytical methods were also applied to assess polymer disintegration on a macromolecular level, but the results obtained showed that these methods were not suitable. Further research was recommended to find a suitable measuring method. The relatively slow disinte-

gration which was observed in the mesocosm test at the applied temperature of 21 °C resulted in a long test duration of at least one year. Slight modifications of the conditions within the natural range, e.g. higher temperatures or the addition of nutrients could accelerate the disintegration and render the tests more practical.

Field tests were used to validate the environmental relevance of existing test conditions for lab and mesocosm tests, and to verify that lab and mesocosm results reflect the natural performance of the materials. The same four materials as studied in the lab and mescocosm situation were tested in the same three habitats at two locations operated by the partners: Salamis Island (Greece) and Elba Island (Italy). Various physical-chemical properties and the composition of the matrices, seawater and sediment were measured.

Degradation of the polymers in the sea (measured as disintegration) was found to be variable, but generally did happen in all experiments at both locations. However, in some experiments the degradation was too slow to be measured as disintegration. The variable degradation rates in different habitats and locations were attributed to the environmental conditions such as the differences in nutrients, the assumed abundance of microorganisms, and also to seasonal and yearly climatic variations. Another cause of the variability of the results was seen in the natural variations of the biological settings in the respective habitat. Bio-fouling[4] was observed and assumed to play a crucial role in the degradation. A tentative experiment towards the role of organismal growth on the polymers has been conducted at the Greek test location. This work indicated that processes linked to fouling are rather complex and worthwhile to be studied in order to better understand biodegradation in marine conditions. Moreover, this knowledge will be useful to compare field observations with results from standardised laboratory and mescocosm experiments, where fouling is usually low or negligible.

In conclusion, inherent biodegradability of materials can be demonstrated using laboratory tests. There was no clear effect of sampling location or sampling time of the natural inocula sediment and seawater on the biodegradation rates. The three lab test and the mescocosm test developed by the consortium are technically ready to be evaluated in a round robin test, in order to agree upon a standardised test system. Initial reproducibility is still found to be rather low. The field tests for all three habitats were technically developed to a stage that they can be now universally applied, and evaluated in a RR test, and finally approved to become a standardised set of methods. The three interconnected test schemes provide a toolset to assess the biodegradation and disintegration of bio-based and other materials in an environmentally relevant manner under marine conditions. The tests allow verifying the claim of marine biodegradability as an inherent material property and thus will lead to better information for producers, procurers, consumers and policy makers.

[4] Every surface exposed to the marine environment will be colonised by micro- and macro-organisms, and eventually covered with a biofilm

3.4 Managed end-of-life options

3.4.1 General approach

The main research questions of this work were “Which managed end-of-life options are suitable for bio-based products?” and “Is it necessary to develop additional test methods and/or standard specifications to stimulate the acceptance of bio-based products in the investigated managed end-of-life options?”. The focus of the research of this work package was on three possible recycling options: (1) mechanical recycling, (2) chemical recycling and (3) organic recycling. Organic recycling was subdivided into (1) centralized (= industrial) composting, (2) decentralized (= home and farm) composting and (3) anaerobic digestion.

The work was initiated with an extensive literature study reviewing the practices, test methods, standard specifications and existing labelling schemes for each of the recycling options. It was checked what would be a could test concept and it was checked whether modifications are required for bio-based products.

3.4.2 Mechanical and chemical recycling

Mechanical recycling of plastics involves the recovery of plastic waste through mechanical processes (separating, grinding, washing, drying, re-granulating and compounding) to produce recyclates that can be converted into new products. An important focus within the mechanical recycling studies is recycling of post-consumer recyclates since bio-based plastics are used in packaging of (food) products and these will be disposed of by consumers. The mechanical recycling of post-consumer plastic packaging waste is challenging and the various factors and processing steps that determine quality of post-consumer recyclates were addressed within the Open-Bio project.

From these tests is was concluded that:

- Bio-based materials can be sorted via NIR and flotation;
- No negative effect were seen in the common washing, grinding drying procedure;
- Similar recycling processes can be used (PLA vs. PET);
- Bio-based materials have similar effects like other “impurities” that are currently found in post-consumer recyclates.

With respect to methods to evaluate the mechanical recycling of bio-based plastics it is needed to study this on a product level and allow a fair comparison. This is possible by adding bio-based materials to actual sorted post-consumer plastics. Studies on reprocessing of aged bio-based materials indicate ageing has a negative effect on recyclability. However, it is not clear how these materials would end-up in actual mechanical recycling schemes and whether ageing effects are still measurable when adding these aged films to actual post-consumer sorted film products were effect will be diluted.

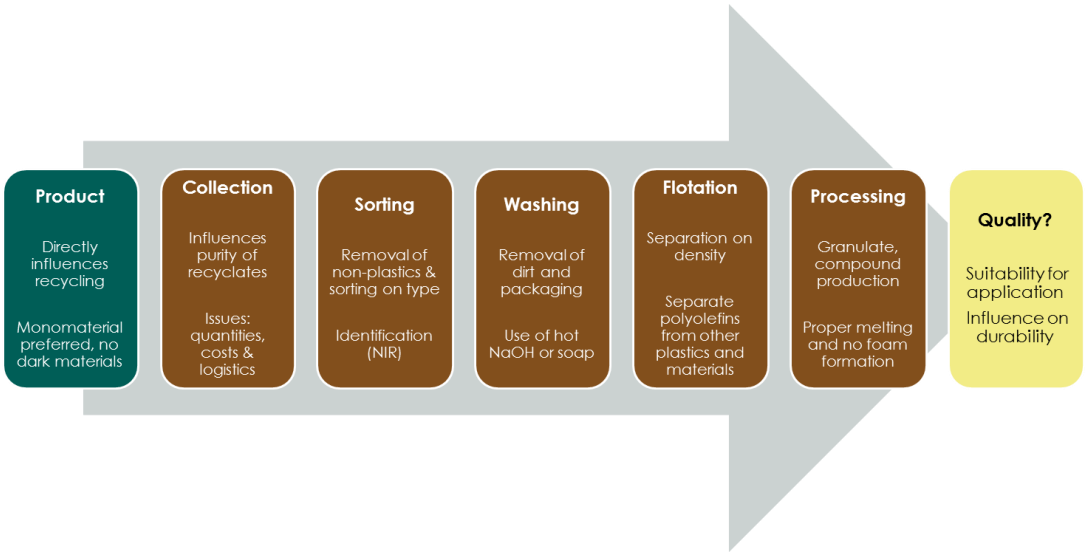


Figure 5 - The various factors and processing steps in the mechanical recycling of (post-consumer) plastics

As another part of the consortium effort, the technical suitability of chemical recycling for bio-based plastics is evaluated. Moreover, also acceptance criteria for recyclates and recycled products are defined and the role of chemical recycling alongside more established waste management practices is explained. An extensive desk study describing the state-of-the-art, as well as experimental results and recommendations on the future application of chemical recycling was laid down in a report. Furthermore, the basics of chemical recycling were explained, and different processes classified as chemical recycling introduced and discussed in terms of feasibility. The characterisation of plastic waste relevant to chemical recycling is briefly presented in the same report, considering classification (type of polymer, origin, sector, recycling shape) and composition. Different examples of chemical recycling of bio-based (PLA, PHA, cellulose acetate esters, PET, PE) and petroleum-based (PC, PA, PU, PS, ABS, PVC) plastics have been collated from published academic studies and patents.

In follow=up experiments, commercial products have been chemically recycled, including mixed wastes, blended materials of different polymers, and plastic retrieved from anaerobic digesters. This represents a clear advance over previously reported chemical recycling practices that only address model systems or pure product streams. The application of chemical recycling is (at present) severely limited by the availability of suitable wastes of appropriate polymers. Given the low amounts of chemically recyclable plastics currently in circulation, alternative applications for chemical recycling are proposed this work, such as the processing of contamination removed from anaerobic digesters, and the removal of contamination in mechanical recycling streams (PLA in a mixture with PET). These integrated approaches to waste management indicate a certain amount of flexibility regarding the implementation of the waste hierarchy might actually present an overall environmental benefit.

Two draft standards are developed: (1) Method of chemically recycling PLA and acceptance criteria and (2) Method of quantitatively analysing plastic waste for chemically recyclable content. These can be used to determine how much of a waste can be chemically recycled, and then provide a specification for the chemical recyclate.

3.4.3 Composting

A proposal was developed in order to improve the European standard specifications for industrial compostable products (EN 13432 and EN 14995). The proposal includes adaptations in order to align the European standards with the recently revised international standards for compostable products (ISO 18606 (2013) and ISO 17088 (2012)) and also a proposal for the inclusion of an amendment related to disintegration. That amendment was prepared because compostable products are often not allowed in industrial composting plants due to the fact that the duration of the disintegration test in the standard specifications (e.g. 12 weeks) is sometimes longer than the duration of the composting phase in reality. This amendment was validated for different polymers. From these validation tests, it can be concluded that the suggested amendment is valid for the major part of the performed tests.

Home composting is a way to convert vegetable, garden and fruit waste (VGF) to compost in small scale installations that are generally located in the backyard. Several types of home composting systems exist with varying dimensions (vermicomposting systems, plastic composting bins, large holding units, rotating composters, composting heaps, etc.). Moreover, it can be concluded that standard specifications for home compostable products only exist at national level. To ensure that the term home compostable (bio-based) product is unambiguously defined, this issue needs to be harmonized at higher levels of formal standardization (e.g. at European level).

In a second phase of the work on decentralised composting, a draft standard specification with requirements for home compostable plastics was developed based on the principles of the existing national standard specifications and labelling schemes. Moreover, also some experimental work was performed in order to investigate if existing test methods to evaluate compostability under industrial conditions can be modified in order to use them to simulate home composting conditions. In a third and last phase of the work on decentralised composting, the laboratory disintegration test methodology was validated by means of a real life validation test. From the comparison between the laboratory tests and the field tests, it can be concluded that materials that were characterised by sufficient disintegration in the laboratory tests were in the majority of the field tests also characterised by sufficient disintegration. It is important to highlight that home composting is a process hard to standardize and if not properly followed could lead to different problems: waste not transformed in compost, smells, insects and if present only partial or poor degradation of home compostable biodegradable materials. For this reason this practice must be done with care and defined: well managed home composting.

3.4.4 Biogasification

Anaerobic digestion (AD) is an accepted technology for the treatment of solid wastes and the generation of energy from biomass and organic residues. Wet mesophilic and dry (both thermophilic and mesophilic) single stage systems are currently most widely used for digestion of solid waste. The review of the available standard specifications and test methods, demonstrated that a specification with requirements for bio-based materials that may end up in a biogasification plant is not available on international, European, American or national

level. Therefore, a draft test method is developed in order to determine the biodegradation and the disintegration of a sample under anaerobic (thermophilic or mesophilic) conditions possibly followed by a post-composting stabilisation based (based on laboratory research) and a draft standard specification with criteria for product suitable for anaerobic digestion systems is developed.

The combined biodegradation and disintegration test methodology was further validated by means of laboratory testing on several types of polymers and on a final product. Based on the performed tests, the standard specification was further refined and improved. The goal of this standard specification is the improvement of the communication between producers of bio-based products and biogasification installations. A difference between biodegradation under anaerobic dry and wet conditions was not clearly observed and therefore no distinction was made between these test conditions although it should be emphasised that wet anaerobic digestion installations might be negatively influenced by the addition of products like plastic bags due to possible problems with entanglement in pumps and rotating equipment.

The combined biodegradation-disintegration tests performed on several polymers in two different thicknesses and on a final product (a PLA coated paper cup) under mesophilic dry, thermophilic dry, mesophilic wet and thermophilic wet conditions demonstrated that biogasification can be a suitable managed end-of-life option with energy recuperation under the form of biogas for several bio-based products. The results of these tests also indicated that biodegradation results obtained in dry and wet systems are comparable as well as biodegradation under mesophilic and thermophilic conditions.

3.5 Labelling

Improved labelling and product communication was one of the recommendations of the LMI Ad Hoc Working Group on bio-based products in 2011. Open-Bio consequently dealt with the question how this could be implemented. From a general assessment of existing label structures (also building on work done in the KBBPPS project) and the possibilities to include bio-based products in them, over a selection of promising and challenging product groups to the development of product group specific recommendations and remarks on implementation. Communication and stakeholder involvement were instrumental in reaching the desired objectives.

The first objective of the consortium was to assess the suitability of ecolabel criteria for bio-based products, or in other words, to find out whether the existing criteria of ecolabels can be applied to bio-based products, whether there are conflicts of harmonization and whether additional criteria can or have to be added in order to adequately label bio-based products. In the following tasks, this research was the basis for conceptualizing the integration or adding-on of bio-based products to an ecolabel. This was done through a classic literature research on consumer attitudes and label influence on purchasing decisions, desktop research about the EU Ecolabel and overlap of existing product groups with bio-based products, expert interviews and stakeholder workshop.

The main conclusions from this task were:

- A label should combine bio-based aspects with environmental information in order to give value to consumers.
- The EU Ecolabel is a good vehicle for this. There is no need to create a new ecolabel. With third party verification of claims and a trusted issuing authority (the EU), the EU Ecolabel fulfils important criteria that are necessary for gaining consumer trust and creating an effective label.
- However, the requirements are different for different product groups, so implementation will be complex. There cannot be one general EU Ecolabel for all bio-based products. One of the most important outcomes of the project was not to design a completely new label, but to suggest changes to the existing EU Ecolabel.
- Concerning the criteria, it can be agreed that the bio-based content should be declared according to the corresponding European standard. This will be a criterion applicable to ALL bio-based products; however, not to all products within a Ecolabel product group containing both bio-based and fossil products. The minimum shares of bio-based content will be different from product group to product group.
- Criteria to be developed need to be quantifiable, pass / fail and also steerable, which means that they can be made stricter from revision to revision.
- A defined share of certified sustainable feedstock should be required for all bio-based products.
- Bio-based products can offer special end of life options such as biodegradability or compostability, which is often quoted as an important environmental advantage and an important product functionality. However, in the framework of developing an ecolabel, this is a controversial issue. Firstly, it does not make sense to include such requirements for all product groups, since many products should be durable and not degrade over time. Secondly, waste regulations are different from country to country, so a European label cannot inform consumers about their choices for disposal.

In the next task, researchers identified a dedicated set of product groups for which exemplary criteria catalogues were developed and discussed. Selection criteria for product groups to be chosen were that:

- Bio-based products (BBP) already have a significant market share in them,
- BBP offer advantages for the environmental impact categories,
- Complexities are foreseen due to the inclusion of both BBP and conventional materials, which will make it difficult to define minimum shares of bio-based feedstock,
- BBP offer quality advantages for the consumer (i.e. high quality natural fibres in textiles),
- Bio-based intermediates (e.g. pulp from cellulosic fibres or solvents) can play a role.

The bio-based products in the EU Ecolabel can be found either as raw materials, intermediates, or end products. Intermediates or process aids can be treated similarly to end products. The following bio-based end products that are already covered by the EU Ecolabel were chosen to be one focal point of the analysis:

- Plant-oil based paints and varnishes
- Rinse-off cosmetics with bio-based ingredients
- Absorbent hygiene products
- Detergents

It was not just the aim of the project to make suggestions to modify criteria of existing product groups, so there were also suggestions developed for new product groups in the EU Ecolabel if they were thought to be able to provide relevant opportunities for bio-based products and were considered relevant for end consumers. A first selection of such "new" categories for the EU Ecolabel could be:

- Mulching films & other plastic agricultural equipment (plant clips etc.)
- Disposables for food

Finally, there are several bio-based intermediates that can play a role for a range of end product groups, increasing the bio-based share and providing beneficial environmental and user properties. They were not treated as a separate category for a labelling catalogue. Instead, their potential as an intermediate for several end product categories was in the focus of future research. These three groups are:

- Wood-plastic composites (WPC)
- Cellulosic fibres
- Bio-based solvents

It was concluded that increasing the share of bio-based feedstocks in the EU Ecolabel criteria catalogues of all selected end product groups – possibly also through future increase of the usage of selected bio-based intermediates – could provide potential environmental benefits, due to bio-based properties such as reduced toxicity, sustainable sourcing of feedstock, reduced CO2 footprint during production and biodegradability, which avoids waste pollution at the end of product life.

The core part of the project was spent on developing product group specific recommendations on criteria development for the above mentioned product groups. They are presented in separate report and are too far reaching to be depicted here. For eight product groups, draft recommendations were developed which could be the basis for revision or development processes of criteria catalogues.

The last research work addresses more general issues: the overarching issues that are relevant for the inclusion of bio-based products in the EU Ecolabel and the quite practical topic of implementation and further exploitation. On the overarching issues for example it is concluded that there needs to be agreement on the reasons why we want to promote bio-based products.

A strategy for implementation of the combined eco- and bio-based label is developed. Several aspects play a role which are further elaborated on in this document, such as:

- Acceptance factors
    - Evidence of environmental advantages of bio-based products
    - Additional costs for producers

- Implementation strategy
  - Who is in charge?
  - Who is interested?
  - Further research needs and next steps

Solid LCA evidence is required that bio-based solutions are advantageous in terms of environmental impact in order for them to be promoted in the frame of the EU Ecolabel scheme. More research effort should be dedicated to fill the knowledge gaps on LCA and biodegradability. Strong commitment is needed from the industry if these initiatives were to be successful, as well as from policy makers at the governing bodies.

3.6 Product information

This work aimed at defining and developing an ideal European product information database and interaction tool on bio-based products to be used for public procurement (business-to-public or B2P) and bio-based producers (business-to-business or B2B). The database should also be used to promote their market uptake in consumer markets (business-to-consumer or B2C). Existing bio-based product databases and best practices in procurement and dissemination activities were mapped. This analysis served as orientation for the development of the database concept. It also showed that B2B websites focusing on bio-based products already exist on the European level while B2P services are, if any, only available on member state level.

Next, relevant target groups and their specific product information requirements were identified. Research was conducted in close cooperation with the Social Acceptance work, which focused on the same target groups. Results showed a general support for standardized product information among business and public procurement stakeholders. It also showed preferred product information items for both stakeholder groups. Research on the consumer information requirements showed that informing consumers requires another approach. Consumers first need to understand the term bio-based, they need to understand what it is about and what effects it has.

Based on the assessment, a concept for the database and interaction tool was developed. It reviewed what product information details shall be included in the bio-based products database and established general guidelines for setting-up and filling the product information database. The product database concept stressed the need to provide full transparency about product information and reference to standards or proving documentation whenever possible. The database included a bio-based glossary to provide general information on terminology and standards used. The concept was tested, validated and refined through a series of stakeholder consultation between March and June 2015. Means of consultation included webinars, workshops and phone interviews.

Consultation with public procurement officials showed that the bio-based share of a product is currently not considered relevant information for their procurement processes and product selection criteria in tender notices. What counts most are product functionality and performance. If this comes with a claim of using biomass as renewable feedstock, it is a ‘nice to

have' only. Therefore, the lack of information on bio-based content and bio-based carbon content on the product supplier site might not be seen as important gap in a product profile.

A database pilot version was developed. It presented product information according to the requirements of public procurement authorities and some additional information which supported procurers to conduct market orientation exercises as part of their procurement need assessment process. Each section included a text field to give information on certificates/labels/standards used to prove the specific claims. Furthermore the tools provided a glossary which listed basic definitions and terminology used to describe bio-based products. It also included information on relevant standards and test methods for bio-based products. All these coming from the other work packages of Open-Bio.

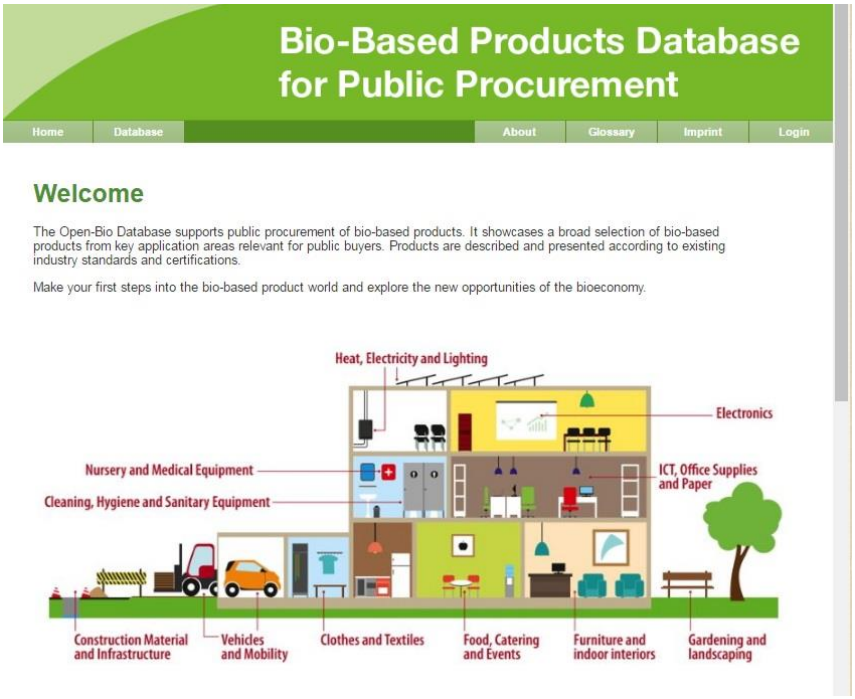


Figure 6 - Screenshot of the home page of the database

The database was filled with initial product information provided by end-product providing companies. The beta-version was described and testing was conducted. Stakeholders were consulted through phone interviews and e-mail communication. Comments and recommendations by public procurers and product suppliers showed that suppliers struggled with the requirement to provide information on the bio-based content and bio-based carbon content including the type of claim (i.e. self-claim or tested by independent third party) and method of verification. There seemed to be a lack of understanding regarding the differences and a lack of knowledge where and how to get the requested information. Since most of the suppliers were not involved in the production of the bio-based materials used in their end-products this caused considerable difficulties to fill the product information templates.

The issue of the bio-based content information requirements was raised at several meetings of the Open-Bio consortium. It was decided to uphold the information requirement and to put

more effort into explaining these information items, the related standards and the measurement methods to bio-based product providers. Nonetheless, it is clear that the expectations of the research community represented by the Open-Bio consortium can often not be met by the product suppliers who quite often do not have information on the bio-based content or are not able to prove their claims according to standardized test methodology.

The database was published (www.open-bio.eu/database) in November 2016 and described in a report 'Final interaction tool'. The launch of the database was made public through press releases, web news articles and in newsletters. At the time of publication the database included 123 products from 26 product suppliers.

3.7 Social acceptance

3.7.1 General approach

To ensure the effectiveness of measures that support the demand of bio-based products the Open-Bio project targets the identification of key criteria for the market acceptance of bio-based products and related standards and information systems, including labelling options for bio-based products.

Apart from determination of the bio-based products properties and expressing them in the correct way to their users and consumers, eventually supported by reliable labels and certificates, acceptance in the market is a factor of importance. Relevant acceptance factors for the following three target groups have been assessed: (1) consumers, (2) businesses and (3) public procurement officials.

3.7.2 Consumer appreciation

A two-stage approach with qualitative and quantitative research among consumers has been taken to increase the understanding of consumers' perception of bio-based products. A positive perception of bio-based products is a condition for a positive attitude and intention to buy bio-based products. In order to understand consumers' perception we have asked for familiarity, associations, emotions and awareness. The research also addressed specific issues related to labelling, product information and standardization, which were of importance for other work under the Open-Bio project.

The findings from qualitative focus group research and quantitative survey on consumer acceptance and the overall results of a two-stage Delphi survey targeting the business community and public procurement officials (based on separate survey questionnaires) complemented the work. Results of surveys conducted among consumers show a high degree of unfamiliarity with bio-based concept and bio-based products among consumers. They have positive associations linked to the environment. However, there are also mixed and negative feelings due to the lack of knowledge and arising questions about bio-based concept and products.

Discussing seven specific bio-based products showed that each products is perceived in its own way. For every product it is important that one's personal benefits are fulfilled first. The bio-based element is perceived as only a small additional positive aspect. However, there-

fore it is important to have a coherent product concept in which all production process phases are sustainable on the social, environmental and economic dimension.

Regarding the labelling of bio-based products, consumers seem to prefer bio-based products with a label. The EU Ecolabel is assessed as neutral to positive, with differences between countries. Italian consumers are much more aware of the EU Ecolabel than Danish and Dutch consumers are. Regarding the sender of the consumer information, consumers perceive consumer organisations as being the most reliable sources of information. For all countries, NGO's and independent certifying organisations were also highly trustworthy. Finally, we asked what information consumers would like to have. They highly ranked information about the recyclability and biodegradability.

3.7.3 Acceptance of Bio-Based Products in the Business-to-Business Market

This study adopted the Delphi method to generate a generalized view on market acceptance of bio-based products. In addition, the survey addressed specific issues related to labelling, product information and standardization, which will directly inform activities in other work packages of the Open-Bio project.

Figure 7 - Market drivers, ranked by average of all responses

The results of the survey indicate that the positive image of bio-based products and their ability to ensure stronger independence from fossil-based resources are considered the most important drivers of market acceptance. High and volatile production costs are key market barriers, the more so as the prospects for receiving a green premium are perceived as rather low. Furthermore, an unsupportive regulatory environment and uncertainty about future regulation seem to hinder a stronger market uptake, whereas concerns about social and envi-

ronmental impacts and the use of GMOs in feedstock production are not considered important market barriers.

Regarding the development of a European label for bio-based products, there seems to be strong support for the introduction of a label as a tool that helps developing and stimulating the B2B market of bio-based products. This label should address additional environmental criteria and feedstock-sustainability-related issues. A significant degree of uncertainty, however, remains regarding the specific details of label design and whether such a label should be integrated with the EU Ecolabel scheme, as survey responses are ambivalent in this point.

In addition, a key finding that emerges from the survey is that important drivers of the market for bio-based products differ distinctly across countries and product groups. Respondents find local supply chains and the independence from fossil resources to be particularly important as market drivers in France and end-of-life-considerations in Italy. In other words, the survey indicates that national trends retain a role in driving markets for bio-based products. Moreover, the survey identifies particularities of sub-sectors of the bio-based economy that need to be considered when designing policy instruments to promote bio-based products.

3.7.4 Acceptance of Bio-Based Products in Public Procurement

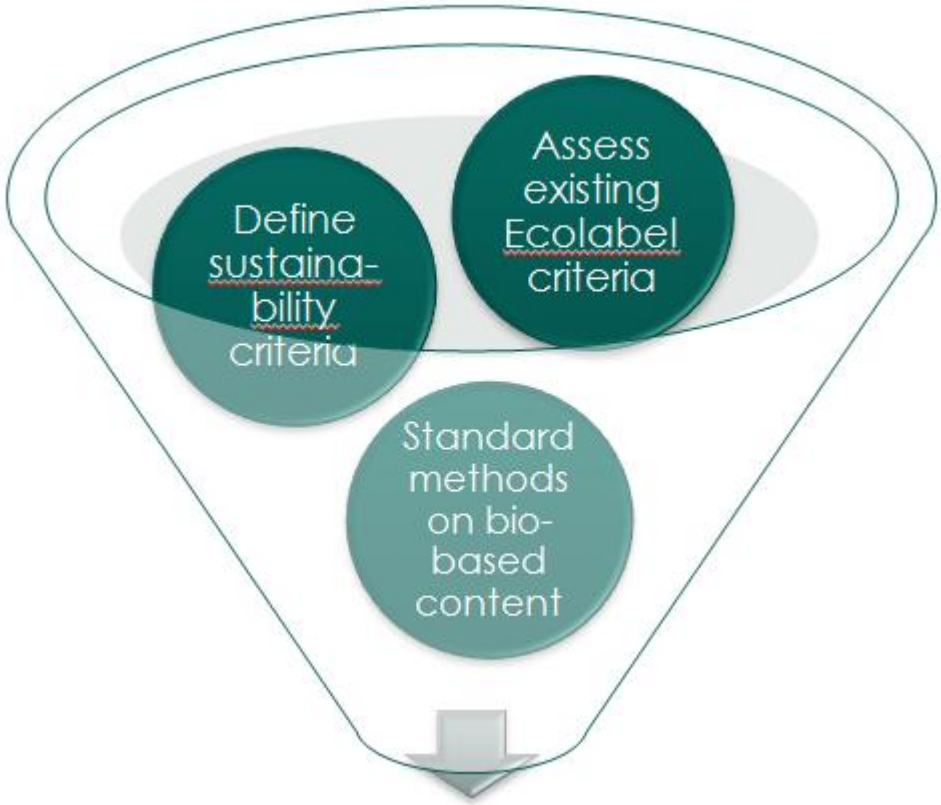
The study on acceptance in public procurement adopts the Delphi method to generate a generalized view on factors influencing the acceptance of bio-based products in public procurement, based on the informed opinion of experts. In this context, the survey places particular emphasis on how current green public procurement practices might stimulate the increased uptake of bio-based products in public procurement. In addition, it addresses questions regarding the role of information on and standardization of bio-based products.

For the current practice of green public procurement, impacts directly related to the production, use and disposal of products receive more attention than impacts related to the use of raw materials, which represents a major challenge for promoting bio-based products on the basis of bio-based content alone. Energy efficiency turns out to be the most important environmental aspect in the current practice of green public procurement, whereas bio-based content or the use of renewable resources figures among the least important environmental aspects.

Key findings of the procurement sector survey include that bio-based products are not yet considered a relevant category in green public procurement and that bio-based content on its own is typically not viewed as a relevant justification for inclusion in green public procurement schemes. Although many organisations do practice green public procurement, only approximately one third of respondents confirms that it would be possible to use bio-based content as a specification in the context of procurement processes in their organizations. Hence, it is more likely that bio-based products enter green public procurement schemes if they can credibly offer a broader set of environmental benefits. First and foremost the concept of “bio-based products” is also unknown for the public procurement officials, as a large share of respondents does not even know what the term “bio-based products” exactly means .It is interesting to note, however, that two respondents suggested in the supplemental com-

ment section that the avoidance of fossil resources represents an important aspect for consideration within green public procurement. This may suggest that raising awareness on the link between bio-based content and the avoidance of fossil-based materials might help increase the willingness to consider this aspect in green public procurement.

Finally, regarding possible measures to promote the public procurement of bio-based products, the results indicate the need for a clear political decision to promote bio-based products via green public procurement schemes. The lack of practical guidance and information on bio-based products creates uncertainty regarding the use of specifications on bio-based content in public procurement. The acceptance of bio-based products in green public procurement would benefit from the provision of detailed product information that compares the performance of bio-based and fossil-based reference products based on accepted environmental criteria. Moreover, eco-labelling schemes are important points of references for green public procurement, suggesting that the incorporation of bio-based content as criteria in relevant labelling schemes could also promote their uptake in green public procurement.



4 Potential impact

4.1 Labelling and other product information

Labels and an information list on bio-based products provide consumers and public procurers with clear information on these products' environmental performance, encouraging sustainable choices. During the project, several efforts were made to disseminate the knowledge and intermediate results to a wide range of interested stakeholders, e.g. labelling experts, bio-based products companies and policy makers both from the Commission and the national authorities.

The final exploitable results are

1) Draft recommendations for development of EU Ecolabel criteria that consider bio-based products in a positive way for eight product groups:
    a. Rinse-off cosmetics
    b. Detergents
    c. Hygiene products
    d. Food disposables
    e. Mulch films and agricultural equipment
    f. Wood-Plastic Composites
    g. Cellulosic pulp
    h. Solvents
2) Two reports with more general recommendations on the inclusion of bio-based criteria in the EU Ecolabel and several factors that are necessary for implementation. These reports will also be disseminated to the respective target groups, i.e. policy and label makers, bio-based industries.

At the time of publication the product information database included 123 products from 26 product suppliers. The requirement to provide information on the bio-based content and bio-based carbon content remained the main problem during data collection. There are good reasons to continue this more liberal way of dealing with the product information requirements. Previous research and consultation with public procurement officials showed that the bio-based share of a product is currently not considered the most relevant information for their procurement processes and product selection criteria in tender notices. What is of more importance is product functionality and performance. If this comes with a claim of using biomass as renewable feedstock, it is a ‘nice to have’ aspect only. Therefore, the lack of information on bio-based content and bio-based carbon content from the side of the product supplier is not necessarily an important gap in a product information profile. One the other hand the strict requirement constitutes a clear barrier for companies to access the database. Currently approximately the same number of products which is already published is waiting for approval. This is in most cases due to the required information about the bio-based content not being provided.

During the final project meeting of Open-Bio, the decision was formalised to use the Open-Bio product information database in the project InnProBio (Forum for Bio-Based Innovation in Public Procurement). The project is financed under the EU Horizon 2020 programme. The InnProBio project specifically deals with public procurement of innovative bio-based products and provides tools and hands-on information for public procurers who want to assess the possibilities of bio-based products and services (www.innprobio.eu).

The Open-Bio database was developed as a test case to see how standardized information and product information requirements can be matched and presented in an ideal database and interaction tool. Within the InnProBio project, this research result can become a valuable tool for public procurement stakeholders who could use it for their purchasing activities. It can also be supported, further filled and developed by InnProBio. This provides the possibility to fill in missing products and product categories. It also provides the opportunity to further develop the database, include new features and tools which can support the public procurement of bio-based products and help sustain the 3-year exercise of the Open-Bio project developing this database.

4.2 Standards

Standards reduce barriers to trade in bio-based products and expand the market potential and the competitiveness of European bio-based industry. Involvement in standardisation activities has been a crucial aspect of the Open-Bio dissemination activities, since this constitutes a direct usage of project results. Please refer to Open-Bio Deliverable D2.7 “Report on SDO involvement“ to get an overview of the participation of Open-Bio partners in meetings and activities of CEN, ISO and national standardisation bodies and to see which project results were directly fed into standardisation activities. Regarding the partners input, some acted as the convenor, other as the “technical contact” or project leader, whereas some were experts in group meetings or reported to plenary ISO or CEN committee meetings.

Highlights to be mentioned are the fact that four full interlaboratory studies on the bio-content and biodegradability being held under the project resulted in the same number of CEN standards. Some direct impact in the standardization field can be seen e.g. in the form of the development of three CEN standards on bio-based content (EN 16640 on bio-carbon content and EN 16785 on total bio-based content with Part 1 using elemental analysis and Part 2 on the material balance method). Next, the bio-lubricants specification standard under CEN/TC 19 uses the horizontal biodegradability concept developed in Open-Bio. CEN/TC 249, Plastics, has adopted the work on toxicity of polymer residuals, whereas the ISO/TC on the same topics has adopted the research on biodegradation in fresh and marine water for revised or newly developed test methods, such as:

- ISO 18830:2016, Plastics -- Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sandy sediment interface -- Method by measuring the oxygen demand in closed respirometer
- ISO 19679:2016, Plastics -- Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sediment interface -- Method by analysis of evolved carbon dioxide

In ASTM a standard has been published on biodegradation in the marine environment:

- ASTM D7991 – 15, Standard Test Method for Determining Aerobic Biodegradation of Plastics Buried in Sandy Marine Sediment under Controlled Laboratory Conditions.

The test systems developed for the marine biodegradation in lab, mescocosm and field environment are technically well developed and give usable results. There are some refinements needed to enhance reproducibility, to further reduce variability for different products and to accelerate the processes in the controlled systems. Following that, methods and specifications can be proposed for standardization. Some aspects still need further development and investigation. The effect of fouling organisms on the biodegradation process in natural settings is not sufficiently understood. Also, fundamentally different ecological settings as e.g. marine biodegradation in the lack of oxygen were not considered in Open-Bio, but may play an important role in the overall assessment of plastic in the seas. This is also true for other habitats like the deep-sea floor which accounts for half of the Earth's surface. At the end of this activity, it can be concluded that the results are too premature to talk about standard specifications for biodegradable plastic material in marine environment. The focus at this moment should be on improving the testing methods.

All functionality testing is summarized in a public deliverable (D4.6), organized by product category to facilitate the exploitation of results. The document will be provided to the relevant CEN committees. As the suggestions are very specific and the Open-Bio partners have no direct influence in these groups, their acceptance is to be awaited. However, during product testing there has be a strong interaction with producers of bio-based materials (especially for solvents, WPC-decking and insulation materials) and follow up on results is expected. A peer reviewed article on the testing of WPC-decking is expected early 2017.

Standard specifications for products suitable for home composting and anaerobic digestion were prepared. Moreover, a test methodology for the simultaneous evaluation of the disintegration and the biodegradation of test materials under anaerobic conditions was prepared and a list with improvements for the current standards for industrial compostable products. Furthermore, also two test methods related to chemical recycling were prepared: (1) Method of chemically recycling PLA and acceptance criteria and (2) Method of quantitatively analysing plastic waste for chemically recyclable content. The developed test methods and standard specifications can be used as starting point for the development of a European standard specification in a relevant CEN group (e.g. CEN/TC 249 "Plastics", CEN/TC 261 "Packaging", CEN/TC 411 "Bio-based products", CEN/TC 444 "Environmental claims", etc.).

Looking at the end-of-use work in general, the several reports on literature studies concerning existing standards, regulation and certification schemes may be a starting points for product development and worldwide harmonization steps. It can be concluded that the project has executed pre- and co-normative work that has either resulted in European standards or might well lead to such standards. At international level, some product specific standards have been co-developed in ISO and ASTM. Here the industry and advisory partners have been instrumental.

Possibilities for harmonising standards and normative measures in the EU, US, Japan, China, Brazil, and other major trading partners have been found difficult. First of all the South-American and Asian countries had little standards to offer. They follow ISO or ASTM work. Australia and New-Zealand are more promising harmonization partners due to the cooperation with Scion as advisory partner and study lab in bio-content, biodegradation and other test methods. Regarding the USA, the two advisory partners and the many reporting to ASTM D20 have initiated an exchange. However, as long as the policies don't change, ASTM standards are not easily adapted. Quite recently, disputes on the research basics regarding the bio-content determination work by Open-Bio have been ventilated by ASTM members. The discussion will continue at a joint ASTM-CEN workshop in Toronto (CA) in 2017.

4.3 Policies

The project was initiated to realise the objectives of different relevant European policy initiatives, including the Lead Market Initiative in Bio-based Products, the Industrial Policy, the Environmental Technology Action Plan and the EU Strategy for Key Enabling Technologies and the Bioeconomy Strategy. While a lot of political impetus comes from the Lead Market Initiative, and therefore mostly from EC DG GROW and DG RTD, based on socio-economic and only partially ecological motives, the EU Ecolabel is governed by DG ENVI and has requirements that are strictly related to LCA evidence on the ecological benefits of each product. This needs to be reconciled in order to promote bio-based products through the EU Ecolabel.

Other controversial issues that pertain to all bio-based product groups or at least to several of them are

- Hot to declare bio-based content (whether through measurements or through mass balance claims);
- Whether the required sustainability certification of bio-based feedstocks poses an unfair burden for bio-based producers and therefore contributes to a non-level playing field;
- Whether biodegradability is an environmental advantage and should be treated as such per se;
- How to directly communicate bio-based content through a label

As was shown during the labelling research, the requirement of the additional burden of providing sustainability certification can have the adverse effect of creating a barrier-to-entry that is too high to cross for the industry. It is important for policy-makers to at least be aware of this, and preferably for them to take actions to either: (1) lower this barrier, or (2) support the industry to make it easier to cross this barrier, or (3) create a barrier at the same level for traditional (fossil) products. Different stakeholders clearly have different ideas on what would be the best way to organize this, so it would be useful to take these ideas on board in the creation of new legislation and support schemes that are related to the bio-based (or circular) economy.

Some of the recommendations for the labelling are closely related to recommendations on legislation as a whole. In order to promote eco-friendly bio-based innovation, it is necessary

to reduce regulatory and administrative burdens, simplify policy and level the playing field between sectors. This pertains to current agricultural, energy and waste policies which need to be re-designed based on the results of accurate regulatory analysis in order to make the transition to a vibrant bioeconomy.

4.4 Use and dissemination of foreground

The dissemination of Open-Bio has been very successful, both in the standardization community as well as on general terms. Awareness of the project is high and both the Project Manager as well as the Dissemination Manager got (and still get) contacted regularly by interested parties in order to obtain information or discuss possibilities. All three Advisory Workshops were well attended and featured fruitful discussions. Agreement with the project's approach was high, but details were fine-tuned and very useful contacts were made that helped also with the more specific research in some of the work packages.

Next, the development of a European certification scheme for biological content is an outcome of interaction between several (advisory) partners and the work executed under Open-Bio. Internationally, the workshop at the September 2016 meeting of ISO/TC 61 focussing on the bio-content and end-of-life (draft) standards developed by Open-Bio gave the project one of the many international outreaches. Standards are developed at ASTM and in Australasia based on the project results and in April 2017 a ASTM-CEN workshop is foreseen where the project will also be represented.

Looking at still to be developed end-of-life use, the acceptance of bio-based materials in organic recycling systems needs to be further improved. This may be achieved by validating the behaviour of materials that fulfil the requirements of standard specifications for industrial compostable, home compostable and anaerobic digestible products in a real life assessment (on large real life scale). The creation of a precedent with products that otherwise cannot (easily) be recycled mechanically and the study of their behaviour in industrial installations, could increase the acceptance by consumers and operators of organic recycling industries.

PLA is the best opportunity for chemical recycling to establish itself (in terms of chemical reactivity and projected market growth), and hence efforts in the project were directed towards this plastic and less attention was given to others. Realisation of the chemical recycling of other bio-based polymers is a longer term ambition. Future research should seek to strengthen the preliminary case for chemical recycling provided by Open-Bio, in anticipation of more quantities of more varied bio-based plastics being produced as the bio-based economy expands.

A highlight of this project's dissemination and stakeholder engagement was the manifold ways in which partners interacted with external experts. The social acceptance research is at the forefront of research on what consumers, policy makers, public procurers, businesses and NGOs think about the bio-based economy, what motivates them and which barriers they see. These results are highly interesting for any further work engaging with different societal groups on the bio-based economy. They are therefore relevant to subsequent research projects (e.g. InnProBio, STAR4BBI, BIOCOM, BioCannDo, etc.) as well as policy makers or other decision makers.

The research about the EU Ecolabel depended very much on specific input both from labelling experts and from the industry of the concerned product groups. The biggest factor influencing the successful exploitation of the research results is interest from industry stakeholders, policy makers and consumers in taking the ecolabelling of bio-based products forward. The results were therefore presented to a EU Ecolabelling Board meeting in June 2016 and the final results summary will be disseminated to all potentially active stakeholders after the end of the project with the strong hope of on-going activities.

During the project, several efforts were made to disseminate the knowledge and intermediate results to a wide range of interested stakeholders, e.g. labelling experts, bio-based products companies and policy makers both from the Commission and the national authorities. A total of 100 representation by the project at conferences, workshops, exhibitions and policy meetings have been registered. This is obviously apart from (inter)national standardization and procurement exchanges.

Draft recommendations for development of EU Ecolabel criteria that consider bio-based products in a positive way have been submitted to the Commission services and to interested companies. It will provide them with the opportunity to follow up on the research with their own initiative on developing or revising the EU Ecolabel with more focus on bio-based products.

Apart from several project related publications in different media outlets, the project partners also decided to publish a scientific statement on the UNEP report on the role of biodegradable plastics in marine pollution in winter 2015/2016. The statement was developed after a request from the Commission to provide scientific expertise and an assessment of the claims made in the UNEP report. The statement offers some corrections to technical mistakes of the UNEP report and preliminary results from the project's research. The consortium concludes that biodegradable plastics are not a solution to littering. Littering must be opposed by means of prevention, waste management (that includes separate collection and organic recycling of biodegradable plastics), public awareness, etc. On the other hand, plastics that are shown to be truly biodegradable in the marine environment could be profitably used in those applications where dispersion in the sea is certain or highly probable (e.g. fishing gear, fish farming gear, paint, etc.). The paper was disseminated to the Commission as well as to the broader public via a press release in February 2016. For the whole paper, please see www.open-bio.eu/publications.

A total of eleven publications in different media (most of them peer reviewed) have been made by project member or are planned to be made after the finalisation of the project. This is a relatively low number as most of the partners felt the work shall be disseminated publicly through standards and conference presentations.

Last but not least, the product database, was also developed in close cooperation with the concerned stakeholders, which are public procurers. From the outset on, their interests were taken into consideration, their information requirements formed the basis of the concept and their feedback was instrumental in the fine-tuning and improvement of the database. The exploitation of this results will take place in the form of another research project keeping the

database alive and developing it further: That H2020 project (InnProBio, see: www.innprobio.eu) deals with bio-based innovation in public procurement and is engaging closely again with the target group of public procurers. The plan and the hope is to find a way to keep the database up and running also afterwards, hopefully independently of limited project funding.

Towards a bio-based future

The Open-Bio project is designed to determine the best methods to encourage consumers to buy bio-based products. By identifying what final users want to know about these products, the team hope to encourage industry to move towards more sustainable products and manufacturing

"The ultimate goal is to ensure that producers will inform their customers about the biological content of a product, or its capability to biodegrade"

As awareness of the human impact on the environment continues to build and build, so too does the sense of responsibility each individual has, in terms of how their actions have consequences. Where before, for example, products were used without any real consideration for where they came from and where they would end up when finished with, now there is more of an onus on traceability and appreciating the full life cycle of a product. Consumers want to know the environmental effects of the products they are using and need information to make purchasing decisions.

It follows that if environmentally friendly products are produced, such as bio-based products (meaning a product that is composed of biological or renewable materials), the attributes of these should be promoted. In addition, the public need to be able to trust the information they are given. With these points in mind, the three-year Open-Bio (Opening bio-based markets via standards, labelling and procurement) project was established in 2013. The aims of the project are to discover how markets can be opened for bio-based products and to investigate how methods of standardisation, labelling and procurement can lead to market development.

UNDERSTANDING CONSUMER NEEDS

Open-Bio, led by Project Manager Ortwin Costenoble of the Netherlands Standardisation Institute, is now nearing completion and has developed standard tests on determining the bio-content, biodegradability, compostability, recyclability and functionality of bio-based products. A key consideration has been to define the properties of bio-based products in order to subsequently discover what final users and consumers want to know about the products to consider purchasing them. "There is already ecological labelling in place for some products or markets, and there is a growing labelling on composting or degradation in soil," explains Costenoble. "We also have sustainably grown feedstock for biofuels that is now also getting ground in bio-based products. The challenge is to see if these claims can be combined and their ways of working can be harmonised."

Through the course of their investigations, the team has found that the better solution is to require different levels of, for instance, bio-content or biodegradability per product. Importantly, they discovered that while consumers do not know much about bio-based products, this does not mean that they want a lot of detailed, technical information. They view labels as helpful, so they should therefore be easily understood at the point of purchase, and be clear in how bio-based labels add to existing labels.

A STANDARD MEASURE FOR BIO-BASED CONTENT AND BIODEGRADABILITY

The work the team has performed has been collated into a database designed to encourage and support public procurers interested in buying bio-based products and services. The database has been developed into a tool that provides relevant information, including the potential applications for specific bio-based products. Encouragingly, the team has found that key information for public procurers is about the general environmental benefits, or the specific functionality, as opposed to more detailed product information. The team collated the information and then surveyed public procurers to understand their perceptions – ones that inform what product data and properties are displayed to maximise the effectiveness.

Perhaps the most important element of Open-Bio, however, is that standardised methods to measure the bio-based content and biodegradability have been developed and agreed upon. The greater the buy-in for methods of standardisation, the more effective those standards will be.

Project Insights

FUNDING
European Union Seventh Framework Programme (FP7)

PARTNERS
Agricultural University of Athens • University of York – Green Chemistry Centre of Excellence • Wageningen University Research • Stichting Energy Research Centre Netherlands (ECN) • Organic Waste Systems (OWS) • Nova-Institute GmbH • Netherlands Standardization Institute (NEN) • Fachagentur Nachwachsende Rohstoffe e.V. (FNR) • Technical University of Berlin • Biomass Technology Group (BTG) • Hydra Institute for Marine Sciences • Novamont • Institute of Analytical Sciences (ISA) • LuAF

CONTACT
Ortwin Costenoble
Project Manager

T: +31 15 2 690330
E: Ortwin.Costenoble@nen.nl
W: http://www.biobasedeconomy.eu/

PROJECT MANAGER BIO
Ortwin Costenoble graduated from Delft Technical University as a materials science engineer. He is now a senior standardisation consultant at NEN Energy. Costenoble is the secretary for international (ISO) and European (CEN) committees and project manager of research activities on topics such as (bio)fuels quality and labelling, sustainable chemicals, sustainability criteria for biomass, chain-of-custody, biosolvents, algae and bio-based products.