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Applications in chemical industry

Summary

The chemical industry is facing large changes in order to be able to transform into sustainable production, in terms of, for instance, use of raw materials, other resource use, and greenhouse gas emissions. This transformation implies also substantial challenges in sourcing sustainable feedstocks, maintaining efficient processes, viable economy, and high credibility. Certification based on mass balance principles, can facilitate a gradual increase of the use of renewable and recycled raw materials, by enabling the use of existing infrastructure and equipment, instead of constructing separate plants and value chains for renewable and/or recycled raw material.

Concepts of mass balance can, however, be quite complex and, in addition, different methodologies and restrictions are applied by different standards and certification schemes, e.g. in relation to physical and chemical traceability of material flows. The study reported here has been performed to increase the understanding of the use of this concept in the chemical industry, and to describe the approaches, provisions and delimitation of standards and certification schemes that this industry is currently using.

The study has been set-up and is financed by the area of Climate-smart value chains, within the program Climate-smart Process Industry. The project involves a broad project group with project management from Chalmers Industriteknik and Johanneberg Science Park. Other industries and organizations represented are Perstorp, Borealis, Sustainable Chemistry 2030, Nouryon, IVL, BASF, Preem, Tarkett, and Sekab.

The study includes a mapping of standards and certification schemes currently used within the chemical industry, in relation to ten different aspects concerning overall mass balance approach and scope, the governance of the system, raw materials covered, sustainability criteria, and balancing methodologies applied. In addition, four different case studies are included to clarify the implications further.

In the study, one standard and four certifications schemes have been mapped. The systems included are the European standard (SS-EN 16785-2) for determination of the bio-based content using the material balance method (in the report called the material balance standard); the ISCC PLUS scheme; the REDcert^2 scheme; the RSB Advanced Products scheme; and the ecoloop scheme.

In the mapping, the material balance standard is a special case, since this standard only relates directly to the balancing methodology. It applies a strict balancing approach and to be able to claim a bio-based product, via the use of mass balance, in Europe one needs to fulfil the criteria of this mandated material balance standard.

For the certification schemes, the mapping shows that these are similar in relation to several aspects. They all require that:

- Verification and compliance of the scheme requirements, as well as the issuance of scheme certificates, are performed by recognized third-party certification bodies.
- The certified system has a certifiable book-keeping system, that keeps track of inputs and outputs of certified materials and products, and similar requirements on balancing over time periods in this system.
- That balancing only includes raw material used for material purposes, and not energy use.
- That product-related claims do not refer to bio-based content, but to the share of the product that has contributed to sourcing of bio-based/recycled material or to the substitution of fossil resources.

There are slight differences in the systems' approach to the use of mass balance accounting unit (mass, energy, carbon). More importantly, though, there are differences in the methodologies used for mass balance calculations, in aspects related to governance and overall organization, and in their approach towards sustainability criteria.

The four case studies were developed in cooperation with representatives from the project participants connected to the chemical companies in Stenungsund and has been discussed and approved by the entire project group. They include process set-ups that mirror the treatment of various raw materials; possibilities for attribution of certified characteristics; restrictions in terms of physical linkages; transferring of credits; and the need for physically existing process steps in the respective standard and schemes applied. In these case studies all the systems included in the mapping, except the ecoloop scheme, have been applied.

The results, in relation to mass balance level and scope as well as balancing methodologies used, show that the material balance standard applies the strictest mass balance approach, which prevents its application to most of the cases studied. Also the ISCC PLUS has, according to the overall mapping, a stricter approach, but can be applied to most of the specific cases studied. The REDcert^{2} and RSB Advanced Products schemes allow, according to the overall mapping, somewhat

larger flexibility, but in different respects. They can also be applied to most of the specific cases studied. REDcert^2 has more restrictions related to credit transfers (case 3), whereas RSB AP is stricter in relation to the need for physically existing process steps (case 4).

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1 Background

The chemical industry is facing large changes in order to be able to transform into sustainable production, in terms of, for instance, use of raw materials, other resource use, and greenhouse gas emissions. This transformation implies also substantial challenges in sourcing sustainable feedstocks, maintaining efficient processes, viable economy, and high credibility. Certification based on mass balance principles, can facilitate a gradual increase of the use of renewable and recycled raw materials, by enabling the use of existing infrastructure and equipment, instead of constructing separate plants and value chains for renewable and/or recycled raw material.

Concepts of mass balance can, however, be quite complex and, in addition to that different methodologies and restrictions are applied by different standards and certification schemes, e.g. in relation to physical and chemical traceability of material flows. It's use in the chemical industry has been limited to date due to uncertainty in the benefits, which is linked to the challenge of communicating the concept. Thus, a need to clarify the use of mass balance, and the methodologies applied, from the perspective of the Swedish chemical industry, has been identified.

1.1 The project

The project Mass balance standards has been set-up and is financed by the area of Climate leading value chains, within the program Climate-smart Process Industry. The overall project area is financed by Vinnova and Västra Götalandsregionen and coordinated by Johanneberg Science Park and RISE through the West Sweden Chemicals and Materials Cluster.

1.1.1 Purpose and objectives

The purpose of the project is to increase the understanding and relevant use of the mass balance concept, and thereby facilitate the transformation to materials and chemicals based on renewable or recycled raw materials. Enabling the use of existing infrastructure and equipment, where the construction of separate plants and value chains for renewable and/or recycled raw material is not technically or economically feasible.

The objective is to describe as clearly as possible the approaches, provisions and delimitation of standards and certification schemes that are currently used within the chemical industry. Further, communication should be developed that inform about the mass balance principles.

1.1.2 Structure and content

The project consists of three work packages:

1. **WP1 Overview of standards and certification schemes**
   WP leader: Ingrid Nyström
   This work package includes a mapping of standards and certifications currently applied within the chemical industry, and relevant for both renewable and recycled raw materials. The mapping aims at clarifying e.g. whether the standards enables product claims, the acceptance from various eco-labeling systems, and the treatment of sustainability aspects and GHG reduction.
2. **WP2 Case studies**
   WP leader: Eva Andersson
   Case studies (at least three), primarily based on data from the chemical industry in Stenungsund, are carried through in order to investigate how various standards can be applied and their implementation can be reliably certified. In addition, potential shortcomings and need for adaptations in relation to the standards should be identified.
3. **WP3 Communication and dissemination of results**
   WP leader: Tove Arnsvik Bjurefalk
   The communication work package is primarily focused on communicating the mass balance principles outside of the project group. Following the identification of purpose of communication, message and main target groups, communication activities (e.g. a broader seminar) should be carried through.

1.1.3 Participants

The project involves a broad project group with project management from Chalmers Industriteknik and Johanneberg Science Park. Other industries and organisations represented are Perstorp, Borealis, Sustainable Chemistry 2030, Nouryon, IVL, BASF, Preem, Tarkett, and Sekab[1].

1.1.4 Delimitations

It should be very clear that the purpose of this project is to objectively describe the various standards and certification schemes, without imposing any judgement *nor* reach any consensus on which scheme to prefer or recommend.

Further, the description of the standards and certification schemes included is entirely focusing on the actual provisions of the standard/scheme, which sets the limits of the boundaries and linkages “allowed”. The actual *application* of the

[1] In the order of which the companies are listed in the project plan.

system by specific certified companies is not described. These companies may, of course, not violate the provisions of the standard or scheme, but may well set stricter limits for their own application. This is further illustrated by the descriptions included – for this purpose - in Appendix A. These descriptions have been directly provided by the companies themselves and is not part of the study result as such.

Standards and certification systems directed to describing methodologies for determining and certifying physical bio-based *content*, based on analysis such as the C14 method, are not included in this project.

1.2 The report

This report describes the analysis and results of the project and follows largely the structure of the project. In Chapter 2, the concept of mass balance is described as a background for the analyses performed. Chapter 3 contains the result of work package 1, while Chapter 4 describes the choice of case studies and case study results. In Chapter 5, the approach of developing the communication message, material and activities is described. The actual material developed is available through other channels. Finally, in Chapter 7, some general conclusions from the project are summarized.

2 The concept of mass balance

The general concept of mass balance is described and communicated by a number of organizations and publications, and it is not within the scope of this report to detail all aspects of the concept. For this, we primarily refer to the three publications referenced in Section 2.1. This chapter should rather be viewed as an introduction to the analysis presented in chapters 3 and 4.

2.1 Mass balance as chain of custody model

The mass balance concept that is discussed and analysed in this study refers to a process by which inputs and outputs, and associated information, are transferred, monitored and controlled as they move through the relevant supply chain.[2] Such a

[2] The term mass balance can also be used as directly signifying the application of conservation of mass to the analysis of a physical system. The use of the term

process is called a chain of custody model.[3] The increasing focus on converting to sustainable renewable or recycled feedstocks, make it increasingly important for companies to be able to follow and control the chain of custody that they are directly active in, but also to be able to transparently communicate and credibly verify it. A verified chain of custody can, for instance, show the origin and sustainability of feedstocks used, the different conversion and transportation steps in the chain, and the efficiency of these steps.

In simplified terms, there are four different chain of custody models available: Identity preservation models, segregated models, mass balance models, and book and claim models. In the first, two renewable or recycled materials are not allowed to be mixed with fossil material. In book and claim models, certificates can be traded, without linkage to the actual material flows. In the following, we only discuss the various definitions of mass balance models.

The term mass balance is in this context well established. Nevertheless, the interpretation and definitions used differ quite substantially, which causes some confusion. **Below, three different definitions, described in three different referenced documents, are summarized. For more details, see the respective reference.**

There is a draft standard ISO/DIS 22095, with the purpose of providing unambiguous definitions and terminology for the different chain-of-custody models[4]. According to this draft, mass balance is a chain of custody model in which materials or products with a set of specified characteristics are mixed with materials or products without that set of characteristics. For this model, the proportion of the input with specified characteristics might only match the initial proportions on average and will typically vary across different outputs. This means that e.g. renewable and fossil input is mixed and that the exact proportions in each final product cannot be guaranteed.

The same standard also defines the controlled blending model, as a separate model in which the mixing results in a known proportion of the specified characteristics in the final output. According to this model the claim may then be referred to a certain percentage.

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mass balance as a chain of custody model is of course derived from this physical meaning. However, the definitions differ and the concepts should not be confused.

[3] ISO/DIS 22095 Chain of custody – General terminology and models.

[4] Draft International standard ISO/DIS 22095 Chain of custody – General terminology and models (ISO/DIS 22095:2019 (E).The information above is based on a draft document circulated for comment and approval, available from Beuth Verlag GmbH.

The International Social and Environmental Accreditation and Labeling Alliance (ISEAL Alliance)[5] has published a guidance documents on chain of custody models and definitions.[6] According to this, in a mass balance model certified physical product is not separated from, and may be mixed with, non-certified physical product at any stage in the production process, provided that the quantities are controlled. In this guidance document mass balance models are divided into batch level, site level and group level mass balance. What distinguishes these different types of mass balance models are, according to the guidance document, whether physical mixing of certified and non-certified content actually happens and at what stage in the supply chain segregation is lost and how often. Batch level mass balances ensures that the end-product contains at least a proportion of certified product, which allow specific end-use claims (such as a declared percentage) to be made. In site level mass balances, the proportion of certified content entering and leaving the site is known, though the proportion in each final product may not be known. [7] Finally, group level mass balances are described as a balance for a "group" that may refer to a company with several sites. At this level the certified claim can be allocated to any physical product leaving the system as long as the volumes are appropriately balanced.[8] The document also notes that these options are significantly different and that the ability to audit is stronger with batch, then decreases for site, then decreases further for group level.

Finally, the Ellen MacArthur published in 2019 a mass balance study (EMF white paper), focusing on chemicals based on recycled materials.[9] In this report, the main argument is that the condition of the chemical industry differ from that of other manufacturing, and that the mass balance approach needs to be adapted accordingly. According to this study, the idea of mass balance is that certified feedstock replaces an equivalent amount of virgin feedstock at the beginning of the values chain (input) to be allocated to a product (output). What happens in between is less

[5] ISEAL Alliance is a global membership association for credible sustainability standards, whose members are sustainability standards and accreditation bodies that meet their Codes of Good Practice. Examples of full members are Fairtrade, SC, RSB, MSC, and Rainforest Alliance. For more information see www.isealalliance.org.
[6] Chain of custody models and definitions, A reference document for sustainability standards systems, and to complement ISEAL's Sustainability Claims Good Practice Guide, version 1.0, September 2016, ISEAL Alliance
[7] In this guidance document, "controlled blending" is mentioned as an example of site level mass balance, which is quite confusing, since it in the standard (22095) is referred to as a stricter model than batch level mass balances.
[8] In this context, the "certified" claim refers to the use of renewable and/or recycled raw material substituting fossil raw material, at least in part.
[9] Enabling a circular economy for chemicals with the mass balance approach – a white paper from co.project mass balance, Ellen MacArthur Foundation, CE100, 2019. To this collaborative project the following organizations contributed: BASF, Eastman, EMF, Michelin, Schneider Electric, Solvay, Tarkett, UL, UPM Raflatac.

relevant, as long as the balancing task can be met in a proven and reliable manner. It also underlines that there is no physical or chemical difference between certified and non-certified product and that there is no guarantee that there is any certified *content* in each final product, only that the total *amount* of certified product corresponds to the amount of certified input.

In conclusion, there are several different mass balance approaches, which have the balancing of output with input in common, but which differ with regard to the methodologies applied and provisions allowed. Thus, within the purpose of this project, it is difficult to find one unambiguous definition. Instead we have chosen the approach described in Section 2.3 below.

2.2 Applications within the chemical industry

The chemical industry market currently products, produced and certified based on the mass balance approach. Below, the use within the companies involved in the project group is described (see also Appendix A).[10]

Perstorp started their work with mass balance in 2009 and launched its first products in 2010. The certification scheme used from 2017 is the ISCC PLUS scheme and today 3 of 7 plants globally are certified. All products are certified both on renewable content and on calculations of greenhouse gas emissions (GHG). All renewable raw material used are ISCC compliant. Examples of certified products include polyols, alcohols and acids for use in e.g. coatings, synthetic lubricants and adhesives.

Borealis is a member of the ISCC. The company has certified several operation units according to ISCC PLUS and is preparing to certify the remaining units.

BASF has sold certified products since 2013 and has now in total more than 150 different products with renewable or recycled content according to a certification based on mass balance. The renewable/recycled content in these products vary between 25 and 100 percent. Examples of products include biomethanol, poly-amide and polyacrylate dispersions and formulations. The certification schemes used are the REDcert-EU, REDcert^2 and ecoloop.

Preem is certified according to the ISCC EU and markets certified renewable diesel and gasoline fuels in accordance to the Renewable Energy Directive for biofuels. It has no certifications directed at the market for chemicals and uses not the certification schemes included in this study.

[10] In the order of which the companies are listed in the project plan.

Tarkett is RSB-certified since February 2020 and will launch certified plastic floor based on mass balance, in April 2020. In this floor, bio-attributed vinyl from Inovyn, also certified by RSB, is used.

Sekab is certified according to the ISCC EU and the ISCC PLUS certification schemes, including production of feedstock until dispatch from the factory. Sekab is also certifying according to the ASTM standard for 100% bio-based content according to the C14 method and uses the SIS/CEN material balance standard.

2.3 Applications within other sectors

The mass balance approach is used within several different sectors. The system boundaries, detailed provisions, regulations and/or certifications used vary of course, and it is outside the scope of this report to go through these in detail. Nevertheless, it may be of interest with a brief overview of some examples:

- The EU sustainability criteria for renewable transportation fuels within the Renewable Energy Directive[11] allows for mass balance. The EU commission has approved in total 15 different voluntary certification schemes for certifying the sustainability of the value chain from feedstock to fuel product sold “at the pump”. The ISCC EU, REDcert-EU and RSB EU RED are three of these certification schemes. According to this regulation, physical and chemical traceability from specific feedstock to actually produced fuels are required. However, the resulting products may then be mixed with fossil products in the storage and distribution chains, which makes the physical share of biofuels in the fuel delivered to each customer unknown.[12]
- The green electricity certificate system, governing the share of renewable electricity in the Swedish-Norwegian electricity system are based on an approach corresponding to the mass balance principle, although it is, for natural reasons, not mass or material based. In this system, the amount of electricity produced from renewable sources are fed into the grid at one point, and the same amount (or less) is sold, via the grid, to customers as

[11] Renewable Energy Directive (2009/28/EC), replaced by the recast Renewable Energy Directive (EU) 2018/2001 (also known as RED II) from 2019.
[12] The criteria for sustainable fuels, according to the Renewable Energy Directive, are not further described in this report. However, they are in several cases used as kind of a benchmark, for comparison of, e.g. sustainability criteria.

"green". The actual origin of exactly the electricity sold to a specific customer can, however, not be specified.[13]

- The use of biogas within the natural gas system is based on the so called green-gas-principle, which is also ensures traceability via a mass balance approach. In Sweden, biogas is, via the gas grid, mostly attributed to the gas vehicle market, since the difference in taxation between fossil and bio-based gas is largest within this market. Consequently, the principle is here considered valid also from a tax regulating point-of-view.[14]
- The marketing of timber certified through the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC) systems to guarantee that it is produced in line with specified principles for sustainable forestry, are also, at least partly, based on the mass balance approach.[15]

2.4 Approach within this project

As described above, there is not one universal definition of the mass balance concept, since there is a number of approaches, or mass balance levels, applied. In Figure 1, below, different levels and their system boundaries are illustrated, at a general level. The purpose of this project is to as clearly as possible, and without imposing any judgement, describe the delimitations and provisions of different mass balance based systems used by the chemical industry.

In describing the different systems, we have therefore chosen to adhere to the terminology used by the respective scheme. Rather than giving them a pre-defined label, we have tried to explain how the concepts are used and what the practical implications are.

[13] In the EMF White Paper green electricity is included as an example of a book and claim chain-of-custody, since electricity from several companies is traded on a spot market. On the other hand, in this case the linkage between input and output (the grid) is very direct and verifiable. It is included here primarily as an example of systems based on principles similar to the mass balance approach, which are widely accepted.

[14] However, there has been a matter between E.ON and the regulatory and tax authorities regarding how this will be treated when transferring of biogas across national borders, which is now mostly sorted.

[15] MOL, A. P. J. & OOSTERVEER, P. 2015. Certification of Markets, Markets of Certificates: Tracing Sustainability in Global Agro-Food Value Chains. Sustainability, 7, 12258., doi:10.3390/su70912258

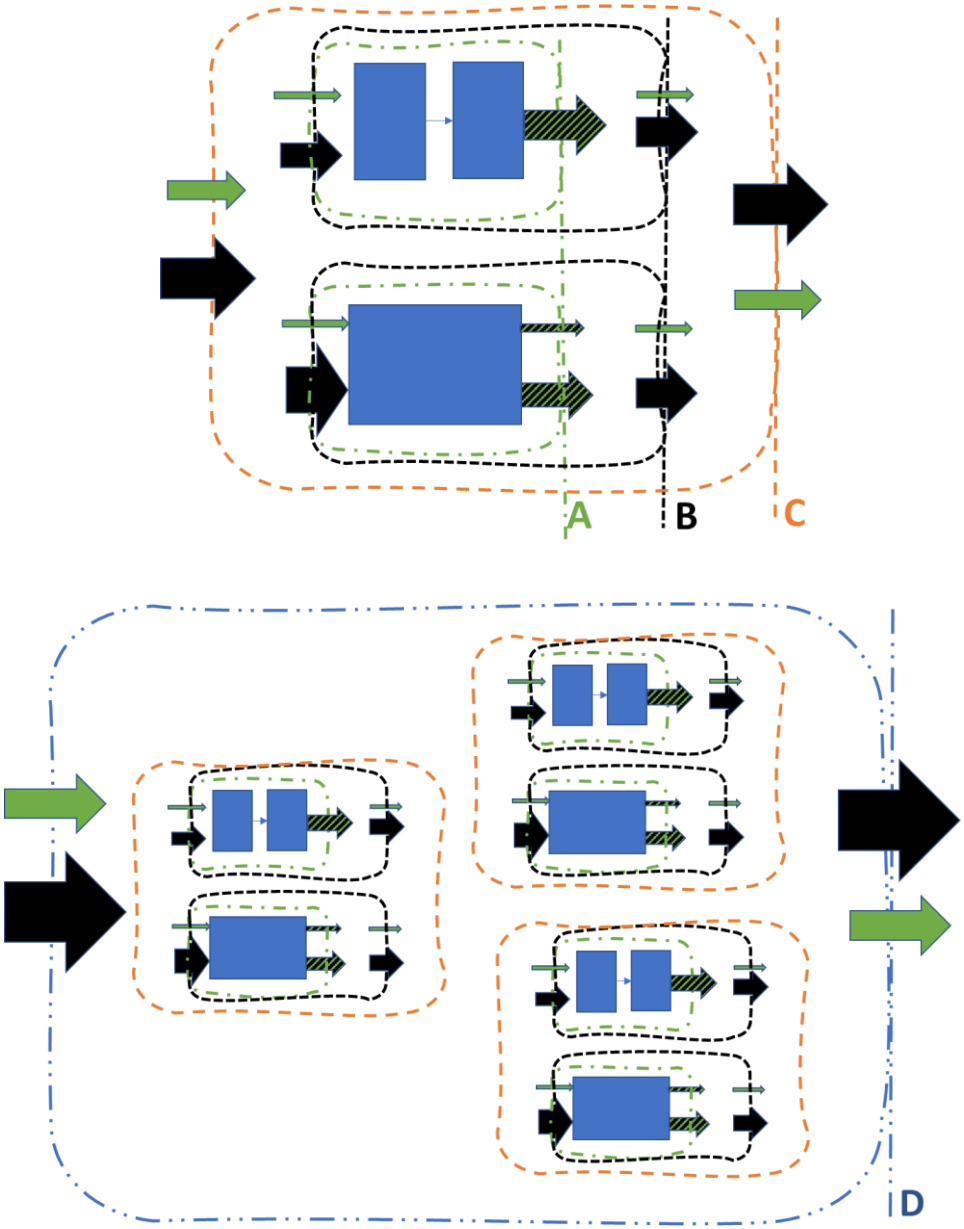

Figure 1 A general illustration of different mass balance levels and their system boundaries. Note: Several variants within each level exist. System boundary interpretations:

A: Batch level. Input, process steps, losses and output is traceable for each feedstock and product. The output can be specified as a percentage of certified material for each product.

B: Batch level with free attribution. Material flows traceable as in A, but free attribution to any product (from the specified process).

C: Site level. Feedstocks traceable and balanced over entire production site. Provisions exist that regulate the types of linkages needed between units.

D: Group level. Feedstocks traceable and balanced over entire mass balance system, which may consist of several sites. Provisions exist that regulate the types of linkages needed between units and sites.[16]

[16] In relation to certification of feedstock, “group level” mostly refers to certification of a group of agricultural small-holders, which is something entirely different.

3 Mapping of mass balance standards and certification schemes

The mapping of mass balance standards and certification schemes are directed towards giving a detailed enough scrutiny and presentation to clarify the main similarities and differences between the standards included. A full understanding of the detailed treatment of various aspects is not possible without application of the scheme provisions to actual cases and the carrying through of a certification process. This is far beyond the scope of this project. However, the purpose of the cases studies described in Chapter 4 is to increase understanding by providing a few more concrete and applied examples. In this chapter, the mapping is presented at two levels: a principal and comparative overview of the standards and schemes identified as relevant; and then a separate description of each of the standards and schemes.

The information in this chapter represents our interpretation of the systems' own documentation and of interviews with certification organizations as well as, in some cases, certified companies. In addition, draft versions of the descriptions have been checked by the organizations behind the standards and scheme, to ensure factual correctness. Nevertheless, in the, often extensive, documentation of standards and schemes, the exact wordings and terminology is important. Therefore, it should be noted that the descriptions mirror our *interpretation* and summary, based on these sources. The aim is to provide an accurate, but at the same time, short and readable description.

In Appendices B through F, the more exact provisions of the systems, in relation to different aspects, are included. Also these are, of course, based on our selection of which parts of the documentation to extract. For all system details, we therefore refer to the original documentation.

Finally, it should be noted that all standards and certification schemes are under continuous development. The descriptions in this report refer to the situation in January 2020.

3.1 Standards and schemes – terminology

The mapping here includes standards and certification schemes that set up principles for book-keeping of inputs and outputs of certified materials and products based on a mass balance approach (see also Chapter 2). By adhering to such principles a company can trace the use of bio-based or recycled material. To

be able to credibly communicate the use to its customers, the company in general is certified against the principles, by an independent certification body. The certification body then certifies that the company has a trustworthy book-keeping system, calculate mass balances and in all other ways follow the provisions laid out in the standard or certification scheme for the products and processes included in the certification.

The difference between standards and certification schemes are not self-evident. In addition, the term “standard” is used in different ways.

National or international approved standards are developed by a broad stakeholder group together with an acknowledged standards organization, such as the European Committee for Standardization (CEN) or Swedish Institute for Standards (SIS). In this report, when we write only “standard”, we refer to such an approved standard.[17]

A certification scheme is the organization, governance and stakeholders that issues and holds a set of provisions (often also called standard), when these are not developed by national institutes or committees. A certification scheme is, in general, provided by some kind of commercial or non-profit organization that develops and sells the set of provisions and related services.

A company, product or process can then be certified against a national standard or against the set of provisions issued by a certification scheme. In the following, we use the term “certification scheme” more loosely, to describe both the organization and the set of provisions it issues.

3.2 Aspects included in mapping of standards and schemes

Based on the project plan and on discussions within the project group, a number of *aspects* defining mass balance standards and certification schemes, have been identified as relevant to the chemical industry. In Table 1 the chosen aspects are described.

Another important aspect is cost. The costs related to these systems consist of direct costs for the standard or to the certification organization, auditing costs for the third-party certification, the setting-up and maintenance of the book-keeping system and material management within the company itself. In addition, there are

[17] In general, the term standard can also refer to standards developed by private companies or by any other type of organization.

of course substantial added costs related to feedstock and adaptation of processes. Within the scope of this study, it would only have been possible to map the direct costs, which represent a minor part of total costs. Therefore, this aspect was excluded from the mapping.

Table 1 Aspects included in the specification of mass balance standards and certification schemes.

	Main and sub-aspects
Mass balance approach	Which principle mass balance approach is used by the standard/scheme? Based on terminology used by respective standard or certification scheme.
Raw materials certified	Is the standard/scheme applicable for renewable or recycled material, or both?
Sustainability criteria	What sustainability criteria are applied to certified material? In relation to sustainability criteria applied in the regulation for biofuel production[18],
Accounting units	Which unit is used for balancing of material use? - Mass-based, energy based or other? - Level of flexibility?
Methodology for calculation of balance	Which methodology is used for calculating the balance between output and input? - How is the yield determined? - Which kind of attributions in branched reaction/processes are allowed? - Are there special provisions dealing with the complexity of chemical processes?
Balancing period	Over which time period should material use balance? - Flexibility and credit transfer?
Product-related claims	How can the linkage to renewable/recycled raw material use be claimed for certified products?
Transparency	Are there transparent information about standard/scheme development process, documentation and certificates on the scheme web-page?
Reliability	Which aspects of organization, standard/scheme development process and stakeholder involvement may affect reliability of system?

[18] According to the EU Renewable Energy Directive.

Acceptance of other systems	Which other standards/schemes are accepted (for e.g. certified raw material) by the standard/scheme?

3.3 Overview of standards and schemes

This overview maps standards and schemes that follow a mass balance approach *and* are currently applied in the chemical industry. They have been identified primarily through discussion within the project group, contacts with industry and with representatives of certification schemes. In total, one standard and four certification schemes have been identified that falls within this scope:

- **Material balance standard** - *Bio-based products – Bio-based content – Part 2: Determination of the bio-based content using the material balance method* (SS-EN 16785-2:2018). This is, thus, an approved and mandated European, and Swedish, standard, which specifies a method of determining bio-based content in products. This standard only governs the material balance methodology.[19]
- **ISCC PLUS** – *International Sustainability and Carbon Certification PLUS*, is a certification scheme for all markets and sectors not regulated by the EU renewable energy or fuel quality directives, such as food, feed, chemical and energy markets and for technical application. It is governed by the ISCC System, which is based on a multi-stakeholder approach.
- **REDcert²** – *Scheme principles for the certification of sustainable material flows for the chemical industry*, is a certification scheme specifically focusing on the chemical industry. It builds on a certification scheme developed by BASF SE and TÜVSÜD in 2012. It is governed by REDcert, which is a shareholder organization.
- **RSB Advanced Products** – *Roundtable of Sustainable Biomaterials; RSB Standard for Advance Products* (Non-energy use).[20] It is governed by the RSB system, which is a member organization. This certification scheme focuses on products only. It includes both bio-based and recycled material-

[19] Part 1 of the same standard (SS-EN 16785-1) describes a standardized methodology for determining bio-based content using the radiocarbon analysis and elemental analysis. These standards are part of a group of standards developed by the CEN technical committee *TC 411 Bio-based products*, governing bio-based products, including standards for terminology, bio-solvents, and sustainability criteria. However, only SS-EN 16785-2:2018 has been studied in this project.
[20] Although the set of provisions prescribed by this certification scheme is named a "standard", it is thus not an approved international/national standard.

based products that are produced in segregated supply chains, and products produced in combination with fossil feedstock.[21]

- **Ecoloop** – ecoloop is a certification scheme for plastic producers, recyclers as well as processors and manufacturers of plastic products. Thus, it focuses on recycled plastics, and is more limited in scope than the other certification schemes included. It is governed by the company ecocycle.

In Table 2 all defined aspects for the standard and certification schemes listed above are summarized. All detailed references for the documentation used for this overview can be found in Sections 3.4 through 3.8, where each standard or scheme is described separately.

Table 2 Overview of all included standards and schemes. For more detailed information on each aspect, see Appendices B through F.

	Material balance	**ISCC PLUS**	**REDcert²**	**RSB**	**ecoloop**
Mass balance level[22]	Material balance for a defined product batch in a defined production unit Content need to be verifiable by C14 analysis	Mass balances for batches of material are kept strictly site, company and material specific	Mass balances for integrated sites and plants (across sites) allowed if there is a physical connection between operations	Mass balanced at site level or across connected sites at same geographic location or across sites at different locations	Physically interconnected sites at same location or different locations
Raw materials certified	Bio-based raw materials only	Bio-based and recycled raw materials	Bio-based and recycled raw materials	Bio-based and recycled raw materials	Waste-based plastics only
Sustainability criteria	Not included. Sustainability criteria are defined in another standard for bio-based products	ISCC 6 principles. Beyond EU Renewable Energy Directive for biofuels. Waste definition according to EU	Minimum EU Renewable Energy Directive equivalent for biofuels Waste definition according to EU waste directive Greenhouse gas	RSB 12 principles. Beyond EU Renewable Energy Directive for biofuels. Waste definition according to EU waste directive Greenhouse gas	Waste-based, definition according to EU waste directive

[21] Within this certification scheme the term “mass balance” is not used (see further Section 3.7)

[22] This is the general mass balance level at which the standard and schemes, respectively, focus on. For more detailed descriptions and specific cases, see next sections and the case studies.

		waste directive[23] Greenhouse gas calculations optional	calculations optional	calculation required (minimum -10%)	
Accounting units	Dry mass only	Mass, volume, energy (lower heating value) or carbon	MBU (mass balance unit) – based on lower heating value (LHV)	Feedstock equivalent – based on chemical value	RMU (raw material unit)
Methodology for calculation of balance	Calculation of material balance, defined as comparison of mass quantities of inputs and outputs, using conversion factors that describe loss of input material to output material, for a defined product batch, in a defined production unit	Calculation of mass balance for specific product and feedstock in specific site, using conversion factors that describe loss of input material to output material. Free attribution is possible if it is chemically/ technically possible.	Amount of fossil-based raw materials replaced by certified product, types of certified material interchangeable. (Bio and recycled separated.)	Quantity of fossil feedstock needed for production based on actual production records (acc to ISO 14044). If more than one feedstock is needed, these are normalized to chemical value.	Recycled feedstock at the beginning of the value chain is allocated to the product, so that input and output match. Product specific.
Balancing period	Defined time period	3 months; positive credits can be transferred	3 months; positive credits can be transferred (max 12 months)	3 months; positive credits can be transferred (max 12 months)	Defined prior to assessment. Valid for max 12 months.
Product-related claims	Bio-based content, in percentage	ISCC Compliant. MIX supporting certified sustainable/ recycled material *or share of product* supporting sustainable sourcing of bio-based/ recycled material	Fossil resources saving product/ This product entails a x% substitution of fossil with renewable/ recycled raw materials	This RSB compliant product entails a x% substitution of fossil with renewable/ recycled raw materials	Certified products made a contribution to recycling management. Four classes, based on proportion (%)

[23] Directive 2008/98/EC on waste or Waste Framework Directive, which sets the basic concepts and definitions related to waste management.

Transparency	Standard available at SIS[24]	All scheme documentation, certificates, summary audit reports, withdrawn certificates and suspended operators published on web-page	All scheme documentation, valid and in-valid certificates published on web-page	All scheme documentation, certificates, summary audit reports, terminated and with-drawn certificates published on web-page	Information, but not full documentation, and valid certificates published on web-page
Reliability	Standard available at SIS	Multi-stakeholder approach, including NGOs and scientific organizations. ISCC Integrity program[25]	Shareholder approach with supporting committees	Multi-stakeholder approach, including NGOs and scientific organizations. Stakeholder consultation obligatory prior to certification.	Network approach
Acceptance of other systems	Not applicable	Only ISCC	All EU approved, FSC/PEFC	RSB plus some other, depending on feedstock	Accepts comparable standards, such as ISCC PLUS, REDcert[2] and RSB AP.

Common for the four certification schemes (i.e ISCC PLUS, REDcert[2], RSB AP, and ecoloop) studied are that the verification and compliance of the scheme requirements, as well as the issuance of scheme certificates are performed by recognized third-party certification bodies.

They also include requirements of a certifiable book-keeping system, keeping track of inputs and outputs of certified materials and products, and have very similar requirements on balancing over time periods in this system. Further, balancing only includes raw material used for material purposes, and not energy use.

Common to the schemes is also that the product-related claims that can be made cannot refer to bio-based content, but to the sourcing of bio-based/recycled material or to the substitution of fossil resources. This is clearly stated in all

[24] Standards available at Swedish institute for standards (SIS), via www.sis.se

[25] The ISCC Integrity Program includes independent on-site assessments to verify conformity of auditors performance and operators performance.

schemes. To be able to claim a bio-based product, via the use of mass balance, one needs to fulfil the criteria of mandated material balance standard.

There are differences in their approach for the use of mass balance accounting unit (mass, energy, carbon), but at the analysis level of this study, these differences cannot be verified as being significant to the application of the various schemes.

There are, however, clearly relevant differences in the **methodology used for mass balance calculations**, in aspects related to **governance and overall organization**, and in approach towards **sustainability criteria**. Below, the standard and four certification schemes included are therefore described, from the perspective of highlighting these aspects. In the case studies (see Chapter 4), differences in balancing methodology are further explored.

The International Trade Center also provides a benchmarking platform called the Sustainability Map (or Standards Map), through which sustainability aspects of different standards and certification schemes can be compared. The service is supported by Germany, Switzerland, EU, USAID and Sweden.[26]

3.4 Material balance standard

The full name of this standard is Bio-based products – Bio-based content – Part 2: Determination of the bio-based content using the material balance method (SS-EN 16785-2:2018).[27] This standard is part of a group of horizontal and vertical standards developed by the CEN technical committee *TC 411 Bio-based products*, governing bio-based products, including standards for terminology, bio-solvents, and sustainability criteria. The development has been commissioned by the European Commission and if regulation is introduced that relates to the production of *bio-based products* these standards should (mandated by law) be followed. Currently, there is no such EU regulation in place. This is thus an approved European and Swedish standard, and, in contrast to the other schemes described below, not a private certification scheme. In this report it will be referred to as the *material balance standard*.

[26] See https://www.sustainabilitymap.org/standards Note that it is important to choose exactly the right standards (and potential add-ons) to receive a relevant comparison.

[27] Part 2 refers to there being also a Part 1 (Bio-based products – Bio-based content – Part 1: Determination of the bio-based content using the radiocarbon analysis and elemental analysis, SS-EN 16785-1:2016), which is a standard relevant for segregated production chains. Both have been prepared by the Technical Committee CEN/TC 411 “Bio-based products”.

As indicated in the overview above, this specific standard focuses entirely on the balancing methodology, and does not include provisions for e.g. sustainability of the bio-based feedstock used. The other standards for bio-based products, governing such aspects have not been studied as part of this project.

The material balance standard is applicable to any solid, liquid and gaseous bio-based product containing carbon, obtained by chemical synthesis, mixing or assembling. The balance is made for a *product batch*, for which the composition of the product and the bio-based content of each input, output and losses in the production unit are known. Further, a measurable bio-based content in the product of each specific batch should be verifiable by analysis.

According to this standard, the balance should be based on dry mass for a defined time period corresponding to a representative product batch. The definition of a product batch is an identified collection of products, manufactured consecutively or continuously under the same conditions, using the same materials conforming to the same specifications. The batch is defined by the product manufacturer and can stretch over a longer time period (months or a year).

By establishing a material balance for such a representative product batch the bio-based content can be calculated, and should be expressed as a percentage. What distinguishes this standard from the certification schemes below, is thus that a *bio-based content* can be calculated and claimed based on this standard. In addition, a validation of the calculated bio-based content in a specific batch, by radiocarbon analysis or elemental analysis, can be requested by the customer.

Companies that choose to follow this standard for their material balance calculations can then in principle be certified against this standard by an independent certification body. There are, however, as of yet, no certifications made based on this standard. This means also that the interpretation of the standard has not been widely tested against real cases, which add uncertainty. The authors of this study interpret that the standard prescribes limited variations in the physical product content.[28] According to a representative involved in the Swedish mirror group to the technical committee larger flexibility would be possible. For further implications of these differing interpretations, see also Case study 1. It is not questioned, however, that the material balance standard prescribes a relatively strict application of mass balancing principles.

[28] Based on formulations in the standard and discussions with with the Swedish Standard Institute

3.5 ISCC PLUS

The ISCC PLUS is a certification scheme, included in the International Sustainability & Carbon Certification (ISCC) system, run by ISCC System GmbH. ISCC is the largest of the studied certification systems, in terms of number of certified companies and products with over 3700 valid ISCC certificates[29], of which 314 ISCC PLUS. It can be used to certify a large range of different types of feedstocks. The organization of ISCC is based on a multi-stakeholder approach, with about 130 different member organizations, from industry, NGOs and scientific organizations.

The main ISCC certification schemes are the ISCC EU, for certification of biofuels according to the EU renewable energy or fuel quality directives, and the ISCC PLUS. ISCC PLUS is, thus, a certification system for all markets and sectors not regulated by those directives, such as food, feed, chemical and energy markets and for technical applications. Through the ISCC PLUS both physically segregated supply chains and supply chains based on the mass balance approach can be certified. Which chain of custody that is used should be clearly stated in the sustainability declaration. In the following – and at all other sections of this report – only the provisions allowed under the mass balance approach is discussed.

The documentation used for this analysis consists of ISCC PLUS System Document Version 3.1 (2 July 2019), ISCC PLUS 204-01 Mass-Balance Requirements (28 June 2016)[30], ISCC 203-01 Guidance for the Certification of Co-Processing (23 November 2016), and ISCC 208 Logos and claims (30 January 2019). In addition, representatives of ISCC have been interviewed, and been given the opportunity to review the scheme specific descriptions in this report.

The characteristics of ISCC PLUS in relation to the **methodology used for mass balance calculations**, **governance and overall organization**, and **sustainability criteria** can be summarized in the following way:

1. The ISCC PLUS mass balance certification is strictly **site, process and product specific and ensures chemical and technical traceability**

[29] Both ISCC EU and ISCC PLUS certificates, as of November 2019. Here, it should be noted that it is difficult to compare the number of certificates between certification schemes, since the scope of each certificate varies widely.
[30] In January 2020 a new version of ISCC PLUS provisions has been made available for public consultation, but is not yet valid and has not been reviewed as part of this project. As part of the development work, the ISCC PLUS 204-1 has been made unavailable at the ISCC web-page.

The mass balance principle used by ISCC PLUS traces the production of each certified product, through each process step based on its input, output and losses of each certified feedstock separately. Further, the certification is always performed separately for each company site. In this way the mass balance accounting system relates always to specific products produced in specific processes that are actually used at the specific site. Free attribution of certified characteristics to a specific product is allowed, but only if output can be chemically and technically based on respective feedstock in existing equipment at the specific site.

2. The ISCC PLUS is also, through the ISCC organization, developed within a **broad multi-stakeholder approach and a transparent process**.

   The ISCC has a broad member organization, with representatives from industry, NGOs (e.g. WWF and Deutsche Umwelthilfe) and scientific organizations. It has also several active technical committees and operates the monitoring program ISCC Integrity Program, which is used to continuously monitor the performance of the ISCC System Users and Certification Bodies cooperating with ISCC. All scheme documentation and detailed information about all certificates (including information about suspended system users and fake certificates, and summary audit reports) is available on the web-page. Further, fundamental changes of the scheme is published for public consultation.

3. The scheme has a strong focus on maintaining **credible sustainability criteria** for feedstock and for the entire chain-of-custody.

   For biomass, the same criteria are applied as for ISCC EU, which includes six sustainability principles, which together form provisions above the minimum criteria included in the regulations for biofuels in the Renewable Energy Directive. For example, the principles include safe working conditions and compliance with human, labor and land rights. These principles are applied through the entire supply chain. Calculation of GHG emissions is however voluntary within the ISCC PLUS.

A couple of other notable comments, in relation to ISCC PLUS, are:

- The product-related claims that are allowed refer to the share of product content contributing to the support of certified sustainable, recycled or biogenic sources based on a mass balance approach. Claims referring to bio-based content are not allowed.
- The scheme does not accept certification by other certification schemes, which is motivated by their strict sustainability criteria.

- ISCC PLUS is not specifically developed for the chemical industry and this is visible in the documentation. It is in some cases difficult to interpret which parts that are relevant for these applications.

For detailed extracts from ISCC PLUS documentation, in relation to all the aspects defined above, see Appendix C.

3.6 REDcert^2

The REDcert^2 is a certification scheme, included in the REDcert certification system, run by REDcert GmbH. REDcert is the second largest of the available certification systems, in terms of number of certified companies and products. It has, in total about 1850 valid certificates, of which 72 are for REDcert^2.[31]

The main REDcert schemes are REDcert-EU, for certification of biofuels according to the EU Renewable Energy Directive in combination with other European regulations[32], and the REDcert^2. REDcert^2 is, primarily a certification system for food and feed industry and for material use within e.g. chemical industry. There are specific scheme provisions for material flows in the chemical industry, which are the only ones that have been included in this study.[33] The REDcert^2 scheme was launched for food and feed in 2015 and then extended for material use (chemical industry) in 2018 by integrating the CMS 71 standard from TÜVSÜD, originally developed by TÜVSÜD in collaboration with BASF. REDcert^2 is entirely based on the mass balance approach. In November 2019 it was revised to include also recycled material from fossil sources.

The documentation used for this analysis consists of REDcert^2 Scheme principles for the certification of sustainable material flows for the chemical industry Version 01 (1 November 2019) and REDcert^2 Guidelines governing the use of the REDcert^2 logo and the representation of claims for products made from sustainable material flows, Version 01 (1 November 2019). In addition, representatives of REDcert have been interviewed, and been given the opportunity to review the scheme specific descriptions in this report.

[31] For REDcert2, one certificate may include several sites with a large number of certified products. See also footnote 22.
[32] Also REDcert-DE, similar but adapted for German regulation
[33] REDcert^2 – Scheme principles for the certification of sustainable material flows for the chemical industry, Version 01, Nov 2019. (SP_RC^{2}C_Sustainable_material_flows_V1.0)

The characteristics of REDcert[2] in relation to the **methodology used for mass balance calculations**, **governance and overall organization**, and **sustainability criteria** can be summarized in the following way:

1. REDcert[2] focuses on providing a certification scheme, for chemical industry, including complex industry structures and **large chemical clusters**.

   The mass balance system used is generally what they call integrated "integrated manufacturing sites and plants". Integrated manufacturing sites and plants are defined as a physically connected arrangement of operating sites at the same location or describes the physical connection of production sites across different locations by dedicated transport routes (e.g. pipelines) without any supply to or from external parties. Such a system can then be considered a single site. This means that several sites within the same company can be treated as one mass balance system, given that material flow within the system can be followed through a certifiable account management system.

   In addition, the scheme includes an option for certification of an "extended mass balance" (EMB) system, which makes it possible to transfer credits within the system, without transportation of product, given that a number of specific conditions are met. This option is further described in Case study 3.

   The mass balance calculations are based on **generalized Mass Balance Units** (MBUs), which all bio-based feedstocks and flows are converted into. As a result, different types of certified feedstocks will be interchangeable in the overall balance into final products, for the entire certified mass balance system. The site certificate is complemented with an annex specifying further operating sites (for an integrated system), and for each sub-site only products that are actually produced at that site can be certified. However, due to the interchangeability of certified feedstocks (e.g. different types of bio-based feedstocks), the production need not be physically linked to the actual certified feedstock used, but could be physically produced from another certified feedstock.

2. The REDcert organization is based on a **shareholder approach**

   The shareholder approach used by REDcert does not involve a broad stakeholder group, as the ISCC PLUS and RSB organizations. There is an advisory committee (consisting of two shareholders, one company representative and one branch representative from the German chemical industry) and recently a wider stakeholder group has been formed, which held their first meeting in the fall of 2019. All scheme documentation is available at the web-page, as well as information about all certificates. However, the

certificate information is not very detailed, and information about specific certified products can in many cases not be found (within the scheme it is optional for operators to publish this information).

3. The REDcert2 **sustainability approach** prioritizes openness towards other certification schemes.

   The REDcert^2 scheme accepts all other certification schemes approved by the EU commission for certification of biofuels according to the Renewable Energy Directive. As a result, the sustainability criteria are at the minimum level in relation to this directive, even if we have not looked closer of the criteria applied by REDcert EU itself (which may well be stricter). The motivation is to support acceptance and material use for various kinds of biomass at the beginning of the supply chain. Calculation of GHG emissions is voluntary within the scheme.

A couple of other notable comments, in relation to REDcert^2, are:

- The product-related claims that are allowed refer to that the product leads to certain share of substitution of fossil with renewable (or recycled) raw materials. Claims referring to bio-based content are not allowed.

For detailed extracts from REDcert^2 documentation, in relation to all the aspects defined above, see Appendix D.

3.7 RSB Advanced Products

The RSB Advanced Products (RSB AP) is a certification scheme, included in the Roundtable on Sustainable Biomaterials (RSB) system. RSB is a member organization, with about 100 members. RSB is a smaller and newer certification system than the two described above, with, in total, 15 operators with valid certificates, of which 3 are in the chemical industry. The organization is based on a multi-stakeholder approach, with members from industry, NGOs and scientific organizations.

The main RSB certification schemes consist of the RSB EU RED, for certification of biofuels according to the EU renewable energy or fuel quality directives, the RSB Global standard (for biofuel, outside the EU) and the RSB AP. The RSB AP should be used for producers of non-energy use products linked to increased use of bio-based feedstock or recycled materials and is the only one that has been studied here. The RSB AP includes three different chains-of-custody, for products that are bio-based; products from non-biogenic end-of-life products or production residues

(waste); and mass-balance. In the following – and in all other sections of this report – only the provisions allowed under the mass balance approach is discussed.

The documentation used for this analysis consists of RSB Standard for Advanced Products (Non-energy use), Version 2.0 (7 December 2018), and RSP Principles and Criteria 01-001 Version 3 (9 November 2016). In addition, a representative of the RSB organization has been interviewed, and been given the opportunity to review the scheme specific descriptions in this report.

The characteristics of RSB AP in relation to the **methodology used for mass balance calculations**, **governance and overall organization**, and **sustainability criteria** can be summarized in the following way:

1. RSB AP certify systems consisting of **one site, to several sites at the same location to sites at different locations.**

   RSB AP has thus broad system boundary for their mass balances and are also, in principle, open to certify different legal entities as one system. The focus is instead that the operator has control of the book-keeping system so that double-booking can be avoided. In fact, RSB AP, in their documentation actually avoids the term mass balance altogether and describe it instead as "certification of products produced in a production system that processes bio-based feedstock or non-bio-based end-of-life products of production residues in combination with virgin fossil feedstock".

   The balancing methodology is quite similar to the one used by REDcert2, and uses generalized feedstock equivalents, which are based on the feedstocks **chemical value** (depending on process). The calculation of the feedstock demand is based on the actual product records of the certified product (i.e. bill of materials), so that losses are taken into account. Similar to the REDcert^2, different types of certified feedstocks will thus be interchangeable in the overall balance into final products, for the entire certified system. For each site, however, specific products are certified, based on the sites' actual production of those products. However, due to the interchangeability of certified feedstocks, the production need not be physically linked to the actual certified feedstock used.

2. RSB AP is a **multi-stakeholder organization** with **a transparent process**

   The RSB have members from industry, NGOs (e.g. WWF and NRDC), government and research (e.g. FAO, NREL, UNEP). The members are organized in five different "chambers"(grower & producers; end users, blenders & investors; Social; Environmental; UN, governments & research).

Development of the scheme is based on consensus so that all chambers have to approve new or revised RSB documents. All scheme documentation and detailed information about all certificates (including information about suspended, terminated and withdrawn certificates, and summary audit reports) is available on the web-page.

3. RSB AP also has a **strong sustainability focus**.

   Certification according to RSB AP requires fulfillment of 12 RSB sustainability principles, including a strong focus on social aspects such as human and labor rights and rural and social development and non-GHG related environmental aspects. In addition, calculation of GHG emissions is included as a requirement, with at least 10% GHG emission reduction. RSB AP recognizes some other certification schemes, depending on the type of certified feedstock, but not all EU Renewable Energy Directive approved schemes. Recognition is based on a benchmark analysis.

A couple of other notable comments, in relation to RSB AP, are:

- RSB AP allows balancing over disconnected sites without any geographical limitations, provided that double-counting can be avoided. Therefore, RSB does not use the mass balance terminology in its scheme documentation.
- The product related claims allowed are linked to the product leading to a certain share of substitution of fossil with RSB certified biomass (or waste recycling) in the production system. Claims referring to bio-based content are not allowed. Claims referring to GHG emissions must not refer to the carbon footprint, but to the GHG emissions avoided in the system boundary.

For detailed extracts from RSB AP documentation, in relation to all the aspects defined above, see Appendix E.

3.8 Ecoloop

The ecoloop certification scheme is provided by the ecocycle GmbH in Germany. The ecoloop scheme is a relatively new certification scheme (launched 2018), which only certifies the supply chain for products from recycled plastics. The certification system was adapted from various other schemes and standards[34]. They

[34] Such as EN ISO 14021:2016 (for environmental declarations, TÜVSÜD CMS 71 (on which REDcert2 is based, see above), EuCertPlast (for plastic recycling) and RAL UZ 30a (Blue Angel, a German eco-label).

have, in total, 13 certified operators with, in total about 60 certified products. The scheme includes provisions related to both mechanical and chemical recycling. Here, we have only included the provisions related to the latter. The development process and the governance of their scheme was, at the time of this study, not very clear from their web page, and overall less information is available on this scheme than the others studied.[35]

The documentation used for this analysis consists of ecoloop general requirements Version 0.9 (29 October 2018), ecoloop modul 1 Version 0.9 (29 October 2018), and ecoloop modul 3 (29 October 2018). This documentation is not available on the ecoloop web-page, but has been received after direct contact with the company. In addition, a representative of the ecocycle organization has been been given the opportunity to review the scheme specific descriptions in this report.

Based on a review of available ecoloop documentation and their web page, the main characteristics can be summarized in the following way:

- The scheme can be used to certify recycled (or waste-based) plastics and is directed towards plastic producers, recyclers as well as processors and manufacturers of plastic products.
- The ecoloop scheme control the mass balancing system for conversion of waste based raw materials into products. The scheme can be used for certification based on mass balance for an integrated chemical production system, consisting of either physically connected production sites at same location or of operating facilities over different locations by means of dedicated transportation systems. Balancing is permitted over different operating units and the balancing methodology based on generalized raw material units, similarly to REDcert^2 and RSB AP.
- The product claims refer to that the product made a contribution to recycling management (and thereby leads to the substitution of virgin fossil by recycled raw material).

For a more detailed description of ecoloop in relation to all the aspects defined above, see Appendix F.

[35] It should be noted that the scheme description is based on available documentation only. No interviews have been performed with the organization.

4 Applied case studies

4.1 Choice of case studies

The purpose of the case studies is, as described above, to provide more concrete examples and thereby increase the understanding of differences between the standard and certification schemes studied. Four case studies have been identified, that illustrate different situations that may be relevant to the implementation of mass balance certification, in order to increase the production of certified products within the chemical industry. The four case studies were developed in cooperation with representatives from the project participants connected to the chemical companies in Stenungsund - Borealis, Perstorp and Sustainable Chemistry 2030 – and has been discussed and approved by the entire project group.

The analysis performed consists of applying different standards or certifications schemes to each of the case studies. This means that for each case study, we describe to what extent it would have been possible to certify the sustainable material used, according to the provisions of each of the included systems.

Based on the overview of available standards and certification schemes (see Chapter 3), the project group decided to apply the material balance standard, and the certification schemes ISCC PLUS, REDcert[2], and RSB AP to the case studies.

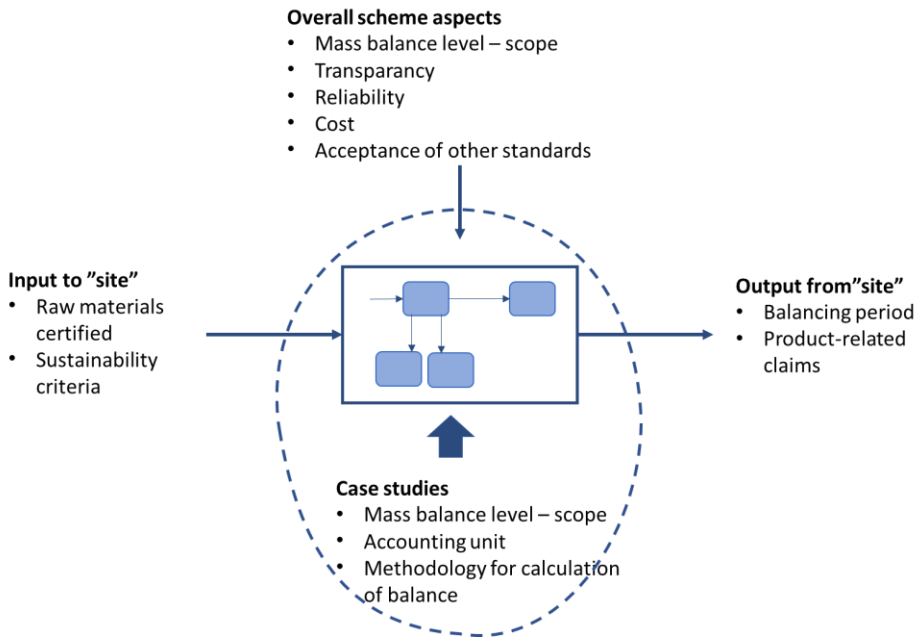

Figure 1 The case study analysis focuses on the aspects related to the overall scope and mass balance approach applied by each certification scheme, accounting units used, and the methodology for calculation of the mass balance

Each case study describes a specific set-up of production site(s) and processes of a company. They are, thus, developed to illustrate the certification schemes' treatment of those specific aspects that vary depending on site and process (see Figure 1). Thus, the case study analysis focuses on the mass balance approach and methodology applied in each standard or scheme.

4.2 Case study 1: Bio-based and recycled feedstock

4.2.1 Description of case 1

In case 1, company A aims at certifying one of their products, based on a mass balance approach. The company consists of two process units (A1 and A2) at the same geographical site. In this case, an existing plant (A1) in company A produces a drop-in chemical (product 1) from a feedstock containing a share of certified biomass and/or recycled material.[36] The certified feedstock is mixed with the fossil feedstock. The products out from A1 are the same as if only fossil feedstock is used, but the product mix distribution and yield can be affected when certified feedstock is added, since the composition of a bio-based feedstock may be slightly different from the corresponding fossil feedstock.

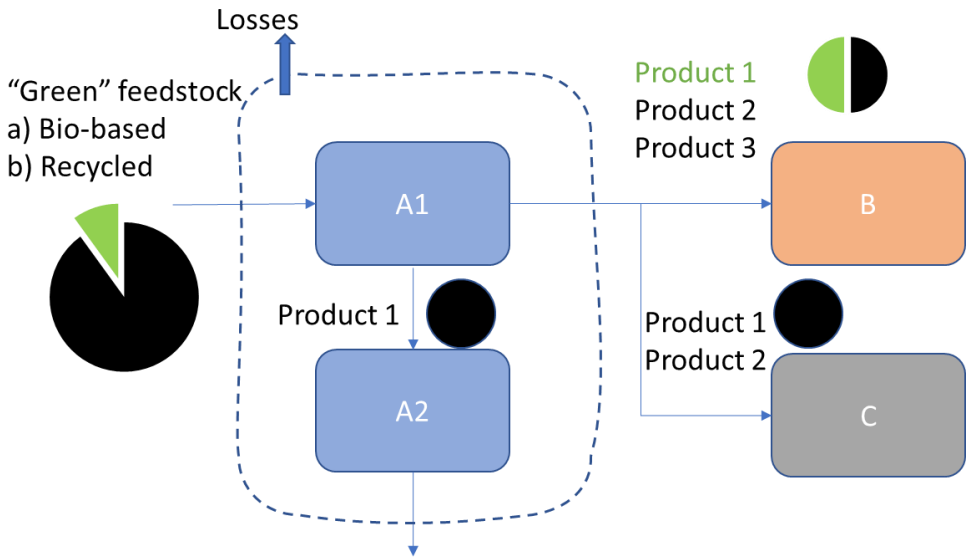

Figure 2 A1 is producing a product (Product 1) that is used in A2 but also sold to companies B and C. Some of the fossil feedstock (black) to A1 is replaced by bio-based or recycled feedstock (green). The dotted line represents the mass balance boundary.

Product 1 is used within the company itself, in plant A2, but also sold to companies B and C. In this case study all the certified Product 1 would be sold to company B,

[36] In the following, "certified" feedstock, material or product is used to denote that they are linked to certified biomass *or* recycled raw material use.

while the internal usage of the same product, and the product sold to company C, would be un-certified (fossil). Companies B and C are connected by pipeline to A1, and all companies are located at the same geographical site (see Figure 2).

The analysis of Case study 1 aims at answering how the provisions of respective standard or certification scheme answer to the following questions:

- Is it possible to certify products based on both bio-based and recycled feedstock, as well as a mixture of both?
- Can all the certified material be attributed to one of the products from A1, even though all the products out from A1 will physically contain some of the certified material?
- How can the amount of certified product be calculated, in relation to the amount of certified feedstock?

Case 1 can be seen as a base case, used to illustrate the principle mass balance concept and to clarify the different balancing approaches used. The description is therefore somewhat more elaborate for this case than for the others.

In addition, a section that extends the discussion about the balancing methodology, beyond the actual situation in this case study is included (see Section 4.2.4). The methodology for calculating the certified output in relation to certified input material, and the possibilities to attribute certified content to specific products (here called the balancing methodology) depend on the type of process, and composition of feedstock. Therefore, two additional examples have been added. We have chosen to include this discussion under Case 1, since it will aid the understanding also of the following cases.

4.2.2 Analysis of Case study 1

Below, each of the questions above is analysed separately, and the related provisions of each of the certification schemes are described and discussed.

Is it possible to certify products based on both bio-based and recycled feedstock, as well as a mixture of both?

The **material balance standard** only includes balancing principles for the use of bio-based feedstock.

The three **certification schemes** can all be used to certify products based on both biomass and recycled material. However, the schemes have been adapted to include recycled material more recently.[37] There is, thus, less experience with

[37] RSB AP included recycled feedstock in 2018 and REDcert[2] as late as November 2019.

certification of these value chains, and there are few concrete examples of issued certificates.

In all schemes, it is also possible to use a mix of bio-based and recycled feedstock. However, the book-keeping needs to be kept separate for these two types of material flows.

Can all the certified material be attributed to one of the products from A1, even though all the products out from A1 will physically contain some of the certified material?

According to the report authors' interpretation of the **material balance standard,** such an attribution is not possible. Then the provisions are interpreted to require that total amount produced from bio-based raw material of *each product* in the process need to coincide with the amount which is technically possible to produce (see the left side of Figure 4). The balancing calculation is made for a representative batch, which can stretch over an extended period and is defined by the operator. This is interpreted as meaning that the balancing only takes place between different time periods within this batch. A batch is defined as a collection of products manufactured under the same conditions, using the same materials conforming to the same specification.

According to a representative of the Swedish mirror group to the technical committee responsible for development of this standard, the standard could also be interpreted as if free attribution (see the right side of Figure 4) is possible, given that no other raw materials are needed to produce the product (labeled as "Alternative interpretation", below). However, this type of process was not discussed during standard development.

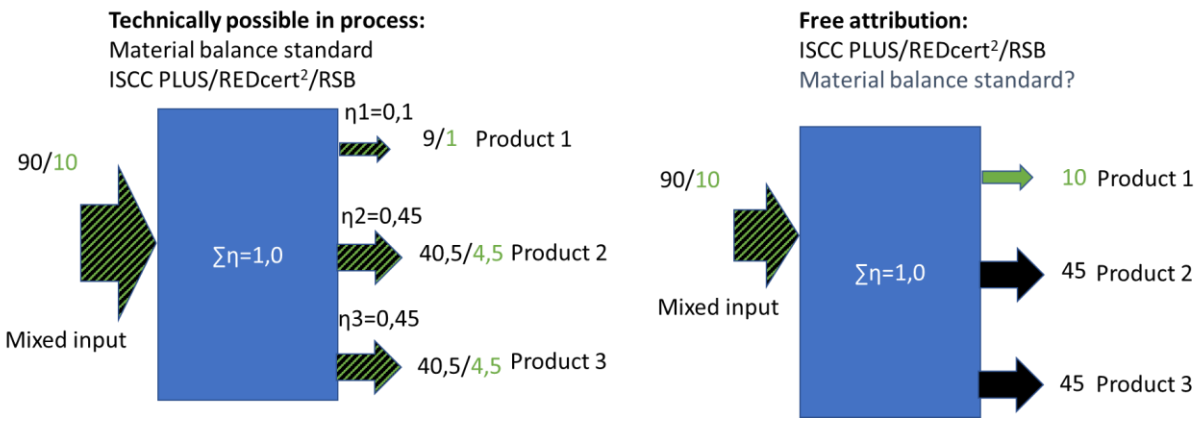

Figure 4 Mass balancing based on technically possible amounts of each product (to the left) and with free attribution (to the right). The example has been simplified by assuming a total product yield of 100 %. Since stricter limitations are always possible, balancing according to the principles on the left could be done in all standards and schemes studied.

All three certification schemes included allow mass balancing with free attribution, which means that all certified material can be attributed to one product, even if the process inevitably results in a mixture of different products, as is described through the flow scheme to the right in Figure 4.

The **ISCC PLUS** allows free attribution, **only** if the product can be chemically/technically based on the actual certified feedstock put into the process and in the actual process equipment installed at the actual site.

The **REDcert²** and **RSB AP** schemes, base their approach on "equivalent units", which are based on the amount of fossil-based feedstocks required for the production of the respective substance equivalents and make different types of for instance bio-based materials interchangeable within the system (see also Section 4.2.4 and case studies 2 and 4).

How can the amount of certified product be calculated, in relation to the amount of certified feedstock?

For the material balance standard and all certification schemes, the total output of certified product is restricted by the amount of certified feedstock used, after accounting for process losses, or phrased differently, in relation to product yield.

According to the **material balance standard**, the inputs, outputs and losses should be specific for each feedstock used, each process step and each product.

For all **certification schemes**, the input of certified material can be multiplied with the overall product yield to get the output of certified material and linked to the product's bill-of-material.[38] This means, that for a process, in which 100 units of feedstock results in the production of 50 units of one product and 40 units of another, the overall yield of 90% can be applied to any one product, instead of 50% and 40%, respectively. This is the implication of free attribution, as described to the right in Figure 4.

Still, the provisions guiding the calculation of the yield differ between schemes.

For certification by **ISCC PLUS** the yield should be calculated for the specific site, process equipment and feedstock. It can be based on either mass, LHV or carbon content. If the certified feedstock has different properties compared to the fossil feedstock and results in a different overall yield, then this yield should be used.

[38] In the chemical industry, each product has its own bill-of-material, specifying the inputs needed and other process specific data. In these, the material need for each product only reflects the share of feedstock attributed to this specific feedstock, so that all bill-of-materials add up to the actual amount of feedstock used.

Losses are calculated as the part of the raw material that does not go into marketable products.

For certification by **REDcert²**, the calculation of the yield is based on how much fossil fuel is avoided when using sustainable feedstock. The conversion of certified materials to mass balance units is based on lower heating value (LHV), standardised to a clearly defined substance (e.g. methane). The MB equivalents entered into the book-keeping system do not have to be differentiated by their raw materials (as long as they are all e.g. bio-based) and are therefore interchangeable.

The REDcert² certification is based on an audit of the specific products certified for each site.[39] However, the actual technology for conversion of feedstock into products need not be used at the site. Thus, more generalized conversion rates, based on other sites or literature and on fossil-based equivalent feedstocks may be used. The energy content of the input is thus used to calculate how much certified feedstock can be attributed to the product. The yield is based on the bill of material and use allocation based on the LCA-method.

For certification by **RSB AP**, the calculation is based on the same principle as REDcert2, with the calculation of equivalent units. RSB AP, however, uses the term feedstock equivalent, and bases this on the chemical value of feedstocks, which may differ between processes (LHV, mass or carbon). The calculation of the feedstock demand is based on the actual product records of the certified product (i.e. bill of materials) so that losses are taken into account. The operator shall account for differences in product yields as well as additional inputs, such as energy or other chemicals, which may be required when using this feedstock. However, also in RSB AP, the equivalent units are, after being entered into the book-keeping system, interchangeable.

4.2.3 Summary of Case study 1 results

Question	Material balance	ISCC PLUS	RED-cert²	RSB AP
Is it possible to certify products based on both bio-based and recycled feedstock, as well as a mixture of both?	Only bio-based feedstock	YES	YES	YES
Can all the certified material be attributed to one of the products from A1, even though	Authors' interpretation: NO	YES	YES	YES

[39] It is, however, optional to the company to issue publicly available product certificates within the scope of the audit process. A site certificate with an annex (if applicable) of further existing operating sites is always issued.

all the products out from A1 will physically contain some of the certified material?	Only the physical (average) share in each product is certified. Alternative interpretation: YES Given that no other raw materials are needed to produce the product			
How can the amount of certified product be calculated, in relation to the amount of certified feedstock?	Site and process specific, based on bio-yield	Site and process specific, based on bio-yield	Based on fossil fuel avoided, normalized by LHV	Based on production data (e.g. yield), normalized to chemical value if more than one feedstock

4.2.4 Extended analysis of balancing methodology

To clarify the balancing methodology, two additional examples have been included here, even if they are not directly applicable *the specific situation described in Case 1*.

Figure 5 shows a strongly simplified example with two different organic feedstocks which both are needed in a process. Thus, the output materials can only partially be chemically/technically based on feedstock 1, but both are produced in the same process unit.

According to **ISCC PLUS**, the principle of free attribution allows that all certified feedstock is attributed to one product (Product 1, in Figure 5). However, in contact with ISCC they recommend that the company claims a share of certified feedstock directly linked to the raw material share in the product (in this case 50%, se Figure 5), to maintain transparency towards their customers.

The principles used for the **REDcert**[2] and **RSB AP** schemes, which make different feedstocks interchangeable, mean that it is accepted to attribute all certified input to Product 1. However, the different chemical values of feedstock 1 and 2 have to be considered in the calculation.

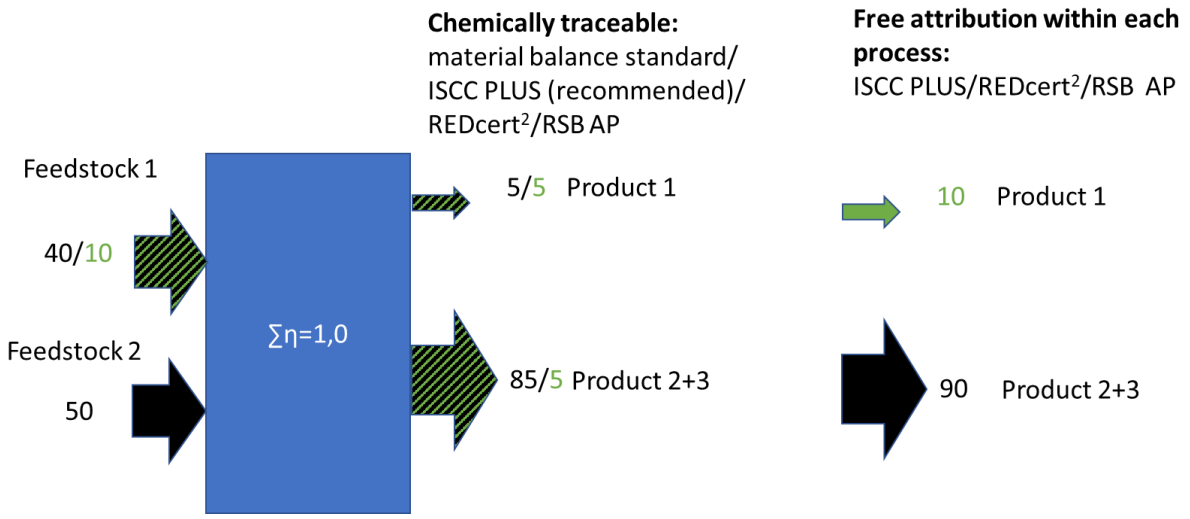

Figure 5 Example of attribution allowed in a process with two different feedstocks, which are both needed in equal proportions to produce products 1, 2 and 3, but where feedstock 2 is not sourced from sustainable feedstock at all. The example has been simplified by assuming a total product yield of 100 %. In addition, the potential effect on output units, which would be a result of different chemical values of feedstocks 1 and 2 is not reflected. As in Figure 4, balancing according to the principles on the left could be done in all standards and schemes studied, since stricter limitations are always possible.

In Figure 6, another process unit is included in the production system. This process unit also uses a feedstock, which cannot be (or is not) sourced from certified sources and produces another product.

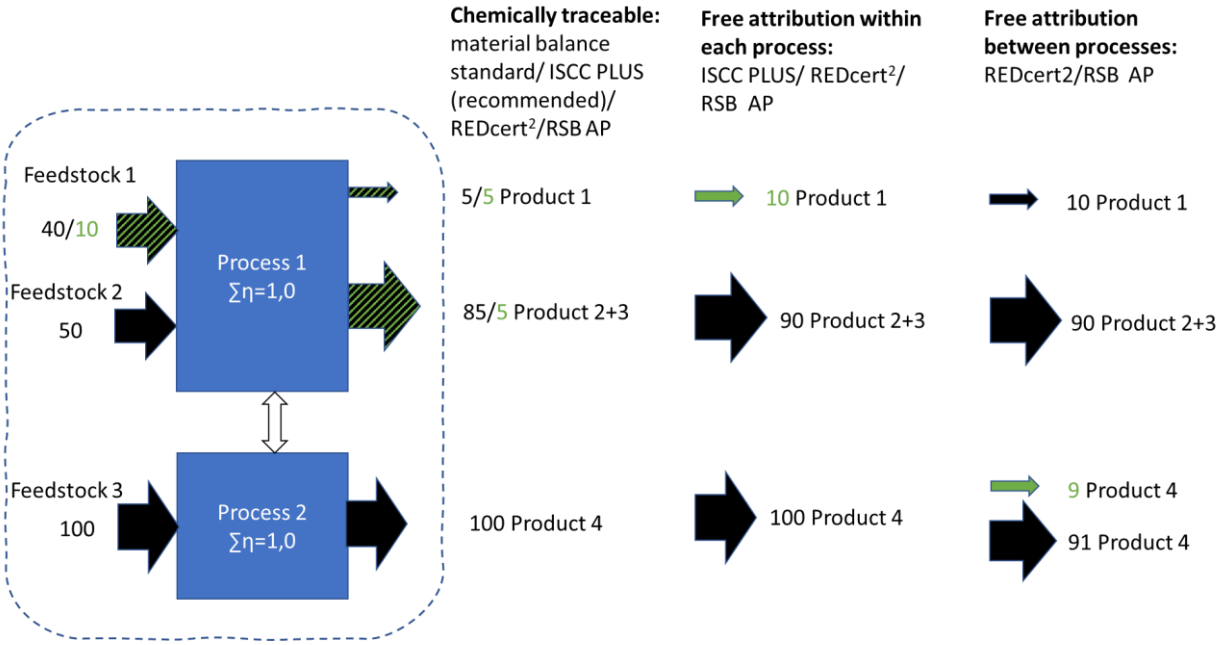

Figure 6 Example of attribution allowed in a mass balance system with two different processes, producing different feedstocks. The example is simplified, e.g. by assuming a total product yield of 100 %.

In this case, **ISCC PLUS** does not allow that the certified feedstock is attributed to Product 4, which in this example is produced in a different process unit. The

scheme requires that the certified product can be produced from the certified input in the process unit on the site where this material is used.

The principle used **by REDcert²** and **RSB AP** allows also that the certified feedstock is attributed to Product 4, that thus is produced in a different process. However, for both these schemes the different chemical values (e.g LHV) of feedstocks 1, 2 and 3 need to be taken into account. Also, for REDcert² it is vital that there is a dedicated connection between process 1 and process 2 (see Figure 6). This does not mean that the certified material needs to be actually transferred between these units.

The impact of different chemical values could be understood through the following example: The production of 10 kg of product 4 requires 10 kg of feedstock 3. However, if the LHV of feedstock 1 is only 90% of that of feedstock 3, 10 kg of feedstock 1 would only result in 9 kg of product 4 (as indicated in Figure 6).

4.3 Case study 2: 100 % Bio-based production unit

4.3.1 Description of case 2

In Case 2, company A adds a new biomass-based process unit and aims thus at producing certified products based on mass balance. The company consists then of three process units (A1, A2 and A3) at the same geographical site. In this case, A3 is producing the same product (Product 1) as one of the products from the unit A1 but based on a different process and from a bio-based feedstock. Company A would sell some of the certified product produced in the unit A3 to the company B. Since the company B is connected by pipeline to A1, the product sold from company A to company B will always be physically delivered from A1 (see Figure 7).

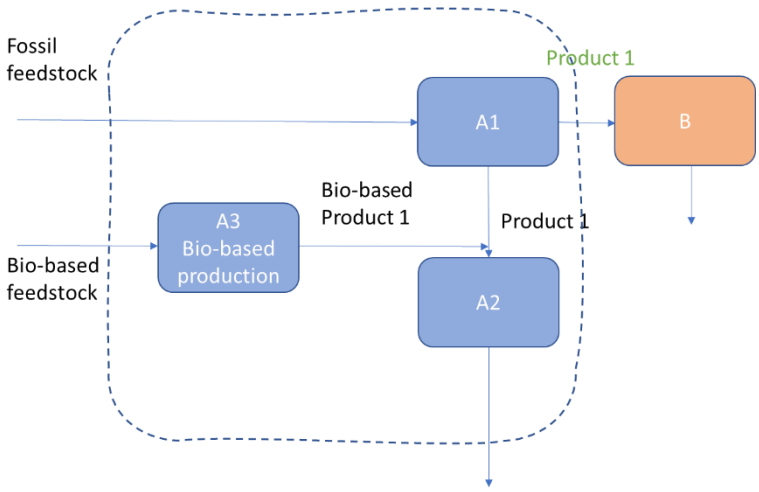

Figure 7 A bio-based product (Product 1) produced by Company A, replaces some of the same product, produced from fossil feedstock, sold to Company B.

The analysis of Case 2 aims at answering how the provisions of respective standard or certification scheme answer to the following questions:

- Can a certified product be sold to company B even though the product sold will always be physically delivered from A1?
- How does the introduction of a new feedstock and process affect the calculation of the amount of certified product in relation to the amount of certified feedstock?

4.3.2 Analysis of Case study 2

Below, each of the questions above is analysed separately, and the related provisions of each of the certification schemes (when differing) are described and discussed.

Can a certified product be sold to company B even though the product sold will always be physically delivered from A1?

According to the **material balance standard** this would not be allowed. Bio-based content in the product needs to be verifiable by analysis. However, if the pipeline between A1 and A2 was a two-ways pipeline, so that (at least some of) the product from A3 could be delivered to the company B, it would be possible.

The delivery of certified Product 1 to company B is allowed under **all certification schemes** included and follows from the overall mass balance principles, in which the accounting system is used to keep track of products sold, and not the physical content of the product. When a company has a certified product, it can thus be sold to any customer regardless of the type of transportation or linkage to the production site. It should also be noted, that the schemes' varying provisions that relate to physical connection, regulate the connection *within* the certified mass balance system.

How does the introduction of a new feedstock and process affect the calculation of the amount of certified product in relation to the amount of certified feedstock?

In this case, the differing methodology for balance calculation between schemes would make an impact on the amount of certified product that can be sold, in relation to the amount of certified feedstock used. The principle differences are important, but the actual practical differences would, in most cases be small.

Calculation of output based on the **ISCC PLUS** provisions, would use the yield of the actual new process unit needed to produce Product 1 from bio-based feedstock (A3). The calculations would be the same for the material balance standard.

Calculation of the amount of MB equivalents, according to the **REDcert**[2] provisions, would be based on the relation in terms of LHV between the fossil feedstock used for production of Product 1 in plant A1 and the LHV of bio-based feedstock.

These calculations can be exemplified in the following way: Assume that the heating value of the fossil feedstock is 44 GJ/ton and the heating value of the bio-based feedstock only 30 GJ/tonone ton. Then, if one ton of Product 1 can be produced from one ton of fossil feedstock then, one ton of certified Product 1 would require 1.47 tons of certified feedstock. The same production could also be linked to one ton of a bio-based feedstock with the same heating value (44 GJ/ton) as the fossil and if the certified feedstock was pyrolysis oil with a heating value of 40 GJ/ton it would require 1.1 tons of certified feedstock. Thus, the product yield would always take the differences in LHV into account. [40] When there are large differences in the efficiency of the technical processes, apart from this, the conversion factor should also be adapted. However, in general the process efficiency is based on the fossil process that the new process would be substituted for.

Finally, according to **RSB AP**, the feedstock equivalents most suitable for the processes used would be chosen by the operator (company A). For the chemical value chosen, the value should be determined based on the quantity of this feedstock that is required to produce one unit of product, in relationship to other feedstocks. In determining the chemical values, the operator shall account for differences in product yields as well as additional inputs such as energy or other chemicals, which may be required when using this feedstock. The yield is thus adapted to the change of feedstock.

For the RSB AP certification, the operator would need to assess the fossil feedstock demand based on ISO14044, normally documented by the production recipe / bill of materials for the production of the specific product. In any case, the different chemical values need to be taken into account for the different feedstocks (as in the example above). Also, in this case, there would be two different pathways in the certification site to produce Product 1 with different yields. ISO 14044 assessments are required to be conservative – only assuming the pathway with the best yield in the assessment would not be accepted in this case.

[40] Note energy consumption for cracking or dehydration is out of scope in the mass balance approach.

4.3.3 Summary of Case study 2 results

Question	Material balance	ISCC PLUS	RED-cert[2]	RSB AP
Can a certified product be sold to company B even though the product sold will always be physically delivered from A1?	NO (see comment above)	YES	YES	YES
How does the introduction of a new feedstock and process affect the calculation of the amount of certified product in relation to the amount of certified feedstock?	Yield calculated based on actual feedstock and process unit.	Yield calculated based on actual feedstock and process unit.	For the different feedstocks, the yields are adapted based on differences in LHV.	Based on ISO 14044, assessment needs to be conservative. For different feedstocks differences in their chemical values need to be taken into account.

4.4 Case study 3: Transfer of credits between countries

4.4.1 Description of case

In Case 3, there is one company (company A) that owns two production plants (A1 and A2), which are located at separate sites in different countries (see Figure 8). The company would like to produce a certified product (Product 1) in plant A2, and transfer credits to its plant A1, so that it can sell certified Product 1 from this plant.

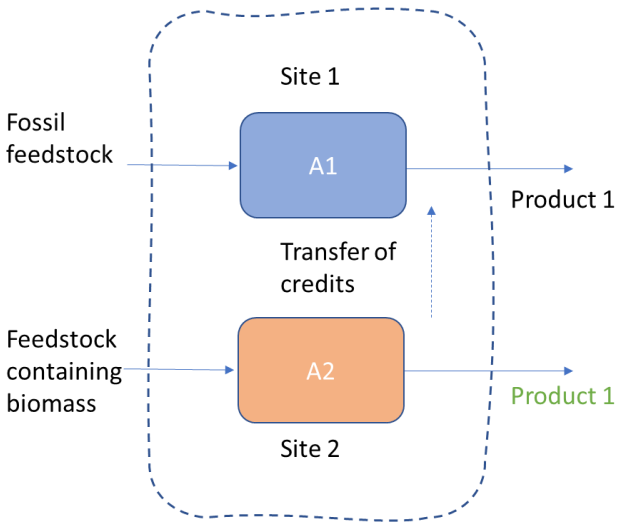

Figure 8 Two sites in different countries within the same company, which produce identical products in identical processes, only from different feedstocks.

The analysis of Case 3 aims at describing how the provisions of respective standard or certification scheme answer to the following questions:

- Is it possible to transfer credits from A2 to A1 so that A1 can sell certified product to their customers, without transferring material?
- Does the more specific locations (e.g. geographical closeness) and other linkages between sites have an impact?

4.4.2 Analysis of Case study 3

Below, the two questions are analysed together since they are closely linked to each other and relate to the same provisions of each of the certification schemes.

Is it possible to transfer credits from A2 to A1 so that A1 can sell certified product to their customers, without transferring material? and **Does the more specific locations and other linkages between sites have an impact?**

The transfer of credits would not be allowed in any situation, according to the **material balance** standard.

Within the **ISCC PLUS** there are specific provisions, that could allow this type of credit transfer, given that a number of conditions are fulfilled. Credits may be transferred between sites[41] given that: a) they concern the same company, b) concern the same product, c) mass balances are kept strictly site-specific, d) ISCC certification are in place for all sites and issued by the same certification body. In addition, the sites must be located within national borders, or within neighbouring countries sharing an inland border. Thus, for ISCC PLUS the transfer in Case 3 is possible, *provided* that the countries where A1 and A2 are located share an inland border. Consequently, the use of this specific provision, does not exempt the general requirement that a company needs to certify each site separately, and do all calculations based on site specific data. Further, ISCC PLUS requires a statement on the sustainability declaration, clearly expressing if a multi-site credit transfer was applied.

In the **REDcert2** scheme**,** the alternative system definition called an extended mass balance (EMB) can also allow this kind of transfer, given certain conditions. According to EMB a transfer is possible between two plants within one mass balance system without a physical connection, given that both plants are under operational management of the same company, products are identical, all sites have a valid certificate and the distance between the sites are at a maximum of 2,000 km. In other situations, transfer of mass balance units – which can origin from different certified feedstocks – is only allowed if products representing the same amount of MBUs are physically transported between sites. The interchangeability of MBUs makes it irrelevant, though, exactly which physical products that are transported.

[41] Processing units and storage facilities certified under ISCC PLUS.

The **RSB AP** certification system allows certification of sites at different geographical locations. Both sites need to be included in the scope of certification so that the accounts can be assessed by the auditor to verify that double-booking does not occur. Within the specified system border, the scheme allows attribution from one plant to another without physical transportation, and without any specific limitations in terms of location.

4.4.3 Summary of Case study 3 results

Question	Material balance	ISCC PLUS	RED-cert[2]	RSB AP
Is it possible to transfer credits from A2 to A1 so that A1 can sell certified product to their customers, without transferring material?	NO	POSSIBLY, since the case concerns the same product, and the same company. The sites also need to be separately ISCC PLUS certified by the same certification body.	POSSIBLY (according to EMB definition), since the case concerns identical products, and the operating sites are under the operational management of the same company. The sites also need to be REDcert[2] certified and have a valid certificate.	YES
Does the more specific locations (e.g. geographical closeness) and other linkages between sites have an impact?		Further, sites need to be located in same country or in countries that share an inland border.	Further, sites need to be within 2,000 km from each other.	NO, but Sites A1 and A2 must be in the same scope of certification so that RSB auditors can assess the accounts and verify that there is no double booking

4.5 Case study 4: Use of a fictional process unit

4.5.1 Description of case

Case 4 includes a production process that never is realised but can act as a fictional process unit with a fictional output of certified material.

Waste material from company A's process unit A1 and company B's process unit B1 is used to produce a marketable product in the (real) process unit A2 (Product 1). Product 1 *could* potentially, chemically/technically, be converted to Product 2. Product 2 is the same chemical that is used as an intermediate in company B's process unit B2 and could thus be used in there. However, to

physically produce Product 2 from Product 1 would require that an additional plant be constructed. In Case 4, this plant is not built, but the companies would, through mass balance certifications, like to transfer credits from Product 1 to Product 2, in order to be able to use a certified product 2 in Company B for production of a certified product out from process unit B2.

Figure and Figure show the same process setup but with different system borders. In Figure , Product 1 is produced at company A (in process unit A2). Company A would certify the production of Product 1 and sell credits to Company B. Product 1 would actually be used in process A3.

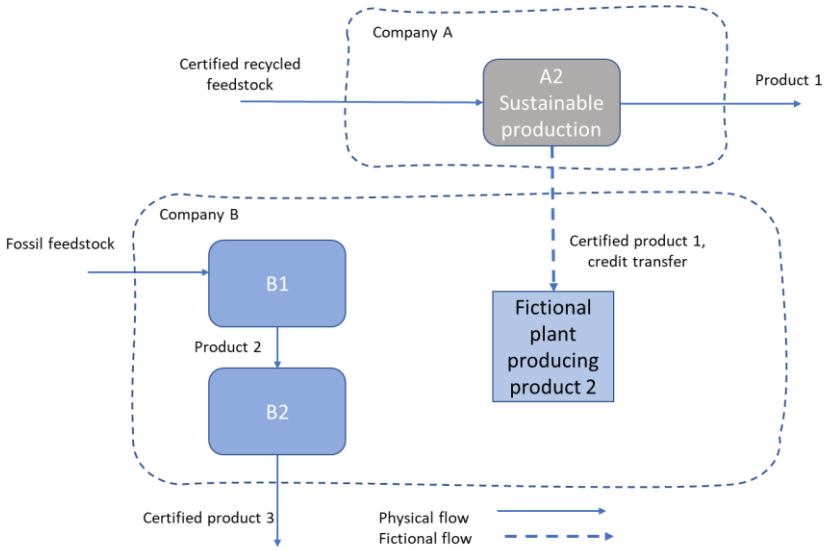

Figure 9 In case 4, the certified product 1 could be converted into an intermediate be used in company B. However, the fictional process unit is not built. The actual production of Product 1 takes place in company A.

In Figure , Product 1 is produced in the same way, from recycled waste material from A1 and B1, but at Company B (in process unit B3). In this set-up the input of certified waste material and the production of the final product (from process B2) is within the system limit of the same certified system (company B).

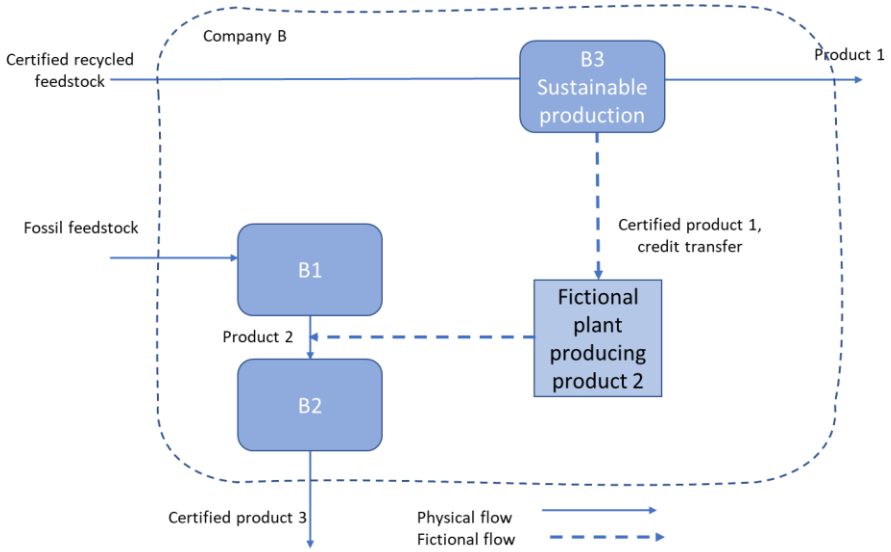

Figure 10 This flow sheet illustrates the same principal case, but with an alternative set-up, in which the actual production of certified product 1 takes place in Company B.

The analysis of Case 4 aims at describing how the provisions of respective certification scheme answer to the following question:

- Would the set-ups described above make it possible for Company B to sell a certified product?

4.5.2 Analysis of Case study 4

Below, the question above is analysed for each of the certification schemes.

Would the set-ups described above make it possible for Company B to sell a certified product?

According to the material balance standard and the ISCC PLUS this would not be possible. These clearly require that the product need to be possible to make from actual input in existing equipment. The same is true for the RSB AP, which also requires that a real facility is constructed.

According to REDcert^2, it would be impossible according to the set-up in Figure 9, since Company A is not allowed to sell only the credits for the recycled product to Company B (without selling the physical product).For REDcert^2, it would however be possible with the set-up described in Figure 10, where company B buys a physical (and certified) waste material from company A. Then the mass balance equivalents could be transferred to any of Company B's products within its own mass balance system, provided, that there is a dedicated connection between process units B2 and B3, and that Company B has a certificate for the product chosen.

4.5.3 Summary of Case study 4 results

Question	Material balance	ISCC PLUS	RED-cert[2]	RSB AP
Would the set-ups described above make it possible for Company B to sell a certified product?	NO	NO	NO, according to Figure 9 YES, according to Figure 10	NO

5 Communication of mass balance in chemical industry

As described in Chapter 1, the main focus of the communication work package has been to achieve a higher knowledge and acceptance for the mass balance principles outside of the project group. The main defined activities of the work package therefore included formulation of purpose and message for the communication, analysis of target groups and stakeholders as well as definition of communication activities.

5.1 Purpose of communication work package

The purpose has been to create understanding and acceptance of the mass balance principles amongst the key stakeholders. A first step has been to clarify what the application of mass balance methods means in the chemical industry and why the use of it is critical for a shift to sustainable feedstock. The aim was to provide guidance on how to communicate jointly about the merits and effects of the mass balance methods. In this work package the focus has been on crystallizing a joint, common message from all actors in the project about the mass balance principle.

5.2 Organization

For this work package, there has been a dedicated working group, consisting of representatives from Nouryon, Perstorp and Hållbar Kemi 2030. Johanneberg Science Park has been leading this work package. The working group have made a stakeholder analysis for defining target groups and have worked on developing a joint communication aiming for creating acceptance for the use of mass balance methods.

5.3 Target groups and stakeholder analysis

The stakeholder analysis has been based on the needs of the stakeholders and the desired result of communication activities have been identified for a range of different target groups (see Table 3).

Table 3 Result of stakeholder analysis, described in terms of target groups, needs and desired result of communication activities.

Target groups	Needs	Desired result
Brand owners *E.g. IKEA, Volvo, Electrolux, Lego, etc*	Knowledge Best practices	Increased demand for mass balance-based products
Policy makers *E.g. buyers* *Marknadsdomstolen* *Svanen-märkningen*	Knowledge	Increased acceptance for mass balance-based products
Stakeholders in the project *BASF* *IVL Svenska Miljöinstitutet* *Nouryon* *Perstorp* *Preem* *Sekab* *Tarkett*	Best practice Expertise	- legitimacy - united voice
NGOs *Eg WWF, Swedish Society for Nature Conservation, Greenpeace, etc*	Knowledge of what mass balance method means, their potential impact and the alternatives when not using it.	Increased acceptance for mass balance-based products

5.4 Communication message and activities

Within the industry and among the project participants there are different views on how and what to communicate the mass balance concept. The project group did not reach consensus on a common communication message and therefore no communication material was developed from this work package. As a

consequence, no communication activities will be held within the project or with the project group as a sender.

6 Discussion and conclusions

The main conclusions that can be drawn from the mapping and case study analysis included in this study are:

- The mass balance concept - when moving beyond the basic principle towards its more detailed, and varying, applications - is complex, and not easy to understand or describe. This is a challenge also after detailed studying of relevant material and when addressing a target group within the industry with a high level of pre-understanding. For the project, a broad project group with strong industry representation has thus been vital.
- There are relatively few standards and certification schemes currently used within the chemical industry, and the experience is in general limited.[42] Although, some companies have extensive experience over a longer time period.
- The mandated material balance standard, which would need to be met if regulations for chemical industry were introduced in the EU that require shares of *bio-based* content, applies a quite strict interpretation of the mass balance approach.
- The certification schemes that are currently most widely applied by the chemical industry have some important features in common: compliance with the scheme is verified through third-party certification; a certifiable book-keeping system is required; and they all recognize that the certification cannot be used to claim bio-based content, but product-related claims need to refer to the resources used.
- There are also important differences between the certification schemes. These include primarily the methodology used for calculation of mass balance which handle the physical and chemical traceability of materials differently; the governance and organization of the scheme development; and the strictness of sustainability criteria included.
- The use of process specific case studies has been useful to increase the understanding of the various provisions in the standard and certification

[42] Even if there is a larger number of schemes developed that target the regulated biofuel industry, whose principles could be applied also for products, they cannot be used to certify other sectors without adaptation.

schemes included. However, to convey the insights needed with a limited choice of cases is a challenge.

There are several aspects which could be further explored with additional resources and differing project scope and methods. One example that would require the study of specific real life cases is a more in-depth study of the implications of varying calculation principles, including detailed treatment of integrated energy and material flows, used in the different standards and certification schemes. This would be needed also to be able to compare the cost of certification schemes. Other examples include the possibility to include more variations of case studies and a systematic comparison of company applications of mass balance approaches.

Appendices Appendix A

Contributions from participating companies, describing their respective mass balance applications

Perstorp

Mass balance

Perstorp sees mass balance as the most realistic way for chemical companies to make the shift from fossil to sustainable renewable and recycled raw materials. A strong reason to shift to sustainable raw materials is to lower the product carbon footprint to reduce climate impact. For Perstorp it is important to make sure that this is made in a sustainable holistic way, addressing all aspects of sustainability. Perstorp has certified GHG-calculations for all products based on mass balance and have chosen ISCC PLUS with high sustainability criteria.

Perstorp applies a mass balance approach since 2010 which has physical and chemical traceability. Physical traceability ensures that the sustainable raw material is transported to the actual production site and an existing process where it is used. For chemical traceability it has to be proven that the product can be made from the specific sustainable raw material and furthermore that this raw material only replaces its own share of the product.

History

Perstorp started working with mass balance for chemical products in 2009 and launched the first renewable products based on mass balance in 2010. In 2017 Perstorp launched an expanded portfolio of mass balanced, low carbon footprint products based on certified renewable raw materials. At this time the global ISCC PLUS sustainability system was available for the chemical industry. Perstorp ISCC PLUS certified its two production sites in Sweden as well as the mass balance system, the products and GHG-calculations for all certified products.

In 2019 Perstorp launched further ISCC PLUS certified products and at this time also the production plant in Germany with further products were ISCC certified, again including GHG calculations. This means that today three of our seven production plants globally are certified and producing products based on mass balance with a renewable content of 20-100 % and which are reducing the carbon footprint from 40-80 % compared to standard fossil products. In 2019 Perstorp helped customers enable a CO_2-saving of 25 000 ton CO_2 (cradle to grave[43]) by choosing renewable products based on mass balance.

[43] Cradle to gate + end of life assuming all carbon is converted to CO_2 at the end of life of the product.

BASF

Mass Balance approach

In the chemical industry, renewable or recycled feedstock is added at the beginning of the production process and allocated to the end product. This calculation-based principle offers multiple advantages: it reduces GHG emissions and fossil feedstock inputs, while the quality and properties of a product remain the same. As a result, the products can be processed exactly like conventionally produced materials.

Independent bodies audit the allocation (i.e., how the volumes of the sustainable raw material are mathematically assigned to the final product). However, at the moment, experts are still using different methods – also known as standards – for auditing and certification.

The ChemCycling™ project

With the ChemCycling™ project, BASF aims to manufacture products from chemically recycled plastic waste on an industrial scale. As we focus on plastic waste for which no high value recycling processes are established yet, ChemCycling™ is complementary to mechanical recycling. Based on the mass balance approach, the content of recycled material is allocated to the product by a third-party audited methodology. The mass allocation for recycled feedstock and the resulting Ccycled™ products are certified by ecoloop.

Biomass Balance approach

BASF’s biomass balance approach contributes to the use of renewable raw materials in BASF's integrated production system and can be applied to the majority of BASF's product portfolio.

BASF has established a closed chain of custody from the renewable feedstock it uses through to the final product. An independent certification confirms that BASF has replaced the required quantities of fossil resources for the biomass balanced product purchased with renewable feedstock.

Examples

BASF has sold certified products since 2013 and has more than 150 different products with renewable or recycled content according to a certification based on mass balance. The renewable/recycle content in these products vary between 25 and 100 percent. Examples of products include biomethanol, polyamide and polyacrylate dispersions and formulations. The certification schemes mostly used are the REDcert-EU, REDcert^2 and ecoloop schemes.

Sekab

Sekab is certified according to ISSC PLUS. Only ISCC certified bioethanol is accepted within the book-keeping system and the CO_2 reduction is calculated according to the RED (Renewable Energy Directive). Our ISSC PLUS certified product is produced from bioethanol, meaning that we have a physical connection between feedstock and the finished product and that the balance is based on the actual chemical reaction taking place between the feedstocks. Energy cannot contribute to the amount of certified product, but is only included in the calculation of CO_2 reduction. Volume produced follows the actual chemical reaction formula, losses of material is deducted in the method and the efficiency is calculated. Under ISCC, the maximum timeframe for a mass balance calculation is three months. ISCC PLUS only accepts feedstocks from ISCC certification schemes, meaning that the feedstocks are traced from cradle to finished products.

Sekab was certified against ISCC plus 2019 for acetaldehyde. Sekab is applying the SIS/CEN standard material balance for Biobased Products since 2020 and is under the evaluation of BioPreferred for 100% biobased ethyl acetate.

Appendix B

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	Material balance	Material balance
Aspects	**Specification**	**Reference/comment**
References	European standard: Bio-based products – Bio-based content – Part 2: Determination of the bio-based content using the material balance method (SS-EN 16785-2:2018), available at Swedish institute for standards (sis.se)	Below referenced as SS-EN 16785-2:2018
Chain of custody	Material balance (which is a mass balance approach). Defined as comparison of physical quantities, expressed by mass, of inputs and outputs for a product in the manufacturing process of this product, over a specified time period	SS-EN 16785-2:2018
Mass balance level **Is the standard applicable for batch level, site level and/or group level mass balance?** **- How is this specified in the specific standard/scheme?**	Specifies a method of determining bio-based content in products using the material balance applied to a representative product batch in a production unit. (Batch level.)	SS-EN 16785-2:2018
Raw materials certified **Is the standard applicable for renewable or recycled material, or both?**	Biomass only	SS-EN 16785-2:2018

Sustainability criteria **What sustainability criteria are applied to certified material?**	Out-of-scope of standard	
	The bio-based content of a product does not provide information on its environmental impact or sustainability, which may be assessed through LCA and sustainability criteria.	SS-EN 16785-2:2018
Accounting units **Which unit is used for balancing of material use?** **- Mass-based, energy based or other?** **- Level of flexibility?**	Dry mass only If oxygen, hydrogen, and/or nitrogen elements are bound to a carbon structure derived from biomass, their fraction shall be considered to be part of the bio-based content. Elements other than C, H, O and N are not considered.	SS-EN 16785-2:2018
Methodology for calculation of balance **Which methodology is used for calculating the balance between output and input?** **- How is the yield determined?** **- Which kind of attributions are allowed?** **- Are there special provisions dealing with the complexity of chemical processes?**	The purpose of this European Standard is to provide a method for the determination of the bio-based content of solid, liquid and gaseous products, based on the accounting of materials entering and leaving the system and on traceability of the materials during processing, to ensure the physical presence of the bio-based material in the output.	SS-EN 16785-2:2018

Applicable to any solid, liquid and gaseous bio-based product containing carbon, obtained by chemical synthesis, mixing or assembling, provided that: — for a product batch, the composition of the product and the bio-based content of each input, output and loss in the production unit are known; and — the bio-based content of the product is verifiable by analysis. This method incorporates only the physical parts of the input and output stream as present in the final product, and does not incorporate material inputs for the energy to be used during the production process.	SS-EN 16785-2:2018
For a defined product batch manufactured in a defined production unit, this method, consists of: a) the quantification of the inputs, by dry mass, of the materials used for producing the bio-based product; b) the quantification of the losses, by dry mass, in the production unit, for each lost material; c) the quantification of the output(s), by dry mass, and d) the calculation of the bio-based content from these data. The traceability system of the production unit provides necessary information and data to perform the calculations. This method requires that the bio-based content of each input and lost material for the defined product batch in the production unit is known.	SS-EN 16785-2:2018
Within a defined time period corresponding to a representative product batch, the material balance for the product is established based on that the sum of input equals the total output plus losses.t	SS-EN 16785-2:2018
A traceability system, capable to provide the necessary information and to ensure the validity of all needed data required and the representativeness of the product batch considered, shall be established in the production unit	EN 16785-2:2018
Balancing period **Over which time period should material use balance?** **- Flexibility and credit transfer?**	Not specified in time, should be a defined time period corresponding to a representative product batch.	SS-EN 16785-2:2018

Product-related claims **How can certified products claim their renewable/recycled content?**	Bio-based content, expressed as a whole number percentage.	SS-EN 16785-2:2018
Transparancy **Are there transparent information about standard/scheme development process, documentation and certificates?**	Standard available at Swedish institute for standards (sis.se)	
Reliability **Which aspects of organization and process for system development may affect reliability of system?**	Approved European and Swedish standard, developed according to CEN under a mandate given to CEN by the European Commission and the European Free Trade Association. Prepared by Technical Committee CEN/TC 411 "Bio-based products".	
Acceptance of other standards **Which other standards are accepted (for e.g. certified raw material) by the standard?**	Not applicable.	

Appendix C

	ISCC PLUS	ISCC PLUS
Aspects	**Specification**	**Reference**
References	ISCC PLUS System Document Version 3.1 (2 July 2019), ISCC PLUS 204-01 Mass-Balance Requirements (28 June 2016) ISCC 203-01 Guidance for the Certification of Co-Processing (23 November 2016) ISCC 208 Logos and claims (30 January 2019).	Below referenced as: ISCC PLUS System Document V3.1-1 ISCC-PLUS-204-01-Mass-Balance ISCC 203-01 Co-Processing Requirements ISCC 208 Logos and claims
Chain of custody	-Physical segregation or mass balance Only **mass balance** alternative reflected in rest of overview	ISCC PLUS System Document V3.1-1
Mass balance level **Is the standard applicable for batch level, site level and/or group level mass balance?** **- How is this specified in the specific standard/scheme?**	Sustainability characteristics remain assigned to batches of material on a bookkeeping basis while the physical mixing of material with different sustainability characteristics and the mixing of sustainable and non-sustainable material is allowed. Mass balances shall be kept strictly site specific	ISCC PLUS System Document V3.1-1
	Under ISCC PLUS, credits can be transferred between sites under the following conditions: 1) Supplier and recipient of credits must be part of the same company; 2) Sites must be located within national borders, or within neighbouring countries (sharing an inland border); 3) Applicable only for the same kind of product; 4) Mass balances must be kept site-specific; 5) ISCC certification must be in place for all sites; 6) Certificates must be issued by the same certification body. Only under ISCC PLUS it is also possible to transfer credits between sites that are part of the same or corporate group or joint venture.	ISCC PLUS System Document V3.1-1

Raw materials certified **Is the standard applicable for renewable or recycled material, or both?**	All types of agricultural and forestry raw materials, waste and residues, non-bio renewables and recycled carbon materials and fuels	ISCC PLUS System Document V3.1-1
Sustainability criteria **What sustainability criteria are applied to certified material?**	Six sustainability principles applies equally for ISCC EU and ISCC PLUS: 1) Protection of land with high biodiversity value or high carbon stock; 2) Environmentally responsible production to protect soil, water and air; 3) Safe working conditions; 4) Compliance with human, labour and land rights; 5) Compliance with laws and international treaties; 6) Good management practices and continuous improvement	ISCC PLUS System Document V3.1-1
	Within ISCC PLUS, the verification of GHG emissions is voluntary and can be added by applying the add-on 205-01 “GHG Emissions”	ISCC PLUS System Document V3.1-1
	If the add-on is applied, this System Document can apply equally for ISCC EU and ISCC PLUS, with some differing requirements under ISCC PLUS (slightly larger flexibility in relation to data sources and basis for allocation of emissions).	
	Waste Framework Directive 2008/98/EC (Article 3) a “waste” can be understood as “any substance or object which the holder discards or intends or is required to discard”. The material has reached the end of its intended life cycle. This has to be proven by relevant documentation if the material shall be eligible for an ISCC certification. For example, the point of origin holds appropriate licenses and permits to act as a legal waste management company or is an entity that generates recovered material as defined in ISO 14021:2016.	ISCC PLUS System Document V3.1-1
Accounting units **Which unit is used for balancing of material use?** **- Mass-based, energy based or other?** **- Level of flexibility?**	Mass, volume, energy (LHV) or carbon	Interview ISCC

Methodology for calculation of balance **Which methodology is used for calculating the balance between output and input?** **- How is the yield determined?** **- Which kind of attributions are allowed?** **- Are there special provisions dealing with the complexity of chemical processes?**	The mass balance system is a chain of custody option where 'sustainability characteristics' remain assigned to 'batches' of material on a bookkeeping basis, while the physical material can be mixed. A mixture can have any form where batches would normally be in contact, such as in a container, processing or logistical facility or a conversion site. Sustainability characteristics can include information on the type and origin of the feedstock, the certification scheme of the material and relevant Add-ons. For material with different sustainability characteristics, the certified party must keep separate bookkeeping. If the input material is processed or subject to losses, appropriate conversion factors must be used to adjust the size of a batch accordingly.	ISCC-PLUS-204-01-Mass-Balance
	Free attribution possible if it is chemically/ technically possible, that the input molecular/ atoms are included in the attributed output	ISCC PLUS Certification – Overview + Interview
	Within the mass balance calculation conversion factors have to be provided for all **elements** of the production and distribution chain where company internal processes include conversion/processing or losses. The conversion factor describes the loss during the conversion of an input material to an output material and is defined as follows: C (%) = Ao/Ai * 100 C: Conversion factor Ai: Amount of process input material Ao: Amount of output yielded by the internal process based on input Ai Under the framework of the mass balance calculation the amount of sold or withdrawn sustainable products within one mass balance period should not be larger than the product of the amount Ai going into the process multiplied by the conversion factor C.	ISCC-PLUS-204-01-Mass-Balance
	In a simultaneous co-processing of bio and fossil inputs the amount of co-processed biofuels is always calculated based on the bio-yield of the process. In order to calculate the bio-output, the amount of incoming bioinputs is multiplied with the relevant bio-yield. The calculation of the bio-yield must always be site-specific and process specific, i.e. done for the process within a site, where the bio-based input material is actually used.	ISCC 203-01 Co-Processing Requirements (Noted elsewhere that these provisions also valid for ISCC PLUS, and not only biofuels)

Balancing period **Over which time period should material use balance?** **- Flexibility and credit transfer?**	The maximum timeframe for a mass balance calculation is three months	ISCC PLUS System Document V3.1-1
	Within the three months period the bookkeeping system does allow to go short of sustainable material. However, for the overall bookkeeping period, the amounts of incoming sustainable input material with specific sustainability characteristics and the amounts of outgoing sustainable output material with specific sustainability characteristics equivalent to the input material must be balanced.	ISCC-PLUS-204-01-Mass-Balance
	It is possible to transfer credits (surplus of sustainable material in the bookkeeping) from one mass balance period to the next. This is possible regardless of the amount of material in stock (sustainable and unsustainable) at the end of the mass balance period.	ISCC PLUS System Document V3.1-1
Product-related claims **How can certified products claim their renewable/recycled content?**	Logos and claims can be applied to ISCC compliant goods (on-product) or in general communication (off-product). Claims are attributes of a product or service that are announced to an audience through marketing channels.	ISCC 208 Logos and claims
	"MIX supporting certified sustainable material" - On-product logo via mass-balance in bio-based supply chains, B2C communication on ISCC certified raw material/product	ISCC 208 Logos and claims
	Share of product content "contributing to responsible sourcing of bio-based materials"	ISCC 208 Logos and claims
	"MIX supporting certified recycled material" -On-product logo via mass-balance in recycled supply chains, B2C communication on ISCC certified raw material/product	ISCC 208 Logos and claims
	B2B statements are made on the sustainability declarations (delivery notes), including the share of certified content in the product, issued to recipients of sustainable products. Certificate holders, who deliver sustainable products to other certified companies, must ensure that the information on the sustainability declarations attached to the sustainable products meet the ISCC requirements.	ISCC 208 Logos and claims

	ISCC Compliant: This statement can be made, if the entire upstream supply chain, including the cultivation or collection of the raw material (e.g. agricultural biomass or waste and residues) is ISCC certified. The material used in the supply chain consists entirely and solely of ISCC material, at least on a quantity bookkeeping mass balance basis. Only ISCC Compliant possible under ISCC PLUS. (For ISCC EU RED Compliant an alternative.)	ISCC 208 Logos and claims
Transparancy **Are there transparent information about standard/scheme development process, documentation and certificates?**	All ISCC documents available on web-page. Multi-stakeholder approach	ISCC web-page (iscc-system.org)
	Certificate information available: All certificates, including valid certificates, withdrawn certificates. Information about suspended system users and fake certificates.	ISCC web-page
	Information about valid certificates: Certificate holder, scope, raw material, add-ons, validity, certification body, the certificate and a summary audit report.	ISCC web-page
	Recently produced and published its first impact report, available via web-page	ISCC web-page
Reliability **Which aspects of organization and process for system development may affect reliability of system?**	The verification of compliance with the ISCC requirements as well as the issuance of ISCC certificates are performed by recognised third-party certification bodies.	ISCC PLUS System Document V3.1-1
	Multi-stakeholder approach with about 130 members, including industry, NGOs (e.g WWF, Deutsche Umwelthilfe) and scientific organisations (University of Illinois, Kiel Institute for the World economy).	Interview ISCC, ISCC web page, ISCC PLUS Certification - Overview
	Newly developed system documents or fundamental changes will be published for public consultation	ISCC web-page

	ISCC operates the ISCC Integrity Program, which is a tool used to continuously monitor the performance of the ISCC System Users and Certification Bodies (CBs) cooperating with ISCC to ensure and maintain the high-quality standard and credibility of ISCC	ISCC PLUS System Document V3.1-1
	Benchmarked at te Standards Map of the International Trade Center (ITC)	sustainabilitymap.org
Acceptance of other standards **Which other standards are accepted (for e.g. certified raw material) by the standard?**	Within ISCC PLUS no certification schemes other than ISCC are currently accepted. Exception for Germany, if compliance with SAI GOLD or SAI SILVER (Sustainable Agriculture Initiative)	ISCC PLUS System Document V3.1-1
	Any material used in an “ISCC Compliant” supply chain must consist entirely of ISCC material. Under ISCC EU, operators can choose to be certified as RED compliant, if other certified raw material. Not possible within PLUS Acceptances of further schemes possible upon positive benchmarking. (None so far)	
Other	Environmental management and biodiversity; Classified chemicals; GHG Emissions; Consumables (calculation of all relevant consumables along the supply chain). (Most relevant examples.) Add-ons are modules that can be applied either for the agricultural production area or for the entire supply chain on a voluntary basis.	ISCC PLUS System Document V3.1-1

Appendix D

	REDCert²	REDCert²
Aspects	**Specification**	**Reference/comment**
References	REDcert² Scheme principles for the certification of sustainable material flows for the chemical industry Version 01 (1 November 2019) REDcert² Guidelines governing the use of the REDcert2 logo and the representation of claims for products made from sustainable material flows, Version 01 (1 November 2019).	Below referenced as: SP_RC²_Sustainable_material_flows_V1.0 REDcert_Guidelines-of_using_the_logo_and_claims_V10
Chain of custody	Mass balance Process-specific or Process-spanning	Only Process-spanning mass balance reflected in rest of overview
Mass balance level **Is the standard applicable for batch level, site level and/or group level mass balance?** **- How is this specified in the specific standard/scheme?**	Integrated manufacturing sites and plants can be considered single site if there is a physical link between the operations on the site. (Integrated manufacturing site: physically connected arrangement of operating sites at the same location or describes the physical connection of production sites across different locations by dedicated transport routes (e.g. pipelines) without any supply to or from external parties.) This does not always apply to third parties that are also based on the site but not part of the company.	SP_RC²_Sustainable_material_flows_V1.0
	The REDcert² scheme allows product-specific conclusions to be drawn about the sustainably certified biomass used at a chemical site or within the scope of an extended mass balance (EMB), but does not make it possible to make statements about the percentages of biomass or waste materials contained in the products or their use for energy.	SP_RC²_Sustainable_material_flows_V1.0
	An extended mass balance (EMB) is defined as a clearly defined domain. Within the limits of this domain, a company is authorised to operate a single accounting system. The individual operating sites included in the spatial boundaries for mass balancing do not	SP_RC²_Sustainable_material_flows_V1.0

	need to be physically connected to one another. Mandatory requirements for the system-compliant compilation of an extended mass balance are as follows: • The operating sites in the spatial boundaries for mass balancing are under the operational management of the same company • The transfer of sustainability properties is only permitted for identical products • All operating sites are certified according to this document and have a valid certificate • The balance limit is a maximum of 2,000 km	
Raw materials certified **Is the standard applicable for renewable or recycled material, or both?**	Certification is possible for products with biogenic raw materials and for products containing recycled materials.	SP_RC²_Sustainable_material_flows_V1.0
Sustainability criteria **What sustainability criteria are applied to certified material?**	Protection of land with high biodiversity value or high carbon stock, protection of peatland and criteria for environmentally responsible biomass production (sustainable management)	SP_EU_Basic_Vers.05 In accordance with EU Directive 2009/28/EC (RED)
	Waste shall be defined as in Article 3 (1) of the Waste Framework Directive 2008/98/EC (WFD).4 According to this definition, waste can be understood as “any substance or object which the holder discards or intends or is required to discard”. Raw materials or substances that have been intentionally modified or contaminated to meet this definition are not covered by this definition.	SP_EU_Production_Vers.05
	Additional requirements by the REDcert concerning traceability and documentation (through self-declaration) and inspection to avoid fraud in relation to biofuels/bioliquids made from waste and residues.	SP_EU_Production_Vers.05
	Recyclable waste and residual material flows should be identified by a waste code or company must prove that the material has no other positive economic value or meaningful further use.	SP_RC²_Sustainable_material_flows_V1.0
	Calculation of GHG emissions voluntary. If reported, GHG calculations must always be individual and process-specific according to principles in REDcert-EU or LCA (ISO 14040)	SP_RC²_Sustainable_material_flows_V1.0

Accounting units **Which unit is used for balancing of material use?** **- Mass-based, energy based or other?** **- Level of flexibility?**	The mass balance equivalent is the is the standard unit for the balancing system	SP_RC²_Sustainable_material_flows_V1.0
	The conversion of fossil-based and sustainably certified raw materials is based on the lower calorific values which are standardised to a clearly defined substance (e.g. methane).	SP_RC²_Sustainable_material_flows_V1.0
Methodology for calculation of balance **Which methodology is used for calculating the balance between output and input?** **- How is the yield determined?** **- Which kind of attributions are allowed?** **- Are there special provisions dealing with the complexity of chemical processes?**	When mass balancing spans processes, it is determined what percentage of fossil-based raw materials is replaced by MB equivalents along the entire value chain. The certificate holder uses a reliable process for continuous monitoring and ensuring adequate availability of MBUs (sourcing, storage, delivery). • The conversion of fossil-based and sustainably certified raw materials is based on the lower calorific values which are standardised to a clearly defined substance (e.g. methane). • The conversion of intermediate products to the mass balance equivalent unit is based on the quantities of fossil-based raw materials required for the production of this intermediate product. It is not necessary for this technology to actually be used within the production facility. In this case, the required raw material quantity can be conservatively estimated on the basis of processes described in the literature and implemented technologically. • The conversion of sustainably certified raw materials not listed in Annex 2 a) is carried out with the same conversion factor as the fossil-based equivalent.	SP_RC²_Sustainable_material_flows_V1.0
	Bill of materials are available for the certified products. Bill of materials define the quantity of fossil-based raw materials required for the production of the respective substance.	SP_RC²_Sustainable_material_flows_V1.0

	The MB equivalents are entered into the account management system in accordance with the verified conversion rates. The MB equivalents entered into the account management system do not have to be differentiated by their raw materials and are therefore interchangeable. MB equivalents can only be entered after the raw materials have been physically transferred to the spatial boundaries for mass balancing and if it is ensured that the raw material is used for material purposes. Sustainably certified materials that are used to generate energy may not be entered in the account management system. The removal is carried out using MB equivalents on the basis of bill of materials.	SP_RC²_Sustainable_material_flows_V1.0
	The entered and removed mass balance equivalents must be managed in an account management system. If both biomass-balanced and recycled products are produced in integrated sites, multiple accounts must be maintained (in the ERP system) to the extent that the statements about the product relate to the origin of the respective raw material (biogenic and/or recycled).	SP_RC²_Sustainable_material_flows_V1.0
Balancing period **Over which time period should material use balance?** **- Flexibility and credit transfer?**	The balancing period must be agreed in advance of the conformity assessment. It may not exceed 3 months after the sale. No negative balance is allowed after the end of the mass balance period. Positive balances may be transferred as long as it is guaranteed that the validity is not exceeded. Entered MB equivalents are valid for a period of 12 months.	SP_RC²_Sustainable_material_flows_V1.0
	The balancing period can optionally be selected as sales-based or production-based. In a sales-based balancing period, the required quantity of sustainably certified materials is removed from the account management system at the time of sale. As a result, it is not necessary for the required quantities to already be available in the system during production.	SP_RC²_Sustainable_material_flows_V1.0
	The mass balance period can be extended beyond the maximum specified period of 3 months, but this must be requested in writing from REDcert, stating the reasons.	SP_RC²_Sustainable_material_flows_V1.0
Product-related claims **How can certified products claim their renewable/recycled content?**	Under the REDcert² scheme a percentage of at least 20% of the fossil-based raw materials required to make this product has been verifiably replaced by an equivalent amount of sustainably certified biomass in integrated manufacturing sites or plants or under the scope of the expanded mass balance. For the production of fossil-based	SP_RC²_Sustainable_material_flows_V1.0

	recycled products at least 20% of the fossil-based raw materials required for production must be replaced by an equivalent amount of sustainably certified recycled raw materials in integrated manufacturing sites or plants.	
	B2B claims: REDcert2 certified	REDcert_Guidelines-of_using_the_logo_and_claims_V10
	On-product claims bio-mass balanced: Fossil resources saving product" or "Fossil resource saving product by using renewable raw materials in the value chain" or "This product supports / comes with / leads to / entails a x% substitution of fossil with renewable raw materials in the value chain."	REDcert_Guidelines-of_using_the_logo_and_claims_V10
	On-product claims recycled products: Fossil resources saving product" or "Fossil resources saving product by using recycled materials in the value chain" or "This product supports / comes with / leads to / entails a x% substitution of fossil with recycled materials in the value chain."	REDcert_Guidelines-of_using_the_logo_and_claims_V10
Transparancy **Are there transparent information about standard/scheme development process, documentation and certificates?**	Documentation and certificate information on web-page	REDcert web-page (www.redcert.org)
	Certificate information available: All certificates, including valid and invalid certificates.	REDcert web-page
	Information about valid certificates: Certificate holder, raw material, validity, certification body, type of certificate, and the certificate. Voluntary for customers to specify certified product on their certificate. Certificates can be on aggregate level (e.g. BASF has one certificate with information about operating sites included.)	REDcert web-page; Interview REDcert

Reliability **Which aspects of organization and process for system development may affect reliability of system?**	The verification of compliance with the REDcert requirements as well as the issuance of REDcert certificates are performed by recognised third-party certification bodies.	REDcert web-page
	Shareholder approach. Advisory Committee and independent neutral Sanctions Committee. Technical committee recently formed, first meeting in fall 2019.	REDcert web-page Interview REDcert
	Benchmarked at the Standards Map of the International Trade Center (ITC)	sustainabilitymap.org
Acceptance of other standards **Which other standards are accepted (for e.g. certified raw material) by the standard?**	A sustainability claim is possible if the upstream chain-of-custody is certified according to the REDcert² or REDcert-EU standards or if the sustainability certificate originates from a voluntary certification scheme that has been recognised by the EU Commission or positively assessed by the Sustainable Agriculture Initiative (SAI) or certified according to the FSC or PEFC standards or originates from another certification scheme recognised by REDcert as “equivalent”.	REDcert_Guidelines-of_using_the_logo_and_claims_V10

Appendix E

	RSB Advanced Products	RSB AP
Aspects	**Specification**	**Reference/comment**
References	RSB Standard for Advanced Products (Non-energy use) Version 2.0 (7 December 2018) RSP Principles and Criteria 01-001 Version 3 (9 November 2016).	References below as: RSB Standard for Advanced Products, v2.0 RSB-STD-01-001_Principles_and_Criteria-DIGITAL
Chain of custody	Three categories: I) Products that are bio-based (minimum 25% in product); II) Products from non-biogenic end-of-life products or production residues; III) Mass-balance (see below) Only Category III) Mass balance reflected in rest of overview	RSB Standard for Advanced Products, v2.0
Mass balance level **Is the standard applicable for batch level, site level and/or group level mass balance?** **- How is this specified in the specific standard/scheme?**	One site **or** Several sites at same geographic location which are connected with pipelines or other means of transport **or** sites at different geographic locations if operator can ensure and demonstrate for all sites that double-booking does not occur, e.g. by limiting the boundary to one legal entity or by having specific contractual relationships in place.	RSB Standard for Advanced Products, v2.0
	Products produced in a production system that processes bio-based feedstock or non-bio-based end-of-life products or production residues in combination with virgin fossil feedstock and that ensures that at least 25% of the virgin fossil feedstock needed to produce the certified product batch are replaced by alternative feedstock	RSB Standard for Advanced Products, v2.0

Raw materials certified **Is the standard applicable for renewable or recycled material, or both?**	IIIa) Products from biogenic feedstock in combination with fossil; IIIb) Products from biogenic recycled feedstock in combination with fossil; IIIc) Products from non-biogenic recycled feedstock in combination with virgin fossil	RSB Standard for Advanced Products, v2.0
Sustainability criteria **What sustainability criteria are applied to certified material?**	12 RSB principles: 1) Legality; 2) Planning, monitoring and cointiouous improvement; 3) GHG emissions; 4) Human and labour rights; 5) Rural and social development; 6) Local food security; 7) Conservation; 8) Soil; 9) Water 10) Air quality; 11) Use of technology, inputs, and management of waste; 12) Land rights Principles 3) - 12) (principle 11) only partly) are directly related to safeguarding sustainability. Only principles 3) and part of 7) and 8) are covered by EU RED sustainability criteria for biofuels/bioliquids.	RSB-STD-01-001_Principles_and_Criteria-DIGITAL
	For waste and residue material all principles except 6) and 8) apply equally.	RSB-STD-01-010-RSB-Standard-for-advanced-fuels_2.2
	The impact of the fossil reference product related to the depletion of fossil resources shall be assessed by determining the fossil feedstock needed as a material for the production. At least 25% of the fossil feedstock equivalents needed shall be substituted by alternative feedstock equivalents (bio-based or recycled). The assessment shall follow the rules as specified in ISO 14044 (2006). Cradle-to-gate **GHG emissions** need to be calculated, covering the product or the product component that the RSB claim is referring to. Certified final products intended to replace fossil derived products shall achieve at least 10% lower lifecycle GHG emissions relative to comparable fossil product.	RSB Standard for Advanced Products, v2.0
Accounting units **Which unit is used for balancing of material use?** **- Mass-based, energy based or**	Where more than one fossil feedstock type is required, the operator shall a) normalise the amount of fossil feedstock required based on the chemical value of the different feedstock types, and b) express the amount of fossil feedstock needed in one common unit (feedstock equivalent)	RSB Standard for Advanced Products, v2.0

other? **- Level of flexibility?**		
Methodology for calculation of balance **Which methodology is used for calculating the balance between output and input?** **- How is the yield determined?** **- Which kind of attributions are allowed?** **- Are there special provisions dealing with the complexity of chemical processes?**	The chemical value of the feedstocks shall be determined based on the quantity of this feedstock that is required to produce one unit of product, in relationship to other feedstocks. In determining the chemical values, the operator shall account for differences in product yields as well as additional inputs such as energy or other chemicals, which may be required when using this feedstock.	RSB Standard for Advanced Products, v2.0
	The operator shall document the amount of bio-based feedstock and the amount of feedstock based on non-biobased end-of-life products or production residues that is used as material in the system. The following feedstock shall not be considered in balance: - Feedstock that is used as energy or other auxiliaries, which will not be present in a final product (e.g. solvents, catalysts) - Feedstock that is used for the production of bio-based products.	RSB Standard for Advanced Products, v2.0
	The operator shall normalise the amount of feedstock based on the chemical value of the different types of feedstock and express the amount of new feedstock in one common unit	RSB Standard for Advanced Products, v2.0
	Operators shall have a documented book-keeping system in place to monitor the balance of alternative feedstock equivalents that have been added to the system and advanced products withdrawn from the system (i.e. sold to customers).	RSB Standard for Advanced Products, v2.0
Balancing period **Over which time period should material use balance?** **- Flexibility and credit transfer?**	Operators shall ensure that alternative feedstock equivalents and advanced product claims are balanced within a 3-month period. Within the balancing period, a deficit may occur, as long as balance is achieved over the 3-months-period. A positive balance may be reported into the next reporting period.	RSB Standard for Advanced Products, v2.0

Product-related claims **How can certified products claim their renewable/recycled content?**	Operators shall use the short claim “RSB compliant Advanced Product”.	RSB Standard for Advanced Products, v2.0
	On-product claims shall refer to e.g. the amount of primary fossil resources saved, or the amount of primary fossil carbon saved by the input of eligible feedstock in the production system, for example: “This RSB compliant product leads to a x% substitution of fossil with RSB certified biomass in the production system”	RSB Standard for Advanced Products, v2.0
	On-product claims for advanced products from fossil end-of-life products, production residues must not refer to any bio-based input and may use for example the following: “This RSB compliant product leads to a x% substitution of fossil resources by waste recycling in the production system”	RSB Standard for Advanced Products, v2.0
	If the certified component is less than 50% of the total mass content of the product, the claim should relate to resp component	RSB Standard for Advanced Products, v2.0
	Claims referring to GHG emissions must not refer to the product or a product carbon footprint but to the GHG emissions avoided in the system boundary.	RSB Standard for Advanced Products, v2.0
Transparancy **Are there transparent information about standard/scheme development process, documentation and certificates?**	All RSB standard documents available on web-page. Multi-stakeholder approach (see below).	RSB web-page (rsb.org)
	Certificate information available: All certificates, including valid, suspended, terminated, withdrawn and expired. Per continent. Informaition about suspended system users and fake certificates.	RSB web-page
	Information about each certificate: Operator, country, operator type, feedstock type, certified material, certification type, certification status, validity dates, and a Public Audit Summary.	RSB web-page

Reliability **Which aspects of organization and process for system development may affect reliability of system?**	The verification of compliance with the RSB requirements as well as the issuance of RSB certificates are performed by recognised third-party certification bodies.	RSB web page
	Multi-stakeholder approach with about 100 members and associate members, organized in five chambers (growers & producers; end users, blenders & investors; social; environmental; UN, governments and research). Examples: NGOs (NRDC, WWF), UN, governments and research (FAO, International Food Policy Research Institute, NREL, UNEP).	RSB web page
	All applications are subject to public consultation via a two week call for public comments.	RSB web-page
	Structured RSB Grievance Mechanism to handle grievances, which can be submitted by anyone	RSB web-page
	RSB is a full member of the ISEAL Alliance	RSB web-page
	Benchmarked at the Standards Map of the International Trade Center (ITC)	sustainabilitymap.org
Acceptance of other standards **Which other standards are accepted (for e.g. certified raw material) by the standard?**	If not fully RSB certified raw material a) specify the amount, b) ensure at least 25% RSB-certified, c) 100% RSB-certified within 3 years (could be 90% if shown RSB feedstock not available)	RSB Standard for Advanced Products, v2.0
	Other certificates can be accepted if benchmark study and approved.	RSB Standard for Advanced Products, v2.0
	Depending on feedstock, some certifications are accepted: Forest feedstock - FSC; some wastes other e.g. UCO - ISCC)	Interview RSB

Appendix F

	ecoloop	ecoloop
Aspects	**Specification**	**Reference/comment**
References	ecoloop general requirements Version 0.9 (29 October 2018) ecoloop modul 1 Version 0.9 (29 October 2018) ecoloop modul 3 (29 October 2018).	Referenced below as: ecoloop-questions- general part ecoloop-questions-modul1 ecoloop-questions-modul3
Chain of custody	1) Mechanical recycling; 2) Chemical recycling – mass balance	ecoloop-questions- general part
Mass balance level **Is the standard applicable for batch level, site level and/or group level mass balance?** **- How is this specified in the specific standard/scheme?**	The balancing of waste based raw materials is permissible over different operating units within an integrated chemical production system. The tern "integrated chemical production system denotes either a physically interconnected arrangement of production sites at the same location or the physical interconnection of operating facilities over different locations by means of dedicated transportation systems. Operating facilities in separated locations can be considered as interconnected.	ecoloop-questions-modul1
Raw materials certified **Is the standard applicable for renewable or recycled material, or both?**	Waste-based plastics only. The aim is to promote and increase plastics recycling at a high level and the use of waste-based plastics. A certification program for plastic producers, recyclers as well as processors and manufacturers of plastic products.	ecoloop-questions- general part

Sustainability criteria **What sustainability criteria are applied to certified material?**	Waste based raw material. Waste defined as all materials or objects which the holder disposes of or intends to dispose of or has to dispose of.	ecoloop-questions-modul1; ecoloop-questions- general part
	A visual inspection is carried out to determine whether the production process can cause exceptional environmental pollution and what existing environmental protection measures are in place.	ecoloop-questions- general part
Accounting units **Which unit is used for balancing of material use?** **- Mass-based, energy based or other?** **- Level of flexibility?**	The conversion of fossil and waste based raw materials is calculated based on RMU (raw material unit). Under the condition the raw materials are not used as energy carrier.	ecoloop-questions-modul1
Methodology for calculation of balance **Which methodology is used for calculating the balance between output and input?** **- How is the yield determined?** **- Which kind of attributions are allowed?** **- Are there special provisions dealing with the complexity of chemical processes?**	The recycled feedstock replaces an equivalent amount of virgin feedstock at the beginning of the value chain (input) to be allocated to the product (output) in such a manner that the input and output match. What happens inbetween is less relevant, as long as the balancing task can be met in a proven and reliable manner.	ecoloop-questions-modul1
	The audit includes checking the company's certificates according to other standarsds, e.g. ISO 14001, ISO 9001, ISO 18001, EMAS, TÜV SÜD CMS 71, EuCertPlast or others. (Other certificates reduce the audit effort.)	ecoloop-questions- general part

	A reliable procedure for continuous monitoring and securing of cover between procurement, storage, and delivery should be employed. The procurement quantities should be clearly labelled and confirmed by both parties (supplier and producer). The conversion of fossil and waste based raw materials is calculated based on RMU.	ecoloop-questions-modul1
	An RMU can only be included in one accounting system. For the production or sale of certified products, the appropiate proportion of waste based raw materials must be booked out of the accounting system. Book entries of RMU's into the balancing system are made in accordance with the verified conversion rates. Once trh RMU's are booked into the account they are not distinguishable from their raw material anymore and are therefore arbitrarily interchangeable. RMU's can only be booked into the account after the physical entry into the system boundary.	ecoloop-questions-modul1
Balancing period **Over which time period should material use balance?** **- Flexibility and credit transfer?**	Booking period shall be defined prior to the conformity assessment. In principle, booking periods based on sales and booking periods basen on production are acceptable as two alternatives.	ecoloop-questions-modul1
	RMU's can, basically, be kept for a period of 12 months in an accounting system. Variations from this rule may be accepted.	ecoloop-questions-modul1
Product-related claims **How can certified products claim their renewable/recycled content?**	Certified products made a contribution to recycling management. It is to be made visible that these certified products (or components) made from waste-based plastics have made a contribution to recycling management	ecoloop-questions-modul3
	Irrespective of whether the certified raw materials come from the area of chemical recycling or material recycling	ecoloop-questions-modul3
	The manufacturer of the final product can choose between indicating the exact proportion of fossil material exchanged or to indicate at one of four levels: >5<25% = low proportion; >25<50% = medium proportion; >50<75% = high proportion; >75% = very high proportion. At the levels of raw materials or indermediate products, the exact value is always indicated.	ecoloop-questions-modul3

	Guarantee of origin adds details on origin and composition of the raw material used (incl chemical or material recycling)	
Transparancy **Are there transparent information about standard/scheme development process, documentation and certificates?**	No Ecoloop documents available on web-page, only overview information about certification steps	Ecoloop web-page (ecoloop.network)
	Certificate information available: All valid certificates (one per product).	Ecoloop web-page
	Information about each certificate: Company, certificate number, audit date and certificate validity.	Ecoloop web-page
Reliability **Which aspects of organization and process for system development may affect reliability of system?**	The verification of compliance with the Ecoloop requirements are performed by recognised third-party certification bodies, but no detailed information at web-page.	ecoloop web-page
	13 network partners that "follow" Ecoloop, consisting of certified companies. No information at web-page of the role of these partners or organization of scheme development.	ecoloop web-page
Acceptance of other standards **Which other standards are accepted (for e.g. certified raw material) by the standard?**	Comparable standards such as ISCC Plus, RedCert2 or RSB Advanced Products are accepted in the ecoloop.program	Information from ecocycle