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Abstract

Promoting non-toxic material cycles in the preparation of Best Available Technique Reference Documents (BREFs)

The main instrument at the EU level to control industrial releases is the Industrial Emissions Directive (IED), particularly through the publication of BAT reference documents (BREFs) for industrial sectors, which include a BAT conclusions chapter setting a reference for permit conditions throughout the EU for IED installations. The EU action plan for the Circular Economy states that Circular Economy in industry will be promoted through the BREF documents, but so far this aspect is not reflected in concrete requirements in BREFs.

The aim of this study is to provide input on how circular economy issues can be addressed in the BREFs in accordance with this new EU policy in order to facilitate recycling, reuse and improve the uptake of secondary raw materials.

A general finding is that CE objectives cannot be reached by amending single regulatory frameworks and, instead, a systematic review of the whole regulatory system is required. IED and BREFs can promote CE objectives only to a limited extent, but, however, more can be done by making better use of the existing mechanisms in a systematic way.

Many BREFs already include BATs on waste recovery and treatment, but requirements promoting non-toxic cycles should be more concrete than at present. For example, cross-contamination of waste materials should be prevented through requirements on source separation in BREFs. More emphasis could also be put on the practical implementation of waste hierarchy, which is the leading principle in supporting efficient material cycles.

The traditional scope of IED and BREFs covers a single industrial installation from gate to gate, whereas the promotion of CE requires life cycle thinking and better connections to upstream and downstream processes. HAZBREF-project recommends introducing a BAT for chemical inventory in sectoral BREFs to support information on the chemical content of the products throughout the whole supply-chain. Product requirements may limit the use of secondary raw materials and quantitative BATs (BAT-AEPLs) in BREF documents are rarely feasible, but increased information on possibilities to use secondary raw materials would support the recovery of waste and prevent waste generation.

Keywords: Industrial Emissions Directive, BREFs, Circular Economy, hazardous substances

Tiivistelmä

Haitta-aineettomien materiaalikiertojen edistäminen teollisuuden BAT-vertailuasiakirjojen avulla

Teollisuuden päästöjä säädellään Euroopan Unionin alueella teollisuuspäästödirektiivillä (IED, 2010/75/EY). Suomessa direktiivin vaatimukset on sisällytetty ympäristönsuojelulakiin (YSL, 527/2014). Merkittäviä välineitä päästöjen sääntelyssä ovat parhaasta käyttökelpoisesta tekniikasta kertovat BAT-vertailuasiakirjat (BREF). Ne ohjaavat teollisuudelle asetettuja ympäristönsuojeluvaatimuksia, ympäristöluvitusta ja lupien valvontaa. Euroopan unioni on asettanut tavoitteeksi sisällyttää BREF-asiakirjoihin kiertotaloutta edistävää ohjeistusta. HAZBREF-projekti selvitti, millaisia mahdollisuuksia nykyinen lainsäädäntö ja ohjeistus tarjoavat tavoitteen toteuttamiseen, keskittyen vaarallisten ja haitallisten aineiden vähentämiseen materiaalivirroissa.

Johtopäätöksemme on, että kiertotaloutta voidaan edistää BREF-asiakirjojen kautta jossain määrin, mutta kiertotalousnäkökulmia ei ole niissä systemaattisesti huomioitu. Monissa BREF-asiakirjoissa käsitellään jo nyt kyseisen teollisuussektorin tuottamia jätteitä ja sivuvirtoja sekä niiden hyödyntämismahdollisuuksia, mutta nykyistä enemmän huomiota pitäisi kiinnittää materiaalien kontaminaation välttämiseen. Myös jätehierarkian toteuttamiseen sekä uusiomateriaalien käyttöön käytännön toiminnassa tulisi tarjota enemmän ohjeistusta. Esimerkiksi uusiomateriaalin käyttömäärälle ei kuitenkaan ole järkevää asettaa sitovia raja-arvoja BREF-asiakirjoissa, sillä jo yhden teollisuusalan sisällä laitosten prosessit voivat olla hyvin erilaisia eikä kierrätysraaka-aineen käyttö ole kaikkialla välttämättä mahdollista mm. tuotteen laatuvaatimusten vuoksi. BREF-dokumentit voisivat sisältää myös viittauksia muihin lakeihin, jotta kiertotaloustavoitteet tulisivat konkreettisemmin huomioitua teollisessa toiminnassa.

HAZBREF-projekti ehdottaa, että eri teollisuusalojen BREF-asiakirjoihin sisällytettäisiin vaatimus kemikaali-inventaariosta, josta kävisi ilmi haitallisten ja vaarallisten aineiden mahdollinen päätyminen tuotteisiin tai jätteisiin. Lisäksi eri toimijoiden välistä yhteistyötä tulisi syventää, jotta tieto vaarallisista aineista kulkisi koko arvoketjussa. Näin vältettäisiin vaarallisten kemikaalien kierrätys uusiomateriaalien mukana. Tuotteita koskevat vaatimukset voivat rajoittaa kierrätysraaka-aineiden käyttöä, joten kvantitatiivisia BAT:eja (BAT-AEPL:t) on harvoin järkevää asettaa BREF-asiakirjoissa. Tiedon lisäämisellä kierrätysraaka-aineiden käytön mahdollisuuksista voidaan kuitenkin tukea jätteiden määrän vähentämistä ja niiden hyödyntämisen edistämistä.

Asiasanat: teollisuuspäästödirektiivi, kiertotalous, haitalliset aineet, vaaralliset aineet

Sammandrag

Främjande av giftfria material cykler genom referensdokumenten för bästa tillgängliga teknik (BREF-dokumenten)

Det huvudsakliga instrumentet på EU-nivå för kontroll av industriutsläpp är industriutsläppsdirektivet (IED), särskilt genom publicering av BAT-referensdokument (BREF) för industrisektorer, vilket innefattar ett kapitel med BAT-slutsatser som ställer en referensram inom hela EU för IED-anläggningar. EU:s handlingsplan för cirkulär ekonomi anger att cirkulär ekonomi inom industrin kommer att främjas genom BREF-dokumenten, men hittills återspeglas detta inte med konkreta krav i BREF-dokumenten.

Syftet med denna studie är att ge input hur cirkulära ekonomiaspekter kan adresseras i BREF-dokumenten i enlighet med denna nya EU-policy, för att underlätta återvinning och återanvändning samt förbättra upptaget av sekundära råvaror.

Ett allmänt fynd är att cirkulär ekonomi inte kan uppnås genom att ändra enstaka regelverk, utan att det i stället behövs en systematisk genomgång av hela regelsystemet. IED och BREF-dokumenten kan endast i begränsad utsträckning främja mål för cirkulär ekonomi, men mer kan dock åstadkommas genom bättre användning av de befintliga mekanismerna på ett systematiskt sätt.

Många BREF innehåller redan BAT-slutsatser för återvinning och behandling av avfall, men krav som främjar giftfria cykler borde vara mer konkreta än i nuläget. Korskontamination av avfall borde till exempel förhindras genom krav på källseparation i BREF-dokument. Man kunde också lägga större vikt vid praktiskt genomförande av avfallshierarki, som är den ledande principen för att stödja effektiva materialcykler.

Den traditionella vidden av IED och BREF-dokument omfattar en enskild industrianläggning från ”grind till grind”, medan främjande av cirkulär ekonomi kräver livscykeltänkande och bättre förbindelser till processer uppströms och nedströms. HAZBREF-projekt rekommenderar att BAT-slutsatser för kemikalieinventarier införs i sektoriella BREF-dokument till stöd för information om det kemiska innehållet i produkterna i hela leveranskedjan. Produktkrav kan begränsa användningen av sekundära råvaror, och kvantitativa BAT-slutsatser (BAT-AEPL) i BREF-dokumenten är sällan lämpliga, men ökad information om potentiell användning skulle stödja återvinning av avfall och förhindra uppkomsten av avfall.

Nyckelord: industriutsläppsdirektivet, BREF, cirkulär ekonomi, farliga ämnen

Preface

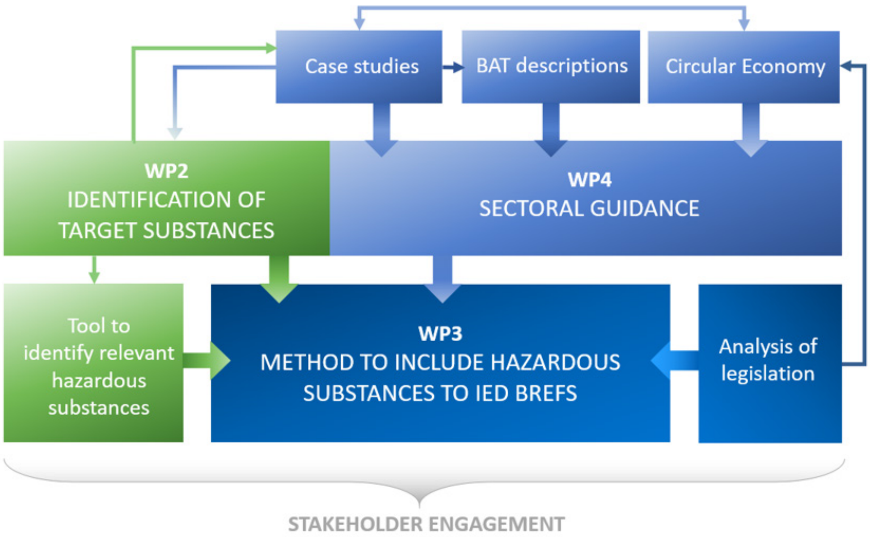
This report is a product of the HAZBREF project *"Hazardous industrial chemicals in the IED BREFs"*, its Work Package 4, Activity 4.4. The report is based on the project deliverable of 16 July 2020 'Promoting non-toxic material cycles – challenges and opportunities in the BREF process'. HAZBREF is funded by the EU Interreg Baltic Sea Region Programme (project #R056). The project started in October 2017 and finished in January 2021. The overall aim of HAZBREF was to increase the knowledge base of the industrial sources and the reduction measures of hazardous chemicals. HAZBREF identified chemicals used in industrial sectors, their use patterns, environmental characteristics and measures to prevent and reduce releases into the environment.

At the EU level the main instrument to control industrial releases is the Industrial Emissions Directive (IED), particularly through the publication of BAT Reference documents (BREFs) and their key chapter: the BAT conclusions. However, these BAT conclusions, in most cases, do not address hazardous substances in a systematic and comprehensive way. HAZBREF developed a systematic approach that will help to exchange and utilize the existing information about hazardous substances between different regulatory frameworks (IED, REACH, Water Framework Directive, Marine Strategy Framework Directive, EU provisions on Circular Economy, Stockholm POP Convention and HELCOM) in the preparation of BREFs. When the use and risks of chemicals are better addressed in BAT Reference documents, the capacity to manage industrial chemicals will be enhanced among both authorities and operators. The information gathered in BREFs is also useful for the Baltic Marine Environment Protection Commission HELCOM in the development of actions to reduce the inputs of hazardous substances into the Baltic Sea. HAZBREF also promoted the circular economy by presenting ways to include circular economy aspects in BREFs.

HAZBREF outputs target both the policy and the enforcement level. At policy level the outputs will strengthen the links between different regulatory frameworks and their key players. At enforcement level at industrial installations the project identified and presented model solutions for hazardous chemical management.

The activities were carried out in four Work Packages:

- WP1 – Project management and administration (Lead Partner SYKE), including the communication and dissemination of results
- WP2 – Identification of target substances (Lead by UBA) that include:
    - 2.1 Identification and selection of target substances
    - 2.2 Fate of substances during emission treatment
- WP3 – Policy improvement (Lead by UBA) that include:
    - 3.1 Strengthening links between regulatory frameworks at different levels
    - 3.2 Developing a method to include substance information into BREFs, improve communication and data flow
- WP4 – Best practices in chemicals management in industry (lead by IETU) that include:
    - 4.1 Sectoral guidance for three IED sectors (chemicals, textile, surface treatment of metals and plastics)
    - 4.2 Case studies in selected installations
    - 4.3 BAT descriptions and model permits
    - 4.4 Circular economy aspects.



Overview of the design of the HAZBREF-project with its four work packages.

The HAZBREF partnership includes 5 organisations from the Baltic Sea region: Finnish Environment Institute (SYKE) (Lead partner), German Environment Agency (UBA), Swedish Environmental Protection Agency (SWEPA), Institute for Ecology of Industrial Areas (IETU) and Estonian Environmental Research Centre (KLAB).

In addition, 27 associated organisations and a wide range of other stakeholders are in HAZBREF, such as ministries and governmental environmental and chemical agencies from several EU countries, permitting and supervision authorities, as well as industries and environmental NGOs. More information about HAZBREF can be found on the project website (www.syke.fi/projects/hazbref).

The following persons have contributed in preparing this report: Helena Dahlbo (SYKE), Emmi Vähä (SYKE), Topi Turunen (SYKE), Kaj Forsius (SYKE), Timo Jouttijärvi (SYKE), Eija Järvinen (SYKE), Annika Månsson (SWEPA), Mariusz Kalisz (IETU), Karl Kupits (KLAB) and Sandra Leuthold (UBA). Constructive and valuable comments were received from Staffan Asplind (SWEPA) and Johann Moltmann (UBA) and other HAZBREF colleagues, as well as from the following stakeholders: the Environment Agency Austria, European Chemical Industry Council (CEFIC), European Environment Bureau (EEB) and European non-ferrous metals association (Eurometaux).

Contents

1 Introduction

1.1 Background

The concept of circular economy (CE) seeks to minimize the need for the input of virgin materials and energy for industrial processes while reducing environmental pressures linked to resource extraction, emissions and waste. This goes beyond just waste, requiring that natural resources are managed efficiently and sustainably throughout their life cycles.

Overall, the aim of the HAZBREF project[1] was the reduction of the use of hazardous substances and better management of the used ones. From this point of interest, the following key characteristics of CE as defined by the European Environment Agency (EEA) are relevant:

- increased share of recyclable and recycled materials that can replace the use of virgin materials
- closure of material loops
- less pollution through clean material cycles
- build-up of waste minimized.

This report focuses on enabling the progress of CE by promoting clean, non-toxic material cycles through the BREF process. Clean, non-toxic material cycles directly contribute to the CE by making waste streams more recoverable as material. In addition, improved circularity may lead to more efficient material use, which again can reduce the use of hazardous chemicals. However, in many situations the material recovery of waste streams is prohibited by harmful chemicals content and provisions on environmental and human health protection.

Non-toxic material cycles can be promoted both at the beginning and at the end of a product lifecycle: 1) by ensuring that the toxic chemicals are not present in the inputs, 2) and are not used in the production processes and products and 3) by reducing the possibility for contamination in the waste management phase. In addition, the toxic contents should be separated in the material recovery processes in order to produce clean recovered materials.

To help the transition from a linear economic model to a more circular economy, where resources are used in a more sustainable way, as part of the CE Package (EU COM 2015a) the European Commission published an Action Plan for CE, called "Closing the Loop"(EU COM 2015b). According to the 2015 Action Plan: *"The Commission will include guidance on best waste management and resource efficiency practices in industrial sectors in Best Available Techniques reference documents (BREFs)[2] and will issue guidance and promote best practices on mining waste."*

The objectives for circular economy were expanded with the second Circular Economy Action Plan published in March 2020 (EU COM 2020a). This plan focuses on circular and sustainable products, circularity in production processes, as well as the waste phase. With respect to the manufacturing processes, it says that: *"In synergy with the objectives laid out in the Industrial Strategy[1], the Commission will enable greater circularity in industry by: assessing options for further promoting circularity in industrial processes in the context of the review of the Industrial Emissions Directive, including the integration of circular economy practices in upcoming Best Available Techniques reference documents."*

The recent Circular Economy Action Plan re-emphasises the role to be played by the IED and the BREFs by "assessing an option for further promoting circularity in industrial processes in the context of the review of the industrial Emissions Directive, including the integration of circular economy practices in upcoming Best Available Techniques reference documents"(EU Commission 2020b).

The CE aspects have already been taken into consideration in BREF review processes: for example, in the review of the BREF for Smitheries and Foundries (SF BREF, EIPPCB 2005) the TWG has

[1] For more information on the HAZBREF project see: http://www.syke.fi/projects/hazbref
[2] This will take place in the context of the regular planned reviews of the BREFs

concluded to decide at a later stage whether to include provisions on residue streams as KEIs in the context of Circular Economy based on data collected through plant-specific questionnaires (EIPPCB 2019a).

In order to provide an understanding of the contribution of the IED to meeting the EU objectives on CE, the Commission launched a project "IED contribution to Circular Economy" which was finalized in summer 2019 (DG ENV 2018). This project covered both the impact of the IED, its predecessor legislation and the BREFs and BAT conclusions already implemented as well as the estimated impact of the BAT conclusions adopted, but not yet implemented. The project gathered and analysed data relevant to five CE topic areas, namely the use of energy and materials, generation of waste, use of hazardous chemicals and industrial symbiosis. Based on the analysis, the IED was found to have, in general, a low contribution to achieving a circular economy. The study concluded that:

- Nearly four fifths of BATs on energy in the IED BREFs are qualitative rather than quantitative. The more recent BREFs (FDM BREF, EIPPCB 2019b and LCP BREF, EIPPCB 2017a) have a more process/subsector-specific quantitative BAT on energy use. However, many of these BATs have been declared as 'indicative'. It is unclear whether this reflects a decision to limit such BATs to be non-binding values. By doing so, this would not support the transition to a CE.
- In relation to materials use, 92% of the assessed BATs are narrative with no associated quantitative performance levels.
- The same is true for waste generation BATs of which 97% are narrative.
- In relation to hazardous chemicals use, only one BAT (in the FDM sector, related to hexane use) has a strict quantitative limit for the use of a hazardous chemical. The remaining BATs are all narrative.
- Most of the BATs on industrial symbiosis relate to the use or recycling of waste in a different process. All of these BATs are narrative.

The EU Environment Council adopted in its meeting on the 25th of June 2018 conclusions on the EU Action Plan for CE and the interface between chemical, product and waste legislation. The Council emphasized the need for information on substances of concern[3] for all actors and the need to ensure, at the latest by 2030, the traceability of substances of concern in materials through the entire supply chain. It also urged the Commission to further develop concrete actions to remove technical, financial and market barriers preventing the recovery and uptake of secondary raw materials, including effective means to avoid, remove or reduce the presence of substances of concern as much and as soon as possible to ensure non-toxic material cycles (Council of the European Union 2018a, 2018b).

The seamless flow of information on hazardous substances between operators in different phases of production within one installation and between different installations in the same value chain is crucial for enabling clean material cycles in CE. This requires bridging the information gaps between the chemical legislation and waste legislation, at a minimum on an installation level, in order to allocate the measures needed to minimize the amount of contaminated materials wisely.

In addition to the above-mentioned requirements arising from the EU Commission, a strong driver towards cleaner and more circular material flows is the economic savings potential that it has for companies. Since the disposal of waste is an environmentally and economically relevant issue for companies (Toropovs et al. 2013), it is beneficial to reduce the amount and hazardousness of wastes in order to improve the circulation of materials. This can be achieved through good management of hazardous substances used within processes.

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[3] The term "substance of concern" has not been defined in REACH Regulation or other chemicals legislation. See the European Parliament resolution of 13 September 2018 on the implementation of the circular economy package: options to address the interface between chemical, product and waste legislation (2018/2589(RSP)), p. 5:_The European parliament considered that the term should refer to SVHC substances, POP substances and specific substances, which have been restricted in Annex XVII REACH and in specific sectoral and/or product legislation. Beyond these "substances of very high concern", HAZBREF WP2 considered those substances as of concern, which have a potential to be released into the environment from the waste stream, and which, in addition, exhibit harmful effects to the environment or human health.

1.2 Findings from previous studies on IED and circular economy

Regarding the topic area hazardous chemicals, the project "IED contribution to Circular Economy" (DG ENV 2018) assessed issues on the reduction of use of hazardous chemicals and chemical substances of high concern and their substitution with safer ones. A general conclusion from the study was that, due to it's aim as an instrument to achieve a high level of protection of human health and the environment in general by reducing harmful industrial emissions across the EU, IED is not the ideal instrument to deliver CE objectives. However, in order to improve the promotion of CE in IED and BREFs, the report recommends the TWG (technical working group) of each BREF to consider whether the following suggestions could be appropriate for the sector under consideration:

- Changes to the IED, such as promoting a better uptake of emerging techniques that have a focus on CE.
- Changes in general to the content/structure of BREFs, such as including BATs on materials use, hazardous chemicals use and industrial symbiosis, and increasing the number of CE BATs set with quantitative targets. Additionally, in providing general information on the sector, an overview of the relevance of the sector to CE objectives could be included.
- Changes to the BREF process exchange of information, such as considering cross-sectoral effects and determining the value chain BAT through collaboration of upstream and downstream partners instead of focusing on determining BATs for each industrial activity separately.
- Changes to the reviews of specific BREFs, such as the TWG deciding to include hazardous chemicals as a Key Environmental Issue (KEI) for sectors in which the quantity of chemical use is relatively high and considering an additional horizontal BREF on CE.
- The need for improved data gathering and availability as to the use of hazardous chemicals in industrial sectors. The data available are generic on the use of total chemicals, but the sub-group of hazardous chemicals is not distinguished in European-wide datasets on the use and/or consumption of chemicals. Indicators such as the material circularity indicator are missing.

Concerning IED contribution to CE on hazardous chemicals use, the study concluded that BATs related to hazardous chemicals are less frequent than other CE topics covered (DG Environment 2018). Only one BAT has a strict quantitative limit for the use of hazardous chemicals, the remaining BATs are narrative. Most of the mentions on hazardous chemicals concern their minimization, and not elimination and substitution as would be desirable from the CE point of view. However, some examples were found on eliminating the use of hazardous chemicals, such as a BAT stating that a process using a dangerous chemical is not BAT (e.g. in CAK BREF, EIPPCB 2014), or recommendations given to substitute certain hazardous chemicals. Even though the substitution of hazardous substances is recommended, substitution is not always possible since there are applications/processes in which hazardous substances have a crucial role and other options do not (yet) exist (e.g. batteries).

In December 2019, the IMPEL network and the Make It Work project made available the guidance "Making the circular economy work" for inspectors and regulators (IMPEL 2019) to enable innovations for the circular economy (i.e. promoting the prevention and recycling of waste). The published IMPEL guidance claims that BREFs could lay down targets for use of recycled material in products and other relevant requirements on circularity. The BREFs should meet the practical needs of the specific sectors and material flows (IMPEL 2019, p. 56). The guidance also has some notions of BATs and BREFs. The guidance holds the following criteria relevant to CE in determination of BAT:

- use of low-waste technology,
- use of less hazardous substances, and
- furthering of recovery and recycling of substances generated and used in the process and of waste.

The IMPEL guidance also suggested:

- That Member States should encourage the development and application of emerging techniques in BREFs e.g., through temporary derogations from BAT for testing.
- That BREFs could develop the sorting of materials (such as plastics) in order to guarantee high-value secondary feedstock after recovery operations, e.g., through the development of a certification scheme along the plastic supply chain and/or a BREF for plastics recycling.
- During 2019–2020, IMPELs group on "Waste Management and Circular Economy" will continue working on the guidance on CE regulation and elaborate further e.g. on the topic of IED and CE.

Huybrechts et al. (2018) concluded in their paper "Best available techniques and the value chain perspective", that BAT-based permit regulations can potentially act as a driver or as a barrier for the greening of global value chains and for implementing sustainable supply chain management and CE. The effectiveness of BAT-based permit regulations depends on how up- and downstream activities are considered in the determination of BAT at the sector level, and in what way these BATs are implemented at the installation level. Through a study on four case sectors, it was shown that while value chain aspects are not systematically considered in the BAT process, there are examples where value chain aspects were considered, either by considering them as 'cross-sector effects', or by determining 'value chain BAT', e.g. collaboration with upstream and downstream partners. Three complementary approaches were suggested for a more systematic consideration of value chain aspects: consideration of relevant 'cross-sector effects', determination of 'value chain BAT' and selection of 'collaboration with upstream and downstream partners in the value chain' as a general BAT for all sectors. (Huybrechts et al. 2018)

1.3 Three approaches to circular economy and non-toxic material cycles

The traditional focus of BREFs is on the installation level (gate to gate thinking). However, for the purposes of a functioning CE, it is necessary to promote life cycle thinking and better connection between all value chain processes, also upstream and downstream of the installation in focus. We therefore consider and discuss the following three approaches for adding a CE focus into the BREF process (Figure 1):

1. **Production waste approach**: Focusing on the quantity and quality of wastes generated at the installation. Can requirements be given on the use of raw materials, chemicals, or the installation processes from the point of view of how they affect the amount and recoverability of production/industrial waste generated?
2. **Secondary raw material approach**: Focusing on the use of secondary raw materials (materials that can be used in a manufacturing process, instead of or alongside virgin raw materials, e.g. by-products or end-of-waste) at the installation. Can requirements be given on the quality of secondary raw materials originating from other facilities/installations/sectors to be used at the installation from the point of view of how this affects the recoverability of the wastes or products produced?
3. **Product end-of-life approach**: Focusing on the recoverability of the product at the post-consumer end-of-life phase. Can requirements be given on the use of materials, chemicals or processes at the installation from the point of view of how they affect the post-consumer product recoverability?

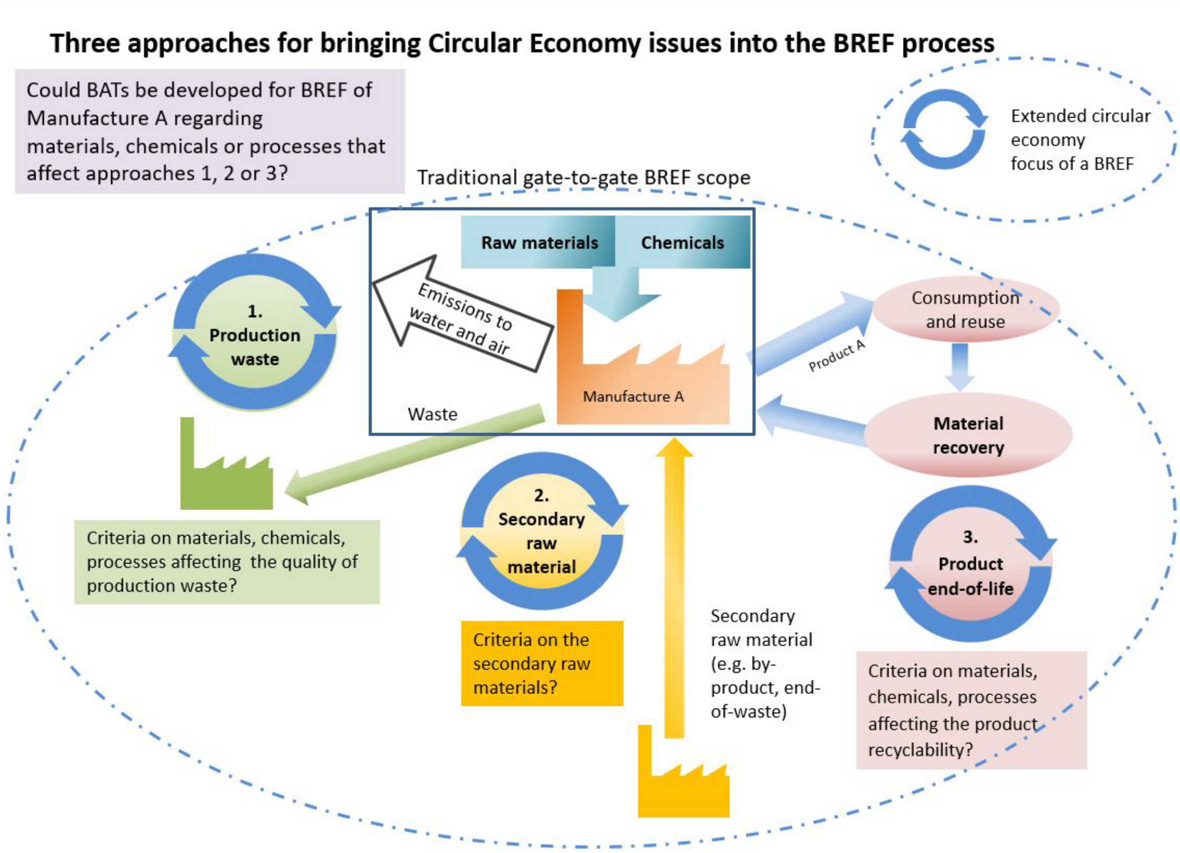

Figure 1. The HAZBREF approaches for promoting CE, specifically non-toxic material cycles, through the BREF process.

Hazardous substances are not the only factor limiting the recovery of wastes or use of secondary raw materials. Other limitations may be caused e.g. by a mismatch of other waste quality aspects with product requirements or a general lack of acceptance and markets for products made of recycled materials. Due to this problem, this report will provide a general overview of the HAZBREF case sectors' situation in waste recycling and evaluate the reasons behind it. In this report "hazardous substances" refer to the Water Framework Priority Substances (Annex X of the Water Framework Directive), Persistent Organic Pollutants listed in the Stockholm Convention[4], Substances of Very High Concern (Candidate List of substances of very high concern for Authorisation)[5] and chemicals, which might pose a danger due to their properties, and which might occur in industrial activities covered by Annex I of the IED as has been defined as "target substances" in the context of HAZBREF Work Package 2[6].

[4] All POPs listed in the Stockholm Convention. (http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx)
[5] Candidate List of substances of very high concern for Authorisation (https://echa.europa.eu/candidate-list-table)
[6] See HAZBREF WP2: Identification of target substances (https://www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Hazardous_industrial_chemicals_in_the_IED_BREFs_HAZBREF/Work_packages/Target_chemicals_WP2)

1.4 Aim of the report

The aim of this report is to:

- analyse the need and possibilities for adding CE promoting elements to the BREF process (cf. other legislation)
- propose measures to be taken for adding these elements in the BREF process
- focus on recycling/circulation obstacles generated by use of hazardous substances in the IED installations, and
- promote decreasing of pollution through cleaner material cycles (non-toxic material cycles).

Additionally, this report aims at contributing to the guidance under preparation in the EU Commission on the inclusion of CE into BREFs.

The report addresses CE aspects specifically in the three HAZBREF case sectors: polymers and fertilisers from the chemical sector, the textile sector, and the surface treatment of metals and plastics. Answers are sought to the following questions:

- How are CE issues currently dealt with in the BREF process?
- What are the legislative possibilities and barriers for including CE issues in BREFs more extensively than now?
- How could/should the CE aspects connected to the generation of non-toxic material circles be addressed in BREFs?

This report contributes to one of the aims of the HAZBREF project which is to promote non-toxic material cycles and the better tracking of substances of concern in BAT conclusions. Thus, the focus of this report is on the CE topic related to the use of hazardous chemicals and on how the BREF process could be used to promote cleaner material cycles.

2 Regulatory frameworks for material cycles

2.1 Introduction

A deeper analysis of the provisions in IED concerning hazardous substances and chemicals is provided in the draft HAZBREF report on “Analysis of interfaces, possible synergies and gaps between Industrial Emission Directive, REACH-Regulation, Water Framework Directive, Marine Strategy Framework Directive, POP-Regulation and Regional Sea Conventions (HELCOM) concerning hazardous substances” (Suhr et al. 2019). The analysis focuses on the information that is provided through different legal frameworks and which could be used in the BREF process. One of the findings of the analysis is that the BREF process should aim at utilizing the existing data instead of aiming at producing the data on the substances by itself. In particular, data provided by REACH and POP Regulations play a key role in promoting non-toxic material streams.

This report focuses directly on CE aspects. The IED and guidance on the drawing up of BAT reference documents, i.e. the BREF guidance (2012/119/EU), provide the framework and possibility to include measures on preventing or reducing waste generation and its harmfulness in BREFs. In order to provide a clear and simplified regulatory framework for the functioning of CE, contradictory and overlapping provisions should be avoided. Moreover, the BREFs should not incentivize operations and techniques that hinder the achievement of the CE objectives. However, in order to support non-toxic material cycles, BREFs could include references to the requirements in other legislation and set specific targets for the sector on issues where general targets are set in other legislation.[7]

2.2 The IED, BREFs and BREF guidance

According to the IED, the permit application of an IED installation shall include a description of used raw and auxiliary materials, other substances used by the installation (Art. 12 1. b IED) as well as a description of prevention, preparation for re-use, recycling and recovery of waste generated by the installation (Art. 12.1 h IED). The IED Article 14, on permit conditions, requires measures for emission limit values for polluting substances that are likely to be emitted. For waste generation, the requirements are only at a general level. Measures to be set for the use of raw materials or auxiliaries are not explicitly mentioned.

Annex III of the IED sets “Criteria for determining best available techniques”. In particular, four criteria relate to the CE issues in this report:

- use of low-waste technology
- use of less hazardous substances
- furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate
- consumption and nature of raw materials (including water) used in the process and energy efficiency.

The BREF guidance lays down rules on the collection of data and drawing up of BREFs and includes the following points related to raw materials and waste generation and recycling aspects:

- The chapter of the BREF guidance entitled “Applied processes and techniques” should include information which might be relevant in the determination of BAT, such as the use of raw materials (including secondary/recycled), consumables and auxiliary substances/materials used, as

[7] For example, one regulation setting waste recovery targets at sector level (e.g., “80% recovery of XXX on annual basis in every MS”) could be supported with a BAT description in the BREF (e.g., “BAT for reducing consumption of virgin raw material is to use at least 30%–60% recycled material”).

well as handling and fate of by-products and residues/wastes. (Chapter 2.3.5 of the BREF Guidance).

- The chapter "Current emission and consumption levels" should address options for the recycling and reuse of materials within the whole process or beyond. (Chapter 2.3.6 of the BREF Guidance).
- The chapter "Techniques to consider in the determination of BAT" should provide a catalogue for techniques used for preventing or reducing waste generation. The techniques described should also cover those which reduce the use of raw materials. (Chapter 2.3.7 of the BREF Guidance).
- When considering cross media effects in assessing potential BAT techniques the "Limitation of the ability to reuse or recycle residues/waste" is mentioned as one issue. (Chapter 2.3.7.2.5 of the BREF Guidance).
- Each BAT conclusion is to indicate the environmental objective/benefit pursued e.g. prevent/reduce the generation of waste. (Chapter 3.2.1 of the BREF Guidance).

The information on hazardous substances in wastes in the existing BREF documents is varying in terms of coverage and level of detail. There is no systematic approach in the BREF process for considering the quality of wastes from the perspective of their suitability as secondary raw materials or the target of achieving non-toxic material cycles.

2.3 **Waste legislation and IED**

2.3.1 The waste hierarchy

The waste hierarchy is a significant policy instrument described in the Waste Directive (EU 2008/98/EC, amended in directive 2018/851/EU) aiming to ensure the best possible alternatives in waste treatment from the point of view of waste avoidance in the first place and followed by efficient material use and minimisation of the harmful impacts of waste and waste management. The five-step waste hierarchy can be divided into two levels: first where the production of waste and the content of harmful substances in materials and products is minimised and the second level where the operational priority order for the existing waste is laid out (Jans & Vedder 2012). The obligations of the hierarchy are set within the IED in Article 11 (d and e). The provisions clearly apply to both the operator and the Member States, the latter are responsible to ensure that those principles are implemented (e.g. through appropriate measures set in permit conditions). The waste hierarchy should be considered to be 'obligations of best effort', rather than 'obligations of results' (See C-461/13 Weser, ECLI:EU:C:2015:433). The key difference is that obligations of best effort allow Member States to use more excuses for failure to comply with the objectives at hand. Most of the time, it suffices for Member States to merely strive to achieve compliance with the hierarchy (van Kempen 2014). In obligations of results, certain results are either achieved or the Member State is responsible for non-compliance with EU law. Usually in national waste legislation the obligations imposed on Member States are transferred to actors in the field, such as waste management operators (European Commission 2012; Jans & Vedder 2012 pp. 480–481). The waste hierarchy can have a significant effect on private operators through the practice concerning national and regional waste management plans and environmental permits. (DEFRA 2011).

Waste materials are subject to waste treatment operations with a very clear predefined priority order: the priority is re-use and recycling (material recovery), the last option is another type of recovery[8].

[8] Article 3(15) WD: 'recovery' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in a plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.

The very last option is disposal, provided that "any impact" on the environment is avoided or reduced[9]. In disposal the material potential of waste is lost as it is landfilled or incinerated with no energy production. However, in recovery the waste is utilized in a useful purpose. Recovery should be distinguished from re-use as the subject to recovery is always considered to be waste, whereas the subject of re-use is never considered to be waste. In WD, there is also a definition for 'preparing for re-use'[10]: it is considered to be a recovery operation and not re-use.

2.3.2 Provisions of waste in IED

The IED includes the general principle that where waste is generated, it is in order of priority prepared for re-use, recycled, recovered or, when not possible, disposed of, but the issues are not explicitly linked to the avoidance of harmful substances (Art. 11 d and e, IED). Article 11 of the IED refers to the waste hierarchy of the WD. Article 4 of the WD regulates that the following *waste hierarchy* shall apply as a priority order (Williams 2015) in waste prevention and management legislation and policy: a) prevention[11]; b) preparing for re-use; c) recycling; d) other recovery, e.g. energy recovery; and e) disposal. The objectives of the waste hierarchy complement all the three before-mentioned approaches for CE issues (Chapter 1.3, Figure 1). The hierarchy addresses the minimization of waste (including minimization of its harmful content), as well as the most efficient waste recovery alternatives. There is also a reference to the avoidance of waste generation and use of hazardous substances, as well as to the furthering of recovery in Annex III of the IED on the BAT criteria, namely points 1–3:

1. the use of low-waste technology;
2. the use of less hazardous substances;
3. the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate.

BREFs can have significant impact in implementing the content of the hierarchy into the actual permits for operators. For example, the BREF Document for the Manufacture of Glass (GLS BREF, EIPPCB 2013) contains provisions that focus on the advantages that the use of recovered glass cullet brings in energy and raw material consumption. The provisions also include keeping the impurities of cullet as low as possible in order to facilitate the use of waste glass. The BREF document for Non-Ferrous Metals Industries (NFM BREF, EIPPCB 2017b) has many BATs addressing the recovery and separation of different materials. The waste hierarchy is mentioned in narrative BATs, without qualitative requirements, in many BREF documents. Narrative BATs are generally applicable, but without qualitative requirements in the BREFs and without defining the economic and technical feasibility the implementation is a very subjective matter.

In addition to BAT criteria in Annex III mentioned above, the IED (Art. 3 lit. 37 and 38) also refers directly to the definitions of waste and hazardous waste given in the WD. From the perspective of CE, the classification of hazardous waste in current waste legislation is not enough for controlling hazardous substances in recyclable materials. It is a crucial question to the operators utilizing waste-based material, whether the materials they are utilizing are considered to be waste according to the EU waste legislation. The basic rule is that if the material is waste, 1) the operator using it must have a permit for waste treatment, or 2) there needs to be national legislation on a notification system on utilizing this kind of waste, or 3) the material has ceased to be waste after having undergone a recovery operation.

[9] Article 3(19) WD: 'disposal' means any operation which is not recovery, even where the operation has, as a secondary consequence, the reclamation of substances or energy. Annex I sets out a non-exhaustive list of disposal operations.
10 Article 3(16) WD: 'preparing for re-use' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.
11 Consisting of measures taken before a substance, material or product has become waste, that reduce (a) the quantity of waste, including through the re-use of products or the extension of the life span of products, (b) the adverse impacts of the generated waste on the environment and human health or (c) the content of harmful substances in materials and products.

Simply put: waste legislation applies to 'waste' and does not apply to 'non-wastes'. For most industrial operators it is easier to use waste-based materials if they are not considered to be waste according to the EU waste legislation. According to Article 3(1), WD waste is a substance or object that has been discarded, is intended to be discarded or its holder is required to discard it. Due to this definition, many discarded materials that could be used in industrial processes instead of virgin raw materials are unavailable for utilization by non-accredited waste disposal/treatment facilities. According to Article 3(2) WD, waste which displays one or more of the hazardous properties listed in Annex III of the WD is classified as hazardous waste.

2.3.3 By-products and End-of-Waste products

Instead of waste, materials can be classified as by-products or End-of-Waste (EoW) products. A production residue that would normally be classified as waste can instead be classified as a by-product if it fulfils the criteria laid down in Article 5 WD[12]. By-products have not been discarded and, thus, have not been classified as waste at any point. However, if the material has already been discarded and is classified as waste, it can cease to be waste after having undergone recovery if it fulfils the EoW criteria laid down in Article 6 WD[13]. By-products are exempted from the obligation to register under REACH Regulation unless they are imported or placed on the market as such (REACH Annex V (5)). EoW substances may also be exempted from REACH registration if the same substance has already been registered and the information provided in the registration is available to the recovery operator. However, if the main constituents of the recovered substance do not match with previously registered substance, the substance is not considered to be the same and the exception does not apply. There is no obstacle for hazardous wastes to cease to be waste and get the EoW status if the criteria of Article 6 are met (See C-358/11 Lapin luonnonsuojelupiiri EU:C:2013:142). However, due to the hazardous properties of hazardous wastes, it is likely that after ceasing to be waste more stringent provisions on chemicals safety (e.g. REACH authorisation or restrictions) would apply to them.

The non-waste categories, i.e. by-products and EoW, are positioned a little bit differently in the approaches to CE used in HAZBREF (chapter 1.3). The by-product status must be taken into account with the Production waste approach (approach 1) because with by-product classification the generation of waste can be reduced as the materials normally classified as waste can be further used as non-waste by-products. Moreover, by-products of an installation can be used in another installation and this way the issue of by-product is connected to the Secondary raw material approach (approach 2). The EoW classification is connected mostly to approach 2. After a material once classified as waste from one installation has ceased to be waste through the process of applying EoW criteria, its use as a raw material in another installation is enabled (see examples in IMPEL 2019, p.160). The difference between by-product and EoW is that a by-product cannot be subject to heavy treatment before its use, whereas EoW criteria can theoretically turn any waste into non-waste after the waste has undergone sufficient recovery operations in order to make it safe to use and fit for its purpose.

[12] A substance or object, resulting from a production process, the primary aim of which is not the production of that item, may be regarded as not being waste referred to in point (1) of Article 3 but as being a by-product only if the following conditions are met: a) further use of the substance or object is certain, b) the substance or object can be used directly without any further processing other than normal industrial practice, c) the substance or object is produced as an integral part of a production process and d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

[13] Certain specified waste shall cease to be waste within the meaning of point (1) of Article 3 when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions: a) the substance or object is commonly used for specific purposes, b) a market or demand exists for such a substance or object, c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products and d) the use of the substance or object will not lead to overall adverse environmental or human health impacts. The criteria shall include limit values for pollutants where necessary and shall take into account any possible adverse environmental effects of the substance or object.

In the Product end-of-life approach (approach 3) the focus is on post-consumer waste management and recoverability of waste. Neither by-product nor EoW status can directly impact this as they are determined in the installations where the material is either generated or recovered. The recoverability of a certain product is often connected to the composition, materials and substances used in the product. For example, promoting the use of non-toxic materials in production leads to non-toxic and better recoverable waste streams both pre- and post-consumption. The recoverability of materials is more connected to the regulation governing ecodesign, products and chemicals than to the legislation on waste. Nonetheless, promoting safe and non-toxic waste-based materials is also possible through application of the, by-product and EoW status. In this way, these classifications can have indirect impacts on the recoverability of the end product. Naturally, the waste management infrastructure is directly linked to EoW through laying down the practical perimeters for waste collection and sorting affecting the composition of the waste streams and the potential quality of the recovered waste-based materials.

2.4 Product regulation

There are not many overarching legislative acts that concern all different kinds of products. However, there is a vast amount of sectoral product regulation and standards that are applicable to certain kinds of materials, products or purposes of use. This regulation naturally has a potential of either promoting or hindering the achievement of CE. Despite the multitude of sector-specific provisions, substances of concern in the products are mostly regulated under EU chemicals regulations, such as REACH and POP Regulations.[14] Product regulation usually addresses quality requirements for a certain type of product and aims at harmonizing the quality of the products between the Member States and the internal market. However, product regulation can also lay down provisions on health protection (Toy safety directive (2009/48/EC), medicine directive (2001/83/EC), etc.) and resource efficiency (Directive on packaging materials (94/62/EC), etc.).

Product regulation can include provisions that promote or restrict CE objectives. That is the case e.g. in the new regulation on fertiliser products (EU 2019/1009) (see chapter 3.1.2). One example of restricting regulation is the directive on packaging materials and its heavy metal limits. In the past they restricted the amount of cullet used in glass furnaces to produce container glass in Germany due to their high lead content (usually caused by lead crystal glass in the waste glass collection system). Today, this problem is solved due to the development of lead-detection systems in the glass recycling facilities. However, addressing CE through sector-specific acts would make the approach spotty and arbitrary, although it is evident that product regulation has the potential to promote the CE objectives.

The Commission has stated multiple times that more than 80% of the environmental impacts of a product are determined at the design stage (See e.g., JRC 2018). Therefore, regulating on the design of the product through the so-called ecodesign framework plays a significant role in achieving CE objectives. Product design can impact all of the three approaches to CE (chapter 1.2): 1) it can increase more efficient material use in the products, and hereby minimize the generation of waste and reduce the amount of harmful substances in the production process, 2) it can promote the use of waste-based materials in products and 3) it can address the recoverability and repairability of the end product. In the EU, the provisions on ecodesign are laid down in the Ecodesign Directive (2009/125/EC). The directive regulates designing at a general level. More specific provisions based on the directive are given in product-specific regulations. Presently the directive and the product-specific regulations have mostly focused on energy intensive products and their energy consumption. The directive explicitly regulates on energy-related products.

CE-related views were presented in the EU action plan for Circular Economy in 2015 and updated in 2020 (European Commission 2015a and European Commission 2020a). They refer respectively to the

[14] The chemicals provisions are further examined in the report of WP3.1 of the HAZBREF project.

Ecodesign Working Plan 2016–2019 (European Commission 2016) and a new Ecodesign and Energy Labelling Working Plan 2020–2024.

The Ecodesign Working Plan and the 2020 Circular Economy Action Plan emphasize that there is an increasing need and political priority to improve material-related aspects in the design part of the product lifecycle. According to the Action Plan, the ecodesign legislation should aim at improving the durability, reusability, upgradability and repairability of as many products as possible and at addressing the presence of hazardous chemicals in those products and increasing their energy and resource efficiency (European Commission 2020b). It has also been recognized that the existing framework for ecodesign could facilitate this improvement. Neither the EU action plan, nor the working plan address the connection of product design and chemicals and chemicals-related matters are left in the realm of chemicals regulation such as REACH. This does not however mean that the ecodesign framework should refrain from referring to the rules laid down in the EU chemicals regime and aiming at complementing them. The EU action plan for the Circular Economy refers to product durability (including reparability, upgradability etc.) and recoverability in connection to the ecodesign regulation. The working plan sets out a long list of product durability issues to consider in product design: e.g. extension of product lifetime, ability to reuse components, minimum lifetime of products, reparability; availability of spare parts, upgradability and design for disassembly. The Commission only mentions the recyclability and reusability of products and does not explicitly mention waste prevention in the Working Plan (de Römph 2018).

Principles of designing products with special consideration for their environmental impacts during the entire product lifecycle have been widely implemented in recent years in relation to manufactured goods. However, the industrial experience gathered from the HAZBREF case studies and feedback from STM plant operators show that the implementation of environmental design principles requires in some activities focusing not only on the product but primarily on the technological processes. A good example of this is the activity of surface treatment, where coatings are an integral part of products or components. On the one hand, the coatings must be durable, and on the other hand they should not constitute significant obstacles to the secondary processing of end-of-life elements. This aspect also supports the inclusion of ecodesign principles in BREFs.

As CE instruments for product design are still mostly lacking, this gives some leeway for regulating circular design through BREFs. Even after the possible inclusion of CE aspects to the ecodesign framework, it seems unlikely that the provisions on substances of concern would be introduced into the framework.

2.5 Conclusions from the analysis on regulations

The provisions of the IED and the BREF guidance provide, at least in principle, the possibility to address the three approaches to CE considered in this document (chapter 1.2) in the BREF process to a larger extent than current practice. The most important conclusions from the regulatory analysis of this chapter are summarized below.

Annex III of the IED sets "Criteria for determining best available techniques", where, in particular, the following four criteria relate to the CE issue:

- use of low-waste technology
- use of less hazardous substances
- furthering of the recovery and recycling of substances generated and used in the process and of waste, where appropriate
- consumption and nature of raw materials (including water) used in the process and energy efficiency.

These aspects are also addressed in the BREF guidance. Requirements for non-toxic raw materials or wastes/residues or cycles are not-ruled out from being addressed in the BREFs, however these principles have not been widely implemented in existing BREFs. BREF stakeholders have raised several arguments against the inclusion of these requirements in the scoping of BREFs, such as e.g. lack of data, confidentiality concerns by industry, legal interpretation issues (e.g. "double regulation" claims) and workload concerns.

In the IED, there are the requirements for the operator to elaborate measures for the prevention, preparation for re-use, recycling and recovery of waste generated, but no explicit provisions that extend operators responsibility beyond the installation or site (Art. 3(3) IED), unless the limitation to "directly associated activities on the same site" is extended to value chain considerations. Current permitting and legislation practices in Member States focus mainly on the site conditions and requirements of the waste management plan in general. The limitations are partly due to the current formulation of the scope of the IED (Annex I), with a current practice to focus on installations within a site operated by the same operator, instead of taking a value chain approach of a given industrial activity.

The requirement in the BREF guidance to collect information on techniques for preventing or reducing waste generation and reducing the use of raw materials, seems to provide the possibility to give more focus in BREFs on CE issues. Also, the requirement to assess "Limitation of the ability to reuse or recycle residues/waste" could be emphasized in the TWG work of BREFs.

As mentioned above, the promotion of CE aspects has not been considered in the preparation of the existing BREFs and BAT conclusions systematically. The ongoing IED evaluation could be an opportunity to propose refinements to the BREF guidance and put more focus on the options on how to promote CE aspects in BREFs.

In order to avoid creating a complicated legislative framework, the IED and BREFs should not aim at laying down provisions that are already set out in other CE related substantive legislation. However, in order to support non-toxic material cycles and improve resource efficiency, BREFs could include references to the requirements in other legislation and set specific targets considered as BAT for the sector on issues where general targets are set in other legislation, but not concretised at an industrial activity level. The substantive regulation on e.g. product design and waste management can effectively regulate certain stages of product lifecycle. It should be taken into account that the IED and BREFs are only able to directly regulate the production stage. The scope of their provisions cannot be extended to directly address the whole lifecycle of a product or material.

When concrete CE related legal obligations have been laid down outside IED, the IED or BREFs could, in addition to highlighting their importance, also ensure legal coherence and practical guidance in implementing these obligations. For example, WD, the Ecodesign Directive and sectoral product regulations lay down provisions that have impacts on the achievement of CE. The starting point here is that

BREFs are best fitted to have an impact on the production process itself. For example, Ecodesign Directive and the product specific regulations have a direct link to products as such. In this way, the ecodesign framework can regulate on the circularity of the products in a more efficient way than BREFs or regulation on the functioning of the industrial installation. However, naturally the desired product (the qualities of which have been laid down according to the eco-design framework) has an impact on the required steps in the production process. In this way the functioning of the installation, the IED and the BREFs can have an indirect impact on the ecodesign of the products as well. Despite the potential of the ecodesign framework, the planned future actions for ecodesign do not include provisions for non-toxic material cycles. All provisions for chemicals will be left in the chemicals regulation. However, the planned actions for ecodesign refer to product durability (including reparability, upgradability etc.) and recoverability.

Many BREFs already have provisions on the waste management. In addition, the IED refers to many concepts of the WD, such as ‘waste’, ‘hazardous waste’ and ‘waste hierarchy’, and so do many BREFs. The interpretation of the definition of waste has a crucial impact on the waste management and this should also be taken in the account in the IED context. The by-product and the EoW category can have significant impacts on approaches 1 and 2 of the CE analysed in this report, and where applicable, the by-product and EoW criteria should be acknowledged in the BREFs. One way to promote CE in production processes could be to identify the most typical by-products of an industrial sector in a sectoral BREF document. Moreover, the provisions concerning waste in BREFs should follow the interpretation of the waste legislation in order to promote legal certainty and more efficient waste management. BREF documents could also be used for the implementation of the waste hierarchy. Currently many BREFs have references to the hierarchy, but not that many elements to complement the objectives of the hierarchy. For example, the Waste treatment BREF (WT BREF, EIPPCB 2018) states “For instance, according to waste hierarchy, operations aiming for recovery prevail over disposal.” These kinds of vague references can be found in many BREFs, but they rarely provide any tangible provisions for operators or permit writers.

Some of the recent BREFs (Waste treatment (WT BREF) and Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW BREF, EIPPCB 2016) include an inventory BAT, which is, however, quite general. Especially in sector BREFs, the inventory BAT should be more specific in order to guide the permit writers and installations to include relevant information on hazardous chemicals/substances used. In order to provide information to further improve the recovery, recycling and re-use of waste/by-products the share of hazardous substances ending up in the product or waste should be investigated. Also, the content of hazardous substances in the incoming raw materials should be part of the inventory. In the Glass manufacturing BREF (GLS BREF), there are even provisions of keeping the impurities of cullet as low as possible in order to facilitate the use of waste glass.

3 HAZBREF case sectors

Three sectors were chosen as case sectors in the HAZBREF project. The sectors were selected from the industries where the BREF review had not yet started and where chemicals use was a key issue. The selected sectors are polymers and fertilisers from the chemical sector, the textile sector and the surface treatment of metals and plastics. HAZBREF partners conducted case studies in these sectors in five countries (Germany, Finland, Estonia, Poland and Sweden). The results of these studies are presented in the sectoral guidance reports (available in HAZBREF project website).

3.1 **Chemicals sector**

3.1.1 Manufacture of polymers

Short overview of the sector in Europe

Plastics or plastic materials are the terms used to describe a large family of different materials with different characteristics, properties and uses. Plastics are composed of polymers, which are constructed from relatively small molecular fragments (monomers), that are joined together. Today, plastics can be fossil-based or bio-based, and in both cases, they can also be bio-degradable. The plastics industry manufactures plastics for a range of industries, including packaging, building and construction, electronics, aerospace, and transportation.

There are close to 60,000 companies operating in the plastic industry sector in Europe, and most of them are small or medium sized enterprises (SME's) (Plastics Europe 2019). Around 45 companies in EU-15 produce the large volume thermoplastic materials which are sold to around 30,000 SME's which process the polymers into products for end use (EIPPCB 2007a).

The world plastics production was 348 Mt in 2017, with Europe having a share of 64.4 Mt. Total European converter demand in 2017 was 51.2 Mt, of which 6 larger European countries (Germany, Italy, France, Spain, UK, Poland) covered almost 70%. Polymer types leading in the converter demand are polypropylene (PP, 19.3%), polyethylene low density and linear low density (PE-LD and PE-LLD, 17.5%), polyethylene high density and medium density (PE-HD and PE-MD, 12.3%), polyvinyl chloride (PVC,10.2%), polyurethane (PUR, 7.7%), polyethylene terephthalate (PET, 7.4%) and polystyrene and expandable polystyrene (PS and EPS, 6.6%) (Plastics Europe 2019).

Globally, 260 Mt of plastic waste is generated annually, of which currently 16% is collected for recycling (McKinsey & Company 2019). In Europe (the EU28+NO/CH), in 2016, 27.1 Mt of plastic waste were collected through official schemes for treatment; 27.3% for landfilling, 31.1% for recycling (63% inside the EU, 37% outside EU), and 41.6% for energy recovery (Plastic Europe 2019). The sources do not specify whether these figures include only post-consumer waste or also pre-consumer waste. However, the volumes of the latter are small compared to the first.

The most voluminous and discussed plastic waste is post-consumer waste, i.e. the plastic products that consumers discard. Hence, of the three CE approaches discussed in this report (see chapter 1.2), the one focusing on the recyclability of the product at the post-consumer end-of-life phase (Approach 3) would be the most relevant for increasing the circularity of plastics. Currently primarily plastic packaging is included in the sorting and recycling schemes of most European countries, and requirements on increasing the rate of plastic packaging recovery have been set in the EU legislation.

Plastic packaging waste consists primarily of food packaging. There are strict restrictions on the use of materials and substances for packaging intended to be in contact with food (2004/1935/EC). However, e.g. in the case of DEHP (Bis(2-ethylhexyl) phthalate), the substance is allowed up to a certain concentration. The safety of Food Contact Materials (FCM) is evaluated by the European Food Safety

Authority (EFSA). Discarded food packaging could be considered potentially clean from hazardous substances and recovering it back to production of food packaging plastics would generate a closed-loop non-toxic material circulation. However, due to the strict quality criteria required from the production line of polymers for food packaging, all operators in the value chain should communicate and be aware of the quality requirements from the polymer producer.

Examples of post-consumer plastic waste types where hazardous substances restrict recovery, are e.g. waste electronic and electric equipment (WEEE), the plastics of which are currently collected and recycled only to a minor extent. They include e.g. flame retardants, which are added to products in order to obtain required safety standards. The increasing circulation of these material flows would require a) separation of the components with a hazardous content and recycling only the clean plastics, or b) recycling the plastic into a use where the same substances are required, i.e. into new EEE, or c) separating the hazardous substances from the plastic material. The latter alternative could be implemented through chemical recycling, where polymers are broken down into monomers, oligomers or simpler molecules, creating new feedstocks for plastics production (Material Economics 2019). There are a range of emerging technologies, such as depolymerisation, pyrolysis, gasification and solvent-based purification, that are suitable for different types of plastics waste (Crippa et al. 2019; Stenmarck et al. 2018).

Polymer additives include many hazardous substances and have recently been scrutinised (ECHA 2019a). In a Danish survey on hazardous substances in consumer products (Hansen et al 2014), 144 groups of substances or single substances that are known to be hazardous and to be used in the manufacturing of plastics were found. The substances were from the following lists:

- Danish EPA's list of undesired substances (LOUS)
- SVHC Candidate List under REACH
- Norwegian list of priority substances
- ECHA's Registry of Intentions
- CMR-substances likely to be present in plastic toys (as assessed by the Danish Technological Institute)
- recognized alternatives to problematic phthalates and BFRs.

Based on the technical function they are used for, these 144 hazardous substances or groups of substances can be classified in ten different groups (Stenmarck et al. 2017):

- antimicrobial substances (e.g. organic tin and triclosan)
- blowing agents (e.g. fluorinated greenhouse gases)
- metal based colorants, stabilisers and catalysts (e.g. cadmium and lead and their compounds)
- flame retardants (e.g. BFRs and organo phosphates)
- monomers, cross linkers, hardeners, chain modifiers and catalysts (e.g. Bisphenol A and formaldehyde)
- organic based colorants (e.g. azo dyes)
- UV stabilisers, antioxidants and other stabilisers (e.g. dibutyltin dichloride)
- plasticisers (e.g. short chain chlorinated paraffins and many different phthalates)
- neutral and reactive solvents (e.g. dimethylformamide)
- others (e.g. nonylphenol and PFOS).

Not all of the 144 substances or groups of substances have been found in products. The existing information on hazardous substances in plastics is information on what could normally be used in the production to reach different attributes. It can also be information on what substances have been found when plastics have been analysed for chemical content. In neither case does this mean that the plastic product or plastic type always contains the hazardous substances (Stenmarck et al. 2017). A risk-based approach is needed in order to focus on the right substances at the right point in time during the life of a product. More efficient management (minimisation, substitution) of hazardous substances requires more information on the chemicals used in the production and their distribution to different media.

The European Commission launched, in December 2018, the Circular Plastics Alliance that gathers public and private stakeholders in the plastics value chains to promote voluntary actions and commitments to produce and use more recycled plastics in the EU. The EU target is that 10 Mt of recycled plastics will find their way into products in the EU by 2025, which is a 150% increase compared to the year 2016. The Circular Plastics Alliance includes over 175 organisations representing industry, academia and public authorities. By signing the declaration, the organisations commit to promote design for the recycling, collection and sorting of plastic waste, increase in the recycled content of plastic products, R&D and investments, including chemical recycling and monitoring of volumes of recycled plastics used in European products. In the plastics industry commitment, announced earlier in 2018 “Plastics 2030 - Voluntary Commitment” (Plastics Europe 2018), the European plastics manufacturers committed to ensure high rates of re-use and recycling (60% for plastics packaging by 2030). To achieve this, PlasticsEurope would strengthen its efforts and collaboration along the value chain and with public authorities towards more sustainable plastics. To accelerate innovation towards more efficient chemical and mechanical recycling it has established three European platforms (i.e. European Council of Vinyl Manufacturers, Polyolefin Circular Economy Platform and Styrenics Circular Solutions).

Sectoral BREFs and other relevant regulation

The BREF concerning polymer production (POL BREF, EIPPCB 2007a) was published under the IPPC Directive and there are no plans to review it in the second review round under the IED. The BREF on large volume organic chemical industry (LVOC BREF, EIPPCB 2017c) published in 2017, covers the production of organic chemicals, some of which are used as raw materials for plastics. Both the LVOC BREF and the POL BREF from 2007 are studied for the purposes of this report. In addition, emissions into the air from polymers production processes will be covered by the BREF concerning Common waste gas treatment in the chemical sector (WGC BREF, EIPPCB 2019c), which is currently under preparation. Emissions into water are covered by the Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWW BREF, EIPPCB 2016).

The Production of Large Volume Organic Chemicals BREF

The Production of Large Volume Organic Chemicals (LVOC) BREF covers:

- simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic),
- oxygen-containing hydrocarbons, such as alcohols, aldehydes, ketones, carboxylic acids, esters and mixtures of esters, acetates, ethers, peroxides and epoxy resins,
- sulphurous hydrocarbons,
- nitrogenous hydrocarbons, such as amines, amides, nitrous compounds, nitro compounds or nitrate compounds, nitriles, cyanates, isocyanates,
- phosphorus-containing hydrocarbons,
- halogenic hydrocarbons,
- organometallic compounds,
- surface-active agents and surfactants.

It also covers the production of hydrogen peroxide as specified in Section 4.2 (e) of Annex I to Directive 2010/75/EU.

Relevant to polymer production are the production processes in which the building blocks for plastics, i.e. lower olefins, ethylbenzene and styrene, ethylene dichloride and vinyl chloride monomer, are produced.

Waste generation in organic chemicals production is very different at different installations. The sources of liquid and solid residues are very specific to each process. In some cases, useful materials can be recovered from residues, with the remaining material being waste. The key pollutants in wastes can be derived from the raw materials and processes applied, construction materials, corrosion/erosion mechanisms and materials related to maintenance. In generic terms, wastes may arise from (EIPPCB 2017c):

- raw material supply and work-up (e.g. off-specification raw materials),
- synthesis (e.g. spent catalyst and catalyst support, wastes due to shut down, contamination arising from corrosion and erosion products inside equipment, product separation and refinement, spent purification media, unwanted compounds produced by side-reactions, process residues, spent reagents and off-specification products),
- materials storage and handling (e.g. waste packaging, product polymerisation in tanks),
- emission abatement (e.g. adsorbents used for spill clean-up, solids produced by the abatement of air pollutants, sludges from wastewater treatment, solids produced by the abatement of water pollutants),
- energy/utilities (e.g. ashes/soot from furnaces, heaters and other combustion equipment),
- infrastructure (e.g. decommissioned plant equipment, construction materials, general site wastes from offices, canteens and laboratories, spent cleaning agents, spent oils, spent heat transfer fluids),
- management systems (e.g. emissions may occur from process upsets or incidents that are attributable to the inadequacies of management systems or the failure of operators to adhere to procedures).

The LVOC BREF contains 19 general BAT conclusions and 71 sector-specific BAT conclusions: 4 concerning lower olefins production, 14 concerning ethylbenzene and styrene production and 10 concerning ethylene dichloride and vinyl chloride monomer production. The BAT conclusions include requirements on residues (such as preventing waste generation or promoting the recovery of wastes generated by application of different techniques during the production processes), but no conclusions specifically focusing on the content of hazardous substances in the generated wastes or the products (Table 1).

The BREF for Production of Polymers

The BREF for Production of Polymers (POL BREF) was drawn up under the IPPC directive and is, therefore, not binding as the BREFs drawn under the framework of the IED are, but it can be used as an informative guiding document and has still valid BATs for polymer production. Polymer production processes will also be covered by the WGC BREF (Common Waste Gas Treatment in the Chemical Sector), which is currently under preparation. The POL BREF focuses on the main products of the European polymer industry, mainly produced in installations dedicated to one specific polymer. The products covered include polyolefins, PS, PVC, unsaturated polyesters, emulsion polymerised styrene butadiene rubbers, solution polymerised rubbers containing butadiene, polyamides, polyethylene terephthalate fibres and viscose fibres. For polymer production installations, no specific threshold was established in drawing a borderline between IPPC installations and non-IPPC installations, as such a threshold was not included in the IPPC Directive (IPPCB 2007).

The further processing of polymers to end products is not included in the scope of the BREF. However, processing techniques, such as the production of fibres or compounding, are included when they are technically connected to the production of the polymer and carried out at the same site, and when they influence the environmental impact of the installation. The treatment of waste gas and wastewater is also a subject included in the BREF, where sector specific conditions require this.

The POL BREF contains 18 generic BATs and 46 specific BATs for the different polymers covered in the document: polyolefins, PS, PVC, unsaturated polyester, ESBR, solution polymerised rubbers containing butadiene, polyamides, PET fibres and viscose fibres. The BATs described in Table 1 can be considered to promote circular economy.

Table 1. Overview of BATs related to waste reduction and recovery in the POL BREF and LVOC BREF.

BREF document	Chapter or BAT (conclusion)	Brief description of the content
LVOC BREF	Generic BAT 17	In order to prevent or, where that is not practicable, to reduce the amount of waste being sent for disposal, BAT is to use an appropriate combination of the techniques given.
	Aromatic production BAT 30	In order to prevent or reduce the amount of spent clay being sent for disposal, BAT is to use one or both techniques given.
	Ethylbenzene and styrene monomer production BAT 41	In order to reduce the amount of waste being sent for disposal from spent catalyst neutralization in the $AlCl_3$-catalysed ethylbenzene production process, BAT is to recover residual organic compounds by stripping and then concentrate the aqueous phase to give a usable $AlCl_3$ by-product.
	BAT 42	In order to prevent or reduce the amount of waste tar being sent for disposal from the distillation unit of ethylbenzene production, BAT is to use one or a combination of the techniques given.
	BAT 43	In order to reduce the generation of coke (which is both a catalyst poison and a waste) from units producing styrene by ethylbenzene dehydrogenation, BAT is to operate at the lowest possible pressure that is safe and practicable.
	BAT 44	In order to reduce the amount of organic residues being sent for disposal from styrene monomer production including its co-production with propylene oxide, BAT is to use one or a combination of the techniques given.
	Formaldehyde production BAT 47	In order to reduce the amount of paraformaldehyde-containing waste being sent for disposal, BAT is to use one or a combination of the techniques given.
	Ethylene oxide and ethylene glycols production BAT 55	In order to reduce the amount of organic waste being sent for disposal from the EO and EG plant, BAT is to use a combination of the techniques given.
	Phenyl production BAT 60	In order to prevent or reduce the amount of tar being sent for disposal from phenol purification, BAT is to use one or both techniques given.
	Toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI) production, BAT 74	In order to reduce the amount of organic residues being sent for disposal from the TDI plant, BAT is to use a combination of the techniques given.
	Ethylene dichloride and vinyl chloride monomer production, BAT 84	In order to reduce the amount of coke being sent for disposal from VCM plants, BAT is to use a combination of the techniques given.
	BAT 85	In order to reduce the amount of hazardous waste being sent for disposal and to increase resource efficiency, BAT is to use all of the techniques given.
POL BREF	Generic BAT 15	BAT is to re-use the potential waste from a polymer plant. Appropriate process-integrated measures help to prevent or reduce the amount of waste from a polymer plant. Examples are given on how waste solvents, waste oil, polymer waxes and scrap, purification bed agents and catalyst residues can be reused or their volume reduced. Generally, reuse is concluded to be favourable over landfilling.
	Specific BAT 13.6.6. (ESBR production)	BAT is to minimize the volume of hazardous waste by good segregation and send them for external treatment.
	Specific BAT 13.6.7. (ESBR production)	BAT is to minimize the volume of non-hazardous waste by good management and offsite recycling.
	BAT-AEL for different polymers (sections 13.2, 13.3, 13.4, 13.5 and 13.10)	BAT-AELs for inert and hazardous wastes.

Findings concerning the polymer sector

The recovery of plastics used for other applications than packaging, such as construction products, cables, electric and electronic equipment, poses a high potential for material cycles being contaminated with hazardous substances. Product specifications determine the properties required from the plastic products used in various applications. Many of these properties can be obtained by adding different chemicals to the polymer material. However, the installation producing polymers does not have control over the chemicals or substances added to the material after it has left the polymer plant.

Improved collaboration with upstream and downstream partners (Huybrechts et al. 2018) of the plastic value chain would improve the flow of information on hazardous substances within the chain and could promote non-toxic circulation of plastics e.g. as follows:

- Knowledge on the composition of plastic end-products would help in sorting out and directing products containing hazardous substances into appropriate, safe treatment. The rest of the waste material would hence be cleaner (i.e. free of hazardous substances) and better suitable for recovery (concerning the approach 3 for CE).
- Use of material free of hazardous substances as input to mechanical or chemical recycling processes would generate secondary raw materials that are free of hazardous substances and can, thus, compensate virgin raw material (concerning the approach 2 for CE).

Chemical recycling is far from a mature and largescale production route, but several European companies are investigating options for future production (Material Economics 2019). This could be a solution for recycling plastic products containing hazardous substances, provided that the chemical recycling processes, such as solvent-based purification, in practice are able to separate hazardous substances from the desired secondary raw material. Chemical recycling produces secondary raw materials (monomers) to be used in polymerization, where only very clean raw material can be utilized. However, processes are different in all polymer production installations, hence the purity requirements are also installation specific. It is essential that together with development of recycling processes, also product design, business models, products and materials are developed towards CE.

Additionally, the following aspects and good practices in use at the polymer installation examined as a case study in HAZBREF enable operating in a resource efficient manner and hence promoting CE:

- The raw materials for polymer production are side streams from the oil refinery. The oil refinery and the polymer production facility are close to each other - forming an industrial symbiosis. As for other sectors and installations, this could be considered an example of how the placing of installations can play a significant role for finding solutions that promote the realisation of CE.
- Oligomers generated in the polymerization process are used as fuels in the aromatic production (industrial symbiosis).

3.1.2 Manufacture of fertilisers

Short overview of the sector in Europe

Inorganic fertiliser production is covered by the Large Volume Inorganic chemical industry – Ammonia, Acids and Fertilisers (LVIC-AAF) BREF, published in 2007. The LVIC-AAF BREF concerns the production of ammonia, hydrogen fluoride, hydrofluoric acid, phosphoric acid, nitric acid, sulphuric acid, oleum and phosphorus-, nitrogen- or potassium-based fertilisers (simple or compound fertilisers). There are over 120 fertiliser production sites in Europe (Fertiliser Europe 2019). This report focuses on the production of inorganic fertilisers, since the scope of the LVIC-AAF BREF does not cover organic fertilisers. It was expected that the review of LVIC BREF would have started by the end of year 2020, which was not the case.

Inorganic fertilisers are fertiliser products without organic substances. The fertiliser types are PK, NP, NK and NPK, in which the letters refer to the elements in the fertiliser product (N = nitrogen, P = phosphorus, K = potassium). The main raw materials in inorganic fertiliser production are phosphorus, nitrogen and potassium, secondary nutrients (e.g. calcium, and magnesium), microelements (e.g. zinc, copper, boron) and other elements (EIPPCB 2007b). Phosphorus is usually obtained from phosphate rock (e.g. apatite), nitrogen sources are more variable.

Fertiliser product quality is controlled in the EU to prevent the pollution of agricultural land. The main concerns related to hazardous substances in the fertiliser sector are impurities of the raw materials, such as heavy metals. It should be also noted that the essential plant nutrients, such as copper and selenium, are toxic in too high concentrations, but in the fertiliser products they are present in very low levels which are not harmful for the environment. Another issue related to hazardous substances is that some slow release fertilisers may contain polymers (microplastics), but the use of such substances in fertilisers will most likely be restricted in the future (ECHA 2019b).

Waste and by-product, the utilization of secondary raw materials and quality of raw material are relevant CE-issues in LVIC-sector. Product recyclability is not relevant for fertilisers. Fertilisers can't be recycled after they have been spread to the soil. Acids used in the fertiliser production are consumed in the process and cannot be re-used. By-product gypsum is formed in high volumes in phosphoric acid production, but the utilization of gypsum is challenging due to the current market, where transportation costs are high, and the price of virgin natural resources are low.

Sectoral BREFs and other relevant regulation

The Large Volume Inorganic chemical industry – Ammonia, Acids and Fertilisers (LVIC-AAF) BREF

Large volume by-products listed in LVIC-AAF BREF are phosphogypsum, fluorosilic acid (also known as fluosilicic acid) and anhydrite. Phosphogypsum is formed in the production of phosphoric acid: approximately 9–11 Mt of phosphogypsum is generated annually in Europe. Fluorosilic acid and anhydrite are formed in the production of HF. The BREF states that: "All these large volume by-products show the potential for valorisation, but transport costs, contamination with impurities and the competition with, e.g. natural resources, restrict the successful marketing. Hence, excess volumes are disposed of, e.g. by landfilling." (p.33).

In the BREF, the link between the quality of raw materials and by-products is already noted. Some statements in the BREF are, however, quite generic, like the statement in the chapter 1.5. The BREF lists the raw materials whose impurities affect the quality of products and by-products. These raw materials are phosphate rock, fluorospar and H_2SO_4. Concerning industrial symbiosis, integrated production system (e.g. production of fertilisers and acids) is recommended in chapter 1.2 to allow efficient material recovery. The chapters in the current LVIC-AAF BREF describing issues relevant for CE are presented in Table 2. Chapters 2.5 *BAT for Ammonia*, 3.5 *BAT for nitric acid,* 4.5 *BAT for sulphuric acid,* 7.5 *BAT for NPK fertilisers,* 8.5 *BAT for Urea and UAN,* 9.5 *BAT for AN/CAN* or 10.5 *BAT for superphosphates* have no BATs addressing CE.

Fertiliser product legislation

Fertiliser product legislation (1009/2019/EC) has been recently updated. The new legislation bans the use of inorganic waste materials in EU fertiliser products until the end-of-waste criteria are fulfilled and an assessment has been made to make sure that the products are safe to use as fertiliser compounds. The legislation also sets maximum limits for contaminants such as metals in the products.

European Joint Research Centre (JRC) has recently published a report addressing struvite, biochar and ashes as secondary raw material sources in fertiliser production (Huygens et al. 2019). The report contains proposals on e.g. eligible input materials and quality requirements for the secondary raw materials used in fertiliser production in accordance to the new fertiliser product legislation.

Table 2. Overview of BATs promoting non-toxic material cycles in the LVIC-AAF BREF.

Chapter in LVIC BREF	Brief description of the content
1.2	Recommendation of integrated production system.
5.2.2.1.2	Secondary raw materials: fatal acid from non-ferrous metal production and spent acid are used as a raw material in the phosphoric acid production. These acids contain mercury as an impurity.
5.2.2.5 and 5.2.2.6	By-products phosphogypsum and fluorosilic acid: "Phosphate rock contains a range of impurities which are distributed between the product acid and the calcium sulphate. Because of the volume of the gypsum production and the type and level of impurities in the gypsum, this co-product constitutes an environmental challenge."
5.4.10	Phosphate rock selection: The production of clean gypsum requires the use of phosphate rock with low levels of impurities.
1.5	BAT is to improve the environmental performance of the production site by a combination of the following techniques --- recycling or re-routing mass streams.
5.5	BAT for wet processes is to market the generated phosphogypsum and fluorosilic acid, and, if there is no market, to dispose of it.
6.5	BAT for the fluorspar process is to market the generated anhydrite and fluorosilic acid, and, if there is no market, to dispose of it, e.g. by landfilling.

Findings concerning the fertiliser sector

Promotion of CE within the review process of LVIC-AAF BREF

There are already some points promoting circular economy in the current LVIC-AAF BREF as stated above. There is potential to promote the utilization of by-products and the use of secondary raw materials (e.g. metals) in a more comprehensive way in the forthcoming review of the LVIC BREF, but this has to be done in such a way which is not contradictory to the product (e.g. fertiliser product) legislation. Some of the produced phosphoric acid is used in animal feed supplements (8% according to the LVIC-AAF BREF) which mean that some of the producers will also have to comply with the EU legislation concerning feed[15].

Moreover, special attention should be given to avoiding contaminants in the use of secondary raw materials when promoting CE in the BREF. For example, as described in the current LVIC-AAF BREF, fatal acid (sulphuric acid) from non-ferrous metal production and spent acid can be used as a secondary raw material in phosphoric acid production, but they contain mercury as an impurity.[16] The inclusion of a BAT on chemical inventory to the LVIC-AAF BREF would facilitate tracking the chemicals of concern in the production site and information sharing throughout the supply chain. If the impurities in raw materials would be better documented (e.g. in the Safety Data Sheets) it would be easier to avoid a contamination of fertilisers with impurities.

Currently the LVIC-AAF BREF states that phosphogypsum should be utilized (EIPPCB 2007b, chapter 5.5), but on the other hand the BREF also states that the contaminants hinder this. Not all phosphogypsum is contaminated, so this statement of contamination could be changed during the BREF review. The BREF could highlight the information that the quality of phosphogypsum depends on the quality of phosphate rock, which means that the producer has to be aware of properties of the phosphate rock used in the production and assess the potential risks when exploring possibilities to use the phosphogypsum. This issue is briefly described in the current LVIC-AAF BREF in chapter 5.4.10, but it only names radioactive components as contaminants of concern.

[15] Animal Feed (https://ec.europa.eu/food/safety/animal-feed_en)
[16] It should be noted that the information in this current BREF is partly outdated, since present processes have improved.

The updated LVIC BREF should also give more examples on the utilization of by-product phosphogypsum (current BREF names e.g. construction materials and road pavements). Also, sufficient treatment of phosphogypsum should still be promoted in the LVIC-AAF BREF in order to make phosphogypsum available for use (chapter 5.4.13 in the current LVIC-AAF BREF). However, there is currently no economically feasible method to remove all impurities from the phosphogypsum. But still economic reasons, such as transport costs, the low price of natural resources and limited availability of high purity phosphate rock, hinder the utilization of phosphogypsum.

For example, in Finland there is current demand to utilize gypsum in agricultural fields to prevent erosion and bind phosphorus in the Baltic Sea catchment area (Finnish Environment Institute & University of Helsinki 2018). In order to spread phosphogypsum into the fields, the gypsum may not contain any hazardous substances and must have a low phosphorus concentration. In order to achieve this, the excess phosphorus must be removed and the quality of phosphogypsum must be monitored to make sure that concentrations of hazardous substances, such as heavy metals, are within acceptable limits.

Metals, which are essential micronutrients to biota, such as copper, zinc, manganese, and selenium, are added to fertilisers. In theory, these metals could be recycled to fertiliser production from various waste streams, providing that they can be extracted from the material in plant-available forms without impurities. The new fertiliser product legislation however hinders this by limiting the use of waste derived raw materials in inorganic fertiliser products. By this approach, the new fertiliser product legislation aims to guarantee the safety of the fertiliser products, but at the same time it sets obstacles for utilization of secondary raw materials[17]. If a company would wish to use a waste derived raw material which is not already included in the Annex II of the fertiliser product legislation, that material would have to go through an EU-wide risk assessment (conformity assessment)[18] prior its use. This process might be too complicated, and time consuming for the fertiliser manufacturers and therefore might lead to lesser use of EoW materials (e.g. recovered metals) in the fertiliser production. In order to support the manufacturers, quality criteria, conformity assessment rules, approval procedure and an EU-wide guidance concerning the utilization of secondary raw materials in accordance with the new legislation is needed.

There are already many practices in the fertiliser industry promoting circular economy. For example, Yara Siilinjärvi generates phosphogypsum that is clean enough to be used e.g. in construction materials and as a soil amendment to bind phosphorus and prevent erosion. Also, some recovered metal salts can be used as essential plant micronutrients and ammonium sulphate from caprolactam industry is used as a nitrogen and sulphur source.

3.2 Surface Treatment of Metals and Plastics (STM)

Short overview of the sector in Europe

The sector ‘Surface Treatment of Metals and Plastics’ (STM), concerns metals and plastics treatment to change their surface properties for decoration and reflectivity, improved hardness and wear resistance, corrosion prevention and as a base to improve the adhesion of other treatments, as defined in the BREF document (EIPPCB 2006). When the reference document was developed, about 18 000 STM installations (IPPC and non-IPPC) existed in EU-15, although the loss of engineering manufacturing, largely to Asia, had reduced the industry by over 30%. More than 55% of the installations were specialist sub-contractors (‘jobbing shops’), while the remainder provided surface treatment within an industrial installation with a different main activity. A few large installations were owned by major companies although the vast majority was SMEs, typically employing between 10 and 80 people. STM process lines are normally modular and assembled from a series of tanks. However, large installations are typically specialist

[17] Article 4, Annex II of the (EU) 2019/1009
[18] Article 15, Annex XIV of the (EU) 2019/1009

and capital intensive. Processes are predominantly water-based. The main environmental footprint relates to energy, water and raw materials consumption. Emissions to water may occur after water treatment and most solid and liquid wastes are recycled due to the value of the metals. However, the surfactants and degreasing materials used may result in water pollution if they are not appropriately collected and treated.

The key consumable raw materials are metals that make up the final coatings, and several chemicals used during electroplating, degreasing, pickling and etching (acids, alkalis, salts, surfactants), as well as abrasives used for mechanical surface treatment. The main waste streams are sludges from wastewater treatment, spent solutions and wastes from process maintenance.

Apart from the consumption of electricity and water, STM sector is a significant user of non-renewable resources (metals), although – where possible – recycled materials such as metal substrates or electrolytes are used. Also, in-line recycling of electrolytes takes place (e.g. chromiumtrioxide).

Two general issues related to CE are pointed out as very important for the entire sector in the STM BREF. They are:

- minimisation of the consumption of raw materials, energy and water, and
- waste management and minimisation of waste production.

The chemicals used have the potential to cause environmental harm particularly to surface waters, ground waters and soil if released from the plant. Process chemicals, which are dragged out of the process solutions and end up in rinsing water are neutralized or removed as solid waste after coagulation and dehydration in the wastewater treatment plant. Both in-process techniques and end-of-pipe processes can affect the type and quantity of solid and liquid wastes produced (sometimes negatively), as well as changing the quality of wastewaters. The secondary effects of certain chemicals in the wastewater mixture should be considered. For example, effluent treatment of cyanides with hypochlorite may result in the production of AOX and complexing agents (including cyanides and EDTA) can interfere with the removal of metals in wastewater treatment or remobilise metals in the aquatic environment. Therefore, the chemicals used in the plant need to be considered when designing the on-site waste water treatment plant. Additionally, other ions, e.g. chlorides, sulphates, phosphates, nitrates and anions containing boron may be significant at a local level and need adequate on-site treatment.

It was estimated (EIPPCB 2006) that STM industry produces 300 000 t of hazardous waste a year in Europe in 2005 (approximately 16 t a year per installation on average). The key emissions of concern are metals which are used as soluble salts. Depending on the process, emissions may contain cyanides (although the historic trend is decreasing), as well as surfactants which often have low biodegradability and accumulative effects (e.g. fluorinated surfactants). Most of the hazardous wastes are spent process solutions containing heavy metals (generated when raw materials are being dragged out of process solutions by the workpieces, and into rinse-waters). Hazardous substances end up in sludges from wastewater treatment (Environment Agency 2004; Natural Resources Wales 2014; European Bank for Reconstruction and Development 2014). In 2003, in Germany 40,000 t of electroplating sludge was generated by nonferrous metal losses (EIPPCB 2006). In 2003, in Germany, approximately 30% of the electroplating sludge was used as a secondary raw material in the non-ferrous metal industry. The remainder was disposed of in hazardous waste landfills.

In some electroplating processes a significant proportion of the input anode materials are lost as sludge and generally end up as hazardous waste. However, some processes, such as copper plating, leave no sludge and some use inert anodes. Other main (potentially) hazardous wastes in STM include:

- *Wastes from abrasive blasting of non-ferrous metals* (a mixture of abrasives and abraded material from the metals) may be hazardous.
- *Waste from the chromic/sulphuric acid etching and other processes* in the pre-treatment stage have a finite life and require disposal on a routine basis.

- *Deburring and/or tumbling wastes*, generated directly from the mechanical surface treatment, may be contaminated with oils, surfactants and abrasive particles, particularly vibratory finishing.
- *Finishing and polishing wastes*: the collected dusts require disposal, as wastes and may be hazardous.
- *Waste from blasting with pellets of dry ice* to remove oil and grease, as well as particles, paint, etc. After use, the pellets of dry ice evaporate so the only waste formed is the solid waste of the stripped coatings.
- *Discarded acidic/alkaline pickling agents:* a significant level of free acidic/alkaline remains.
- *Discarded acidic etching solutions*, i.e. concentrates generated in the acidic etching process (hydrochloric acid, copper chloride and hydrogen peroxide): By optimum management of all parameters and by enriching the copper, these wastes can be sold. The regenerated hydrochloric acid can be re-used in the process. The methods of recovery have not proven to be successful.
- *Bare printed circuit board wastes*. May include a wide range of heavy metals, rare earth elements, and other chemicals. May be hazardous, but also valuable for recovery/ recycling.

Crucial issues to reduce raw material and water consumption are the retention of active components in the processes, the appropriate rinsing techniques to recover the drag-out, and to reduce the amounts of wastes. In some processes this can be achieved by techniques such as cascade rinsing, evaporation, recovery and/or the recycling of process solutions. Where particularly toxic metals such as Cadmium or Chromium (VI) are used, special techniques (such as closed-loop systems or processes) are required to prevent their release into the environment.

Onsite use of common spent process liquids, such as acidic solutions from etching in the neutralization stage of the wastewater treatment system, is becoming more popular as disposal costs rise. Rinsing water is usually pre-treated onsite prior to discharge into downstream wastewater treatment facilities. An increasing number of plants uses closed water loops that allows for reuse of nearly the entire stream of process water. In order to achieve water qualities required for reuse in the process, very effective removal techniques for the wastewater pollutants must be used.

Sectoral BREF and other relevant regulation

The most significant environmental issues for the STM processes are the use of raw materials and energy, as well as the need to ensure that the wastes and wastewater produced are appropriately treated and recycled. General information on the surface treatment of metals and plastics are given in chapter 1 of the STM BREF, including a list of key substances of concern across the sector, as metals, non-metals, surfactants, complexing agents, acids and alkalis, other ions and solvents (table 1.4 in the STM BREF). When emitted these substances will be found in process waste and wastewaters as well as washing water of wet scrubbers.

The STM BREF characterizes several techniques within 11 main groups of processes with information about the generated wastes, but:

- There is a lack of information on the breakdown products in the processes.
- No information is given about potential by-products.
- Waste codes according to European Waste Catalogue (EWC) are lacking.
- Wastes are not classified properly, but only in a general way as hazardous or non-hazardous process wastes are not characterized at all.

General aspects of waste management and CE are considered in the following subchapters of the STM BREF:

- 2.13: Abatement of potential releases into the environment (wastewater treatment as a basic end-of-pipe-process delivering waste, pre-treatment of generated waste on STM sites, and techniques of (further) waste treatment used by external operators. Solid and liquid waste management.

- 3.3.2: Overall emissions – wastewater, wastes. General information and guidelines which could be useful when designing the processes towards CE.
- 3.4: qualitative and quantitative information about printed circuit board manufacturing, including data about raw materials and auxiliary products used and their potential disposal.

Further, the STM BREF document, already at the time of writing, described procedures and activities which are defined and named as cross-linked to what is nowadays called CE. These are mainly general descriptions of industrial good practices for achieving BAT, including environmental management and process optimization.

The STM BREF (EIPPCB 2006) contains 33 generic BATs and 25 specific BATs for the different processes in the STM sector: BATs are described in chapter 5, but aspects of CE and wastes are mentioned there only in generic BATs. However, the following BATs can be considered to promote non-toxic material cycles (table 3).

Table 3. Overview of BATs promoting non-toxic material cycles and circular economy in the STM BREF.

Chapter		Brief description of the content
5.1 Generic BAT		
5.1.1 **Management tecniques**	5.1.1.5	*Process line optimisation and control* It is BAT to optimise individual activities and process lines by calculating the theoretical inputs and outputs for selected improvement options and comparing with those actually achieved.
5.1.2 **Installation design, construction and operation**		It is BAT is to design, construct and operate an installation to prevent pollution by the identification of hazards and pathways, simple ranking of hazard potential and implementing a three-step plan of actions for pollution prevention.
5.1.5 **Waste minimisation of water and materials**	5.1.5.1 5.1.5.2 5.1.5.3 5.1.5.4	*Water minimisation in-process.* *Drag-in reduction.* *Drag-out reduction.* *Rinsing (reduction of water consumption by using multiple rinsing).*
5.1.6 **Materials recovery and waste management**	5.1.6.1 5.1.6.2 5.1.6.3 5.1.6.4 5.1.6.5	*Prevention and reduction.* *Re-use.* *Materials recovery and closing the loop.* *Recycling and recovery.* *Other techniques to optimise raw material usage.*
5.1.7 **General process solution maintenance**		It is BAT to increase the process bath life, as well as maintain output quality, particularly when operating systems near to, or at, the closing of the materials loop.
5.1.8 **Waste water emissions**	5.1.8.1 5.1.8.2 5.1.8.4	*Minimisation of flows and materials to be treated.* *Testing, identification and separation of problematic flows.* *Zero discharge techniques (may not be BAT due to too high energy consumption and investment costs, but in certain, very limited cases it can be the best option, and case by case assessment is needed).*
5.1.9 **Waste**		BAT for waste minimisation are given in Section 5.1.5 and for materials recovery and waste management in Section 5.1.6.
5.2 BAT for specific processes		
5.2.5 **Substitution for, and/or control of, hazardous substances**	 5.2.5.1 5.2.5.2 5.2.5.3 5.2.5.4 5.2.5.5 5.2.5.6 5.2.5.7	It is a general BAT to use less hazardous substances. BAT to avoid or possible to replace the use of 7 main hazardous substances: *EDTA* *PFOS (perfluorooctane sulphonate)* *Cyanide* *Zinc cyanide* *Copper cyanide* *Cadmium* *Hexavalent chromium.*

Many operations and techniques are described, paying attention to prospective waste characteristics. For minimisation and prevention of waste in surface treatment processes, key activities are:

1. reducing the amount of hazardous material in the waste by substitution
2. extension of the service lifetime of the process solutions (Process Solution Maintenance)
3. decrease of the drag-out of process solutions
4. feedback of the dragged-out process solutions into the process tanks.

The quality requirements of the products are agreed upon between the provider and customer, often based on industry standards or ISO documents. For the STM sector, these requirements are applied to the quality control of coatings. In this regard, examples of technological parameters include corrosion resistance testing, laboratory testing of resistance in liquids and solutions, determination of coating thickness, sealing degree testing, testing of light-coloured coatings resistance, abrasion resistance testing, gloss test, etc. Additional general specifications of quality aspects can be found under the ISO 9000 standard. The ISO 9000 series standards relate to quality management and quality assurance, they are necessary when planning the export of products to countries of the European Community, USA and Japan.

Findings concerning the STM sector

STM techniques are supporting CE by creating durable and long-lasting surfaces, the life of metals, such as in automotive bodies, car components, covered polymers and construction materials can be extended. On the other hand, the variety of chemicals and metals used in STM techniques hinders CE friendly recycling (of the consumables and of the products at the end of their useful life) or leads to very high costs. But for basic metals (such as Zinc, Copper and Nickel) from well-defined waste streams recovery processes are currently widely used. The majority of electroplating facilities do not recover their process wastes themselves, but send them to external treatment.

For reuse and recovery of waste, the STM BREF suggests that wastes that cannot be recovered internally may be valorised externally by third parties. Examples of external valorisation could be listed as:

- hydro and pyro metallurgical non-ferrous metal refining (recycling includes the refining of copper, nickel, chromium and zinc from suitable electroplating sludge as metals or metal compounds)
- manufacture of usable metal concentrates
- phosphoric and chromic acids, spent etching solutions, etc.
- aluminium hydroxide from anodising can be precipitated and recycled, for example as a coagulant for sewage treatment.

The STM sector is traditionally associated with large water usage creating a wet working environment. However, many of the currently operated installations applying BAT recommendations have moved away from this way of working by closing the water cycles or at least reducing the water consumption by using staged rinsing techniques. Currently, also the regeneration and maintenance of technological baths are widely used techniques. All of these techniques extend the life of the bath, prevent the formation of waste and are also economically justified. Liquid waste originates from the periodically exchanged technological solutions/liquids, including solutions of highly concentrated chemicals. Liquid waste also includes galvanic baths, which are separately managed (regenerated first, which extends their life and reduces the amount of waste, ultimately subjected to the recovery of raw materials). Residues are neutralized, recycled and/or disposed of.

Beside the used process solutions, wastewater is a potential resource for secondary raw material (SRM). Metals removed from wastewater end up in solid wastes (sludge, which is usually dewatered to 60%–80% water content) and, together with some used process solutions, may be recovered, usually outside the STM installation. The waste operator treats the sludge, but it is not within the scope of STM BREF. For the external processors of liquid waste, including used baths, the problem is the irregularity of waste generation, the varied or often unknown exact composition and the hard-to-predict quantities. Often, these quantities are small, which makes logistics difficult. Due to the use of many hazardous substances, most waste from STM processes is classified as hazardous.

In order to improve recyclability of the waste streams it is necessary to keep certain waste and wastewater streams separate. A list of all chemicals and their composition used in the installation and a process chart, which is connected to the chemicals used, helps to determine which streams could be put together and which need to be kept separate. This also helps the external recyclers to optimize recycling, since they will have better information on the composition of the sludge or liquid waste. This aspect could be an issue for the revision of the STM BREF. Furthermore, the explanations on the substitution of hazardous substances should be extended in the STM BREF explaining which substitutes and limitations for the substitution exist.

An existing problem, but not associated with BAT, is the fact that the durability of coatings (substrate preparation, coating thickness, quality of finish) is usually decided by customers ordering the processing of entrusted components in electroplating plants. Visual properties of coatings are also important to customers and, hence, they are not willing to change the processes easily, e.g. from Cr(VI) to Cr(III). This makes it difficult to follow the requirement of substituting hazardous materials with less hazardous ones.

In order to fulfil CE objectives, we should aim towards a zero emission approach. In STM BREF, the issue was listed (5.1.8.4. Zero discharge) as possible to be achieved for a whole installation, based on a mixture of techniques, but not required as BAT due to high power consumption and the potential of producing wastes that are difficult to dispose of because of their composition. The combination of techniques required to achieve zero discharge are also high in capital and running costs. They are used in isolated cases for specific reasons.

Also, techniques where the metals are merged non-specifically into mineral matrices (glass, ceramics, cement) are not considered recycling, but may be an option (EIPPCB 2006).

From the three HAZBREF CE approaches proposed in this report some aspects are strongly linked to STM activities. Production waste approach (approach 1) focusing on the quantity and quality of wastes generated at the installations, can play an important role. The use of raw materials and chemicals are characterized in stand manuals and technological recipes (for some processes also in BREF). The quality of chemicals used may vary greatly and may have an influence on product quality and recyclability as well as process waste management. Secondary raw material approach (approach 2) is certainly important for the sector. Several metals are used in the sector, so their excavation from waste streams and refining as SRM should be enforced if they fulfil quality requirements. Product end-of-life approach (approach 3) refers to the post-consumer phase. This must be considered with renovation processes of previously electroplated elements, such as removal of a coating. But in practice, after the coatings are removed and converted into waste streams, the two other approaches are more relevant. However, the product end-of-life approach can play an important role in metallurgical processing of post-consumer metal elements, or even more important in coated plastic recycling.

3.3 Textiles Industry (TXT)

Short overview of the sector in Europe

On a global level, the textile production has a massive environmental impact. The impact occurs from all stages throughout the whole value chain, from fibre production to the way textiles are discarded. One of the more severe impacts is due to the chemicals that are used throughout the supply chain; the most significant impact is during the production phase and especially within the wet processes. The Swedish

Chemical Agency has identified 3,500 substances used in textile production, of which 10% are considered to be of high potential concern to human health or the environment (KEMI 2014). In total, 92% of the toxicity impact from a textile product stems from the production phase (Roos 2016).

In a circular economy, non-toxic textile raw materials are a prerequisite, which means that the supply of hazardous chemicals throughout the value chain must be prevented. This requires good knowledge of which chemicals/substances are hazardous, which have the right technical functions, and which non-hazardous alternatives are available on the market. Only then can you ensure high-quality non-toxic textile materials at the end of the first life cycle (Östlund et al. 2015).

To give the textiles their final properties, chemicals such as e.g. detergents, dyestuffs and durable water and oil repellent are added in wet treatment at the finishing process. These chemicals contribute to the environmental impact from the textile industry. The figure 2 (Roos 2016) illustrates the chemicals-related challenges in the textile life cycle. The wet treatment process is the most chemical-intensive phase in the textile life cycle.

According to Euratex, in 2018, there were around 171,000 textile and clothing companies in the EU-28 (Euratex 2018) but the majority, approximately 80%, of textiles consumed in the EU are imported from outside the EU. In addition, it is common that semi-finished textile materials are imported from outside the EU, while the final textile article is produced and labelled in the Union. This would mean that more than 80% of the textile production involving chemical substances occurs outside the EU (KEMI 2014). Between 17% and 20% of the global water pollution from industries is caused by the dyeing and finishing treatment of textiles production (Kant 2012) in countries with, sometimes, poor environmental legislation and supervision. In the EU, every year, 4.3 Mt of textile waste are incinerated or ends up at landfill (Svenska Miljöinstitutet 2016).

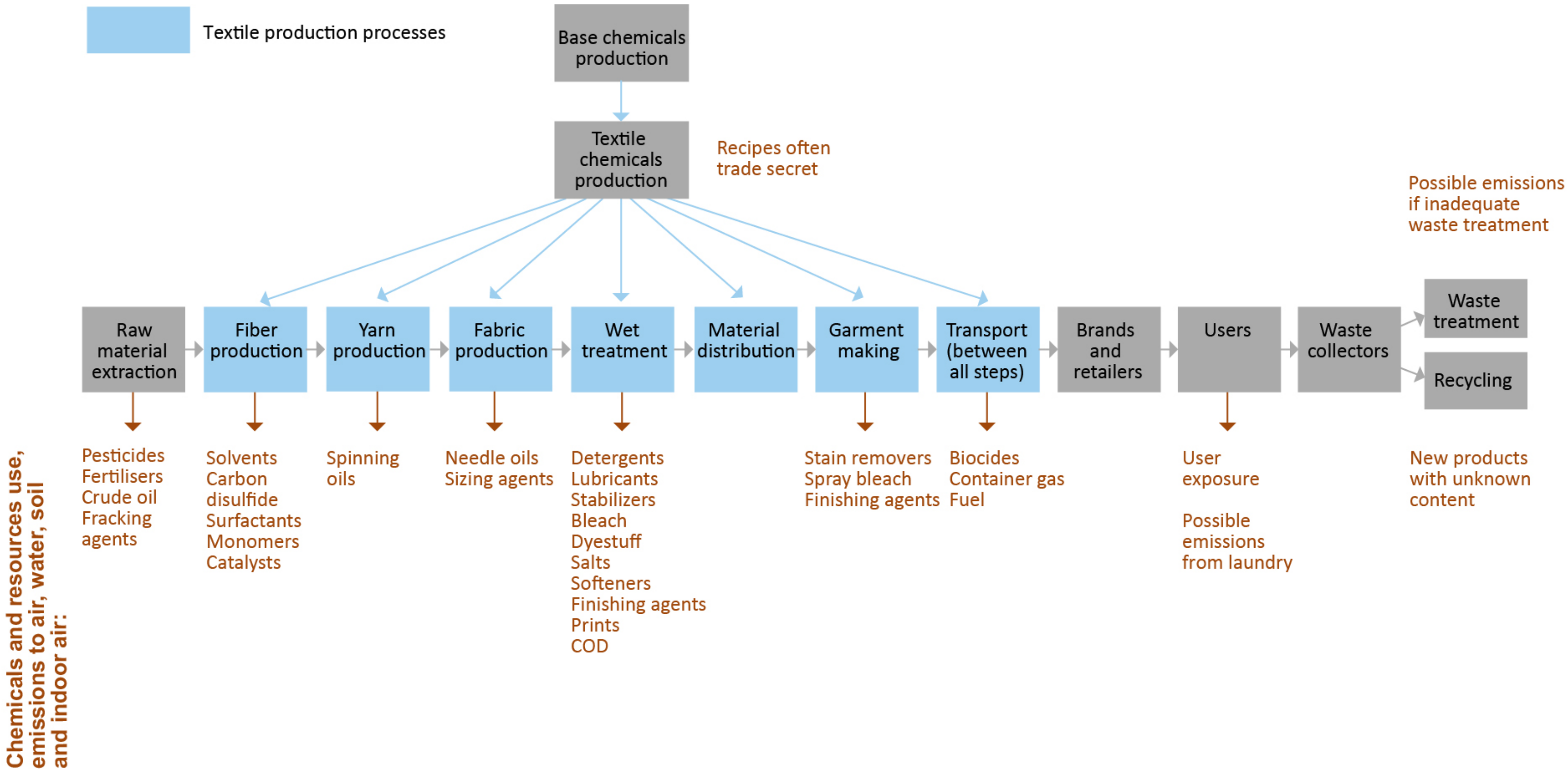

Figure 2. Chemicals-related challenges (in brown) in the life cycle of textiles (Modified from Roos 2016).

The textile waste management of clothing at the EU level is illustrated in Figure 3. At the EU level, the amount of landfilling of the consumed textile clothing in 2014 was about 57%, whereas currently e.g. in Sweden and Finland landfilling is negligible in comparison with incineration. Wasted textiles may leak hazardous substances from landfill areas (KEMI 2014). The recycling rate of textile waste was 10% in 2014, with most of the textile waste being recycled into insulation material, wiping cloths, mattress stuffing and other lower-value applications. The share of closed-loop recycling back to textiles is estimated to be around 1% (from global figures, Ellen MacArthur Foundation 2017).

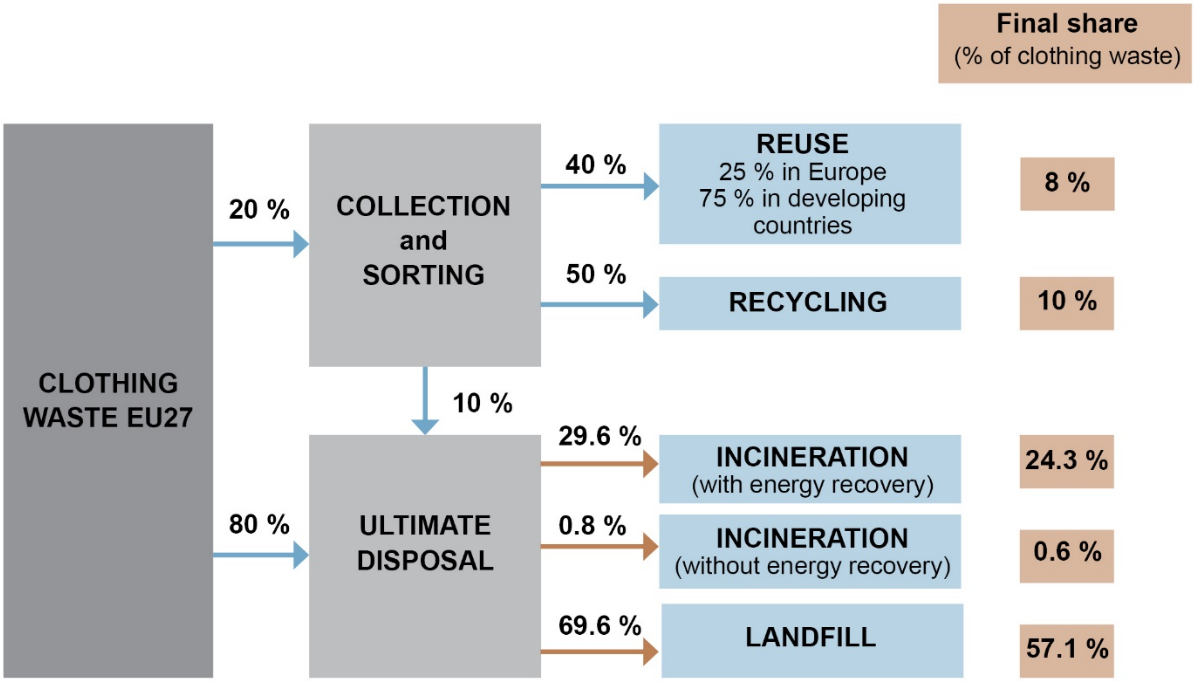

Figure 3. End-of-life routes of textile waste in the EU27 in 2014 (Wolf et al. 2014).

According to the EU's amended Waste Directive, the Member States are obliged to implement a separate collection of textile waste in 2025 at the latest. By 31 December 2024, the European Commission shall also consider, amongst others, recycling targets for textile waste.

Sectoral BREFs and other relevant regulation

The review of the TXT BREF started in 2017 and at the Kick-Off Meeting (June 2018) for the review of the TXT BREF, the KEI for relevant CE issues were concluded to be the amount of waste/by-products generated for certain streams, consumption of energy and water, amount of wastewater discharged and emissions into the air and water of certain hazardous chemicals (e.g. CMR substances).

The current TXT BREF, published in 2003, concerns plants for the pre-treatment (operations, such as washing, bleaching, mercerisation) or dyeing of fibres or textiles where the treatment capacity exceeds 10 t per day. Particular attention is given to the processes; fibre preparation pre-treatment, dyeing, printing and finishing.

The TXT BREF contains 6 generic BATs and 29 specific BATs for the different processes in the textile sector. The BATs identified in the following Table 4 can be considered to promote circular economy.

Table 4. Overview of BATs that can be considered to promote circular economy in the current TXT BREF.

Chapter or BAT (conclusion)	Brief description of the content
5.1 Generic BAT	Management The good management practices in BREF 2003 is an attempt to point out general principles and pollution prevention approaches that are almost universally applicable in textile mills. Selection & use of chemicals The selection and use of chemicals are an attempt to use less chemicals and substitute some chemicals. To substitute surfactants that are not biodegradable or bioeliminable. Avoid or reduce the use of complexing agents, antifoaming agents. Selection of incoming fibre raw material BAT is to seek collaboration with upstream partners in the textile chain in order to create a chain of environmental responsibility for textiles. It is desirable to exchange information on the type and load of chemicals that are added and remain on the fibre at each stage of the product's life cycle.
5.2.1	Use of integrated dirt removal/grease recovery loops combined with evaporation of the effluent and incineration of the sludge (water & energy).
4.5.1	Recovery of sizing agents by ultrafiltration This technique is suitable for specific types of sizing agents, such as water-soluble synthetic sizing agents e.g. PVA, polyacrylates and carboxymethyl cellulose. It has also been confirmed that some modified starches, such as carboxymethyl starch, can be recycled. The concentrate is recovered during the technique and can be re-used for sizing. The permeate can be recycled as water in the washing machine.
5.2.2 Washing	Use of fully closed-loop installations for fabric washing (scouring) with organic solvent. The new installations are fitted with closed-loop active charcoal filters. The exhaust duct has been eliminated and the purified air is now recycled to the fabric deodorising / cooling section of the machine: this avoids any air-stream exhaustion to the outside environment. Moreover, with the closed-loop filters it has been possible to re-design more efficient sealing systems at the machine inlet and outlet sides with consequent benefits for the workplace as well.
5.2.2 Dyeing	pH-controlled dyeing techniques (water and dye batch) This technique offers recycling and recovery of spent dye baths. With a pH-controlled system, the hot spent bath can be recycled for the next batch, instead of being cooled down before re-use. This is not possible in a temperature-controlled dyeing system because in that case the dyeing cycle cannot be started at the so called "treatment temperature" but must be started at a lower temperature (e.g. 50°C) in order to prevent uneven dyeing. Additional benefits in terms of time and energy savings can be achieved when the hot spent dye bath is recycled because the dye liquor can then be re-used for the next dyeing cycle without the need to cool it down and warm it up again.
5.3 Wool scour sludge disposal	Use of wool scour in brick -making Clay for brick-making should contain a certain amount of organic material, since it improves the quality. Some clays are deficient in organic content and, for this application, an addition of wool scour is excellent.

Findings concerning the sector

To promote a more circular economy in the textile sector we need to start in the design phase as 80% of the environmental impact of textiles is determined there. We need to keep the end-of-life of the product in mind already in the design phase. In a CE, textiles must be designed suitable for recycling and having a longer life than in the current fast fashion mode (Niinimäki et al 2020). It is also important to consider that transparency throughout the production chain is essential in a resource efficient and toxic free circular economy (Rex et al. 2019).

The first priority of the waste hierarchy, prevention, can, in the case of textile waste, be obtained by increasing the textiles active life at one or multiple users, which at best leads to a decreased production and consumption of new textiles. This would reduce the total environmental impact of the textile. A double life span of a textile product decreases the environmental impact by 49 %. According to a report from the research programme Mistra Future Fashion, the environmental impact of the textile production could be reduced with up to 70 % if the textile could be used up to three times longer compared with today. The pre-requisite for this is that the textile replaces a newly produced garment.

The most voluminous and discussed textile waste is post-consumer waste, i.e. the textile products that consumers discard. Hence, of the three CE approaches discussed in this report (see chapter 1.2), the one focusing on the recoverability of the product at the post-consumer end-of-life phase (Approach 3) would be the most relevant for increasing the circularity of textiles. But it is important to consider that recycling, both chemical and mechanical, should be the last step when reuse, repair and resale are no longer feasible.

There are several challenges in increasing textile waste recycling: the use of fibre mixtures makes it difficult to sort and separate different materials and the quality of textile materials is low. Additionally, there is a potential risk of textile waste containing hazardous substances, which however, have not been analysed from textile wastes. Nevertheless, one important step in promoting the recovery of textile waste is to substitute hazardous substances in the production phase (Östlund et al. 2015). This could be highlighted more in the TXT BREF.

To facilitate and increase the economics of recovery, greater transparency is needed in a circular textile value chain. Tagging could be a solution for this. The use of tags could be of great value not only in the end-of-life stage, but throughout the entire life cycle. A tag with accessible information about the fibre composition, specific chemical treatments and sorting instructions, as well as including data about the design and care-instructions. (Englund et al 2018). Another solution could be to promote a form of "textile EcoDesign Directive", since the design and material choices are of utmost importance for the possibility of recovery.

To promote a non-toxic circulation of textiles, a chemical inventory is needed in the textile industry to know what chemicals/substances are used. Additionally, improvement of the collaborations with the upstream partners in the textile value chain is needed, as mentioned in the TXT BREF from 2003, in order to create a chain of environmental responsibility for textiles. When textile waste recycling is increased, diverse waste flows from diverse origins may be mingled. Recycling of post-consumer textiles and a non-hazardous material flow can be contaminated by an addition of textiles containing hazardous substances. (KEMI 2016). One suggestion to deal with this is to store chemical information or a confirmation of non-toxicity of chemicals used on the label. This approach is similar to the approach of voluntary environmental textile schemes, such as Blue Sign and OEKO-TEX. Another approach could be tagging each item with e.g. a RFID tag. The RFID system could be useful for the professional sector, *e.g.* police or firefighting uniforms, where it is important to keep track of specific items in terms of the number of washes, sizes etc. There have been discussions whether this method could be suitable even for consumer wear to promote a more efficient recovery (Östlund et al. 2015).

To help the consumers to change their behaviour and be more aware of the content of hazardous substances in textile goods, a first step is to introduce the app LIFE AskREACH[19]. The aim of LIFE AskREACH is to facilitate the communication between the consumers and the companies and to help the consumers to get information about the content of Substances of Very High Concern (SVHCs) in consumer goods, such as textiles. The AskREACH project has developed a European wide database for article suppliers to submit information on SVHCs in their articles. The database is now open for suppliers to submit their data. The consumer smartphone app was launched officially in 2019. The application allows consumers to access the information provided in the database and make SVHC requests for articles not found in the database[20]. Suppliers of goods containing more than 0.1% of an SVHC must inform their customers of this proactively, according to Reach Art. 33.

[19] https://www.askreach.eu/
[20] https://www.askreach.eu/submit-your-article-information-to-the-askreach-database/

4 Conclusions

4.1 General conclusions

The focus of the HAZBREF project was on hazardous substances and how the IED and BREF process can help to promote non-toxic material cycles. However, in this report we also considered other aspects that promote more efficient material cycles, since increased material circulation reduces the need to use new materials in production. Nevertheless, it is not advisable to promote material circulation that keeps hazardous materials in the loop and may lead to increased chemical risks, through e.g. substituting the current raw materials with recovered materials that might contain more hazardous substances. Currently, there are still materials and processes for which substitutes for hazardous substances are not available and, in these sectors, risk reduction measures are more important than substitution. In general, in order not to shift problems from one phase of production or life cycle to another, decision-making should be based on systemic assessments (e.g. life cycle assessment) capable of generating a holistic view of the impacts of the sector studied.

CE extends over multiple legal frameworks, such as product design, product legislation and standards for product requirements, IED for operational requirements for industrial installations and WD for waste management. The implementation of CE requires better alignment between IED, WD, product legislation and applicable regulations relevant for more efficient material use and non-toxic material streams. CE objectives cannot be reached by amending a single regulatory framework. Instead, a systematic review of the whole regulatory system is required.

Currently authorities in Member States define by-products and End-of-Waste (EoW) products differently. Harmonization is needed in order to have a common European approach and promote the use of these possibilities in increasing the circularity of materials. This kind of harmonization is one of the objectives and tasks of the IMPEL network. This enables companies to better understand the CE objectives.

An overall conclusion from our study is that IED and BREFs can promote CE objectives only to a limited extent[21]. However, more can be done to make better use of the IED's existing mechanisms. The provisions of the IED and the BREF guidance provide the possibility to address the three approaches to CE[22] in the BREF process. In the sectoral studies, we identified possibilities of addressing certain aspects for promoting non-toxic material cycles, which directly contribute to improving the recoverability of secondary raw materials.

The traditional scope of IED and BREFs is the installation (gate to gate thinking), whereas CE needs to apply a life cycle thinking and a better connection of upstream and downstream processes. This requires better implementation of value chain thinking. For example, the regulation of product design and quality directly impact the content of future waste streams once these products are discarded.

Systematic and transparent collaboration with upstream and downstream partners (Huybrechts et al. 2018) of the value chain improves the flow of information on hazardous substances within the chain and enables the promoting of the non-toxic circulation of materials by helping to sort out and direct (sub)products containing hazardous substances into required treatment. The rest of the waste material would, hence, be better suitable for recovery.

The producer can't always fully decide what substances to use in the process, since customer demands play a significant role (e.g. in surface treatment). Sometimes the downstream partners may

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[21] This came up in the HAZBREF stakeholder discussions, as well as in the Ricardo study.

[22] Three approaches for adding a CE focus into the BREF process are analyzed: 1. Production waste approach focusing on the quantity and quality of wastes generated at the installation, 2. Secondary raw material approach focusing on the use of secondary raw materials (materials that can be used in a manufacturing process instead of or alongside virgin raw materials, e.g. by-products or end-of-waste) at the installation, and 3. Product end-of-life approach focusing on the recoverability of the product at the post-consumer end-of-life phase.

consider that the use of more environmentally friendly substances is contradictory to the desired product properties. Therefore, it is important that comprehensive information on the environmentally friendly substances and substitution possibilities are made available to the customer by the supplier. The customer should be aware of the environmental and health risks and the functionality of the substances.

The most important phases of the value chain for promoting CE objectives vary from sector to sector. For example, in the textile sector the most important phase is the design phase as 80% of the environmental impact of textiles is determined there. It is also important to consider that transparency throughout the production chain is essential in a resource efficient and toxic free circular economy (Rex et al 2019). One important step to promote the recovery of textiles is to substitute hazardous substances in the production phase (Östlund et al. 2015). For some sectors, for example STM, the design of the production process has more potential for promoting CE objectives than the product design. Currently, the CE elements in the regulation of product and process are mostly lacking and this gives some leeway for including circular design aspects in BREFs.

Reasons related to logistics often limit circular material flows: the transportation costs might prevent the utilization of secondary raw materials. The location of production sites is crucial in order to support industrial symbiosis and circular material flows. A large integrated site usually has much more options to use side streams, by-products etc. internally. For example, in Finland oil refinery and polymer production are in the same site, which enables efficient material flows between different companies.

The following subchapters describe measures that could be incorporated into the BREF process. The proposed measures are listed under the three HAZBREF CE approaches. It must be acknowledged that the proposed measures are not necessarily limited under a single approach, but in order to avoid repetition are only listed under one approach.

4.2 Production waste approach

The Production waste approach fits well into the current installation focus of BREFs and many BREFs already include BATs on waste recovery and treatment. However, actions promoting non-toxic cycles should be given more focus than currently. Cross-contamination of waste materials should be prevented through requirements on source separation in BREFs. The WT BREF and sectoral BREFs could provide requirements on the separate collection and storage of different waste fractions in cases where combined collection hinders promotion of CE. This would offer better prerequisites for the application of EoW criteria and more efficient waste recovery by preventing cross-contamination and enabling fulfilment of different product requirements and standards. The WT BREF has a distinctive role in that it can apply to all wastes treated in IED sized WT plants, whereas sectoral BREFs can only affect specific waste streams.

Waste hierarchy is the leading principle supporting efficient material cycles in waste management. The hierarchy is already referred to in many existing BREF documents, although in practice it has rarely had any binding effect. Thus, more emphasis should be put on the practical implementation of waste hierarchy within sectors. For example, the BREF could include a requirement for the operator to regularly consider the recoverability for each waste type produced (e.g. quality of waste, available techniques). As a minimum, good practices of CE within the sector should be listed in the BREF documents. For example, the STM sector study identified the regeneration and maintenance of technological baths to be widely used, and economically justified, methods to extend the life of the baths and to prevent the formation of waste. A more ambitious implementation would be to set quantitative performance levels. However, this would require evidence from operators supporting the determination of such levels and this may not be feasible for all sectors.

4.3 Secondary raw material approach

The second HAZBREF approach to CE requires the implementation of value chain thinking into the BREF process. The circulation of waste-based materials between installations or sectors demands a better connection of upstream and downstream processes. Sectoral BREFs should refrain from making statements that could discourage the application of solutions that promote CE and, instead, introduce examples of successful practices for waste recovery and the use of secondary raw material. Sectoral BREFs should also be used to indicate the most common by-products and their possible further uses in industrial processes. Product requirements may limit the use of secondary raw materials and quantitative BATs (BAT-AEPLs) are rarely feasible, but increased information on possible uses in the form of narrative BATs in BREFs would support the use of the by-product criteria of WD and prevent waste generation.

In the current LVIC-AAF BREF, phosphogypsum is listed as a high-volume by-product. The BREF states that it is BAT to market the phosphogypsum, but also that the marketing of the phosphogypsum is challenging due to impurities, transportation costs and competition with natural resources. The BREF has little opportunities to influence current market and transportation costs, but it could influence the possible contamination of by-product phosphogypsum. Our case study in fertiliser production also shows that not all phosphogypsum is contaminated with impurities. The future LVIC BREF should take the variation in the quality of phosphogypsum into account when describing the properties and possible uses of by-products. In a wider perspective, a similar approach should be used with other wastes in different BREFs.

Valuable metals from STM industry can be extracted from the wastewater, sludge or other waste materials and they are used in other sectors. For example, certain metals are essential plant nutrients and added to fertilisers. The new fertiliser product legislation, however, hinders the use of waste derived raw materials in inorganic fertilisers. If a company would want to use a waste derived raw material, such as EoW product which is not already included in the Annex II of the fertiliser product legislation, the material would have to go through an EU-wide conformity assessment prior to its use. This process is complicated and might be too time consuming for the manufacturer and might lead to lesser use of EoW materials.

One of our findings points out that some operators do not utilize waste-based materials (by-products, EoW) because they would need to register the material according to REACH. The operators consider the registration process to be too complicated and resource consuming.

4.4 End-of-life approach

The End-of-life approach goes way beyond the current scope of IED and BREFs. The idea of setting requirements on product quality or other characteristics in BREFs is not as such possible in the current BREFs. Yet, one means to support non-toxic material flows would be to introduce BAT for chemical inventory in sectoral BREFs, especially in sectors where hazardous chemicals are used and/or formed/emitted. An inventory BAT is already included in the waste treatment (WT) and Common Waste Water (CWW) BREFs, but it should be developed to specifically serve CE issues in sector BREFs. The purpose would be to get information to which extent hazardous substances, such as POPs and SVHCs, end up in the product or waste from the installation. The inventory could be supplemented with information on how to prevent or minimize the accumulation of hazardous substances in waste and products. The inventory should be designed in such a way that it would facilitate the utilization of generated waste/by-products and also generate better prerequisites for the recovery of post-consumer waste.

In order to help the utilisation of post-consumer waste, the information of the chemical content of the products should be transferred throughout the whole supply-chain all the way from the production of raw materials until the waste treatment phase of the post-consumer product (Huybrechts et al 2018). For example, the textile sector study noted that due to the use of a variety of chemicals in different life cycle phases, there is a need for a system to trace the chemical content of post-consumer textiles in order to promote the recovery of fibres. There are several ideas on how the tracking of chemicals could be executed[23], but none of them yet addresses the problem of undeliberate contaminations, such as a non-hazardous textiles material flow being contaminated by an addition of textiles containing hazardous substances (KEMI 2016). If the chemical composition of waste-based materials cannot be identified, they cannot be recovered. Acquiring data on the chemical composition is much harder, if not impossible, in the end-of-life phase than in earlier life cycle phases. The same applies to the polymer sector and also to other sectors, such as the production of pulp, paper and board (PP BREF), manufacture of glass (GLS BREF), etc.

One supporting tool for transferring the information on substances in the supply chain could be the SCIP-database (**S**ubstances of **C**oncern **I**n articles, as such or in complex objects (**P**roducts)) currently being developed by ECHA (ECHA 2019c). The companies will need to submit information to the database on SVHCs[24] in articles from 2021 onwards, in addition to the obligation to inform customers (REACH Art. 33(1)). The aim of the database is “to promote the substitution of hazardous chemicals and a circular economy” by providing information of hazardous substances for consumers and waste operators. In order for companies to be able to fulfil the obligation of submitting information to the SCIP-database, the information flow from downstream users of chemicals in the value-chain is required. This could be supported by the chemical inventory BAT in sectoral BREFs.

To state the obvious, new provisions in BREFs concerning product design cannot affect the quality of existing products. An option is to foster for a differentiated approach, depending on the maturity of products. Nevertheless, future BREFs could include a new kind of guidance concerning CE design for new products. For existing products, CE BATs should focus on waste recovery to make sure that legacy substances[25] are removed from material cycles.

4.5 Horizontal vs. sectoral BREFs

There have been some discussions on whether CE aspects can be promoted best in a horizontal BREF dedicated to CE aspects or by including CE aspects to the review of sectoral BREFs. For example, the Ricardo study recommends consideration of an additional horizontal BREF on Circular Economy. Moreover, in the IED Forum some proposals to merge the horizontal Industrial Cooling Systems (ICS) BREF with the Energy Efficiency (ENE) BREF into one resource efficiency BREF have been presented, which could give the possibility to emphasize CE issues in more detail.

Horizontal BREF could be one option for implementing overall CE aspects within the scope of application of the IED. However, sectoral BREFs can address the specific CE challenges of a sector more effectively. For example, the avoidance of cross contamination of waste materials or waste hierarchy issues can be promoted on a general level in a horizontal BREF as stated above, but in sectoral BREFs there can also be specific issues on wastes and practical implementation of the waste hierarchy. Furthermore, the implementation of horizontal BREFs is not always focused in permitting. Sectoral BREFs can lay down tailor-made solutions for each industrial sector (e.g. the CE aspects identified in the sectoral case-studies of HAZBREF). Incorporating concrete CE provisions into horizontal BREFs can be difficult, as it would require provisions that are applicable to several industrial activities. For example, in our study on the three different sectors we found out that the applied three different approaches are not

[23] For example, the ChemChain project https://cordis.europa.eu/project/id/875783; www.chemcha.in
[24] Candidate List of substances of very high concern for Authorisation (https://echa.europa.eu/candidate-list-table)
[25] Legacy substances refer to substances of concern that may now be banned or, otherwise, restricted, even though they might be present in products already on the market or in waste streams as a consequence of their legitimate use in the past: e.g., brominated flame retardants that were mainly used in plastic products and textiles.

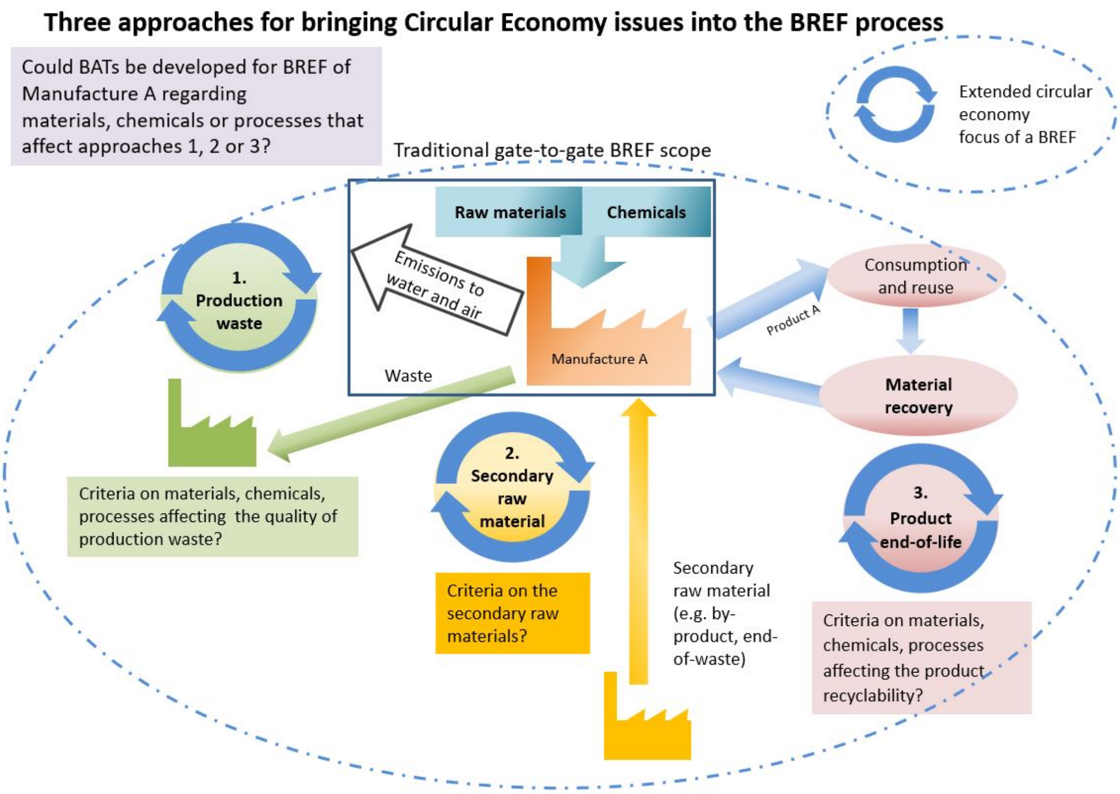
relevant for all the sectors due to the differences in production processes and products (e.g. plastics vs fertilisers).

To conclude, HAZBREF clearly supports including concrete CE aspects in sectoral BREFs, rather than preparing a horizontal CE BREF with vague general BATs that are difficult to implement in practise.

5 Executive Summary

This report *Promoting non-toxic material cycles – challenges and opportunities in the BREF process* is the result of HAZBREF activity 4.4 of work package 4 "Best practices in chemicals management in industry"[26]. This report focuses on enabling the progress of Circular Economy (CE) by promoting non-toxic material cycles through the BREF process. The following three approaches for adding CE aspects into the BREF process were considered:

- **Production waste approach**: Focusing on the quantity and quality of wastes generated at the installation. Can requirements be given on the use of raw materials, chemicals, or the installation processes from the point of view of how they affect the amount and recoverability of production/industrial waste generated?
- **Secondary raw material approach**: Focusing on the use of secondary raw materials (materials that can be used in a manufacturing process, instead of or alongside virgin raw materials, e.g. by-products or end-of-waste) at the installation. Can requirements be given on the quality of secondary raw materials originating from other facilities/installations/sectors from the point of view of how this affects the recoverability of the wastes or products produced?
- **Product end-of-life approach**: Focusing on the recoverability of the product at the post-consumer end-of-life phase. Can requirements be given on the use of materials, chemicals or processes at the installation from the point of view of how they affect the post-consumer product recoverability?



[26] For more information on the HAZBREF project, see: https://www.syke.fi/projects/hazbref.

The aim of this report was to:
- analyse the need and possibilities for adding CE promoting elements to the BREF process (cf. other legislation)
- propose measures to be taken for adding these elements in the BREF process
- focus on recycling/circulation obstacles generated by use of hazardous substances in the installations covered by the Industrial Emissions Directive (IED).
- promote pollution reduction through cleaner material cycles (non-toxic material cycles).

This report seeks answers to the following questions:
- How are CE issues currently dealt with in the BREF process?
- What are the legislative possibilities and barriers for including CE issues in BREFs more extensively than now?
- How could/should the CE aspects connected to the generation of non-toxic material circles be addressed in BREFs?

The report focuses on the CE aspects of the HAZBREF case sectors: polymers (POL) and fertilisers (LVIC), textiles (TXT), and the surface treatment of metals and plastics (STM).

General conclusions

The focus of the HAZBREF project was on hazardous substances and how the IED and BREF process can help to promote non-toxic material cycles. However, in this report we also considered other aspects that promote more efficient material cycles, since increased material circulation reduces the need to use new materials in production. Nevertheless, it is not advisable to promote material circulation that keeps hazardous materials in the loop and may lead to increased chemical risks, through e.g. substituting the current raw materials with recovered materials that might contain more hazardous substances. Currently, there are still processes in which hazardous substances cannot be substituted. In these processes, risk reduction measures are more important than substitution.

CE extends over multiple legal frameworks, such as product design, product legislation and standards for product requirements, Industrial Emissions Directive (IED) for operational requirements for industrial installations and Waste Directive (WD) for waste management. The implementation of CE requires better alignment between IED, WD, product legislation and all applicable regulations. CE objectives cannot be reached by amending a single regulatory framework. Instead, a systematic review of the whole regulatory system is required.

Currently, authorities in Member States define by-products and End-of-Waste (EoW) products differently. Harmonization is needed in order to have a common European approach and promote the use of these possibilities in increasing the circularity of materials. This kind of harmonization is one of the objectives and tasks of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL network).

In order to avoid creating a complicated legislative framework, the IED and BREFs should not aim at laying down provisions that are already set out in other legislation applicable for promoting CE. The IED and BREFs are only able to regulate the production stage and their scope cannot be extended to address the whole lifecycle of a product or material. However, BREFs could include references to other legislation and set specific targets considered as BAT. This would make the general targets set in other legislation more concrete at an industrial activity level. When concrete CE-related legal obligations have been laid down outside IED, the IED or BREFs could, not only highlight the importance of these obligations, but also provide legal coherence and practical guidance in implementing them.

Even if the IED and BREFs can promote CE objectives only to a limited extent, more can be done by making better use of the existing mechanisms. The provisions of the IED and BREF guidance give the possibility to address the three HAZBREF approaches to CE in the BREF process, but, thus far, the promotion of CE aspects has not been systematic in the BREF process. Also, the ongoing IED evaluation can offer an opportunity to refine the BREF guidance and the way in which the CE aspects are promoted in BREFs.

The traditional scope of IED and BREFs covers a single industrial installation from gate to gate, whereas promoting CE needs life cycle thinking and better connections to upstream and downstream processes. This requires an improved implementation of value chain thinking. For example, the regulations of product design and quality directly impact the content of future waste streams.

In its sectoral studies, the HAZBREF project identified some possibilities that could promote non-toxic material cycles by directly improving the recoverability of secondary raw materials. Systematic and transparent collaboration with upstream and downstream partners in the value chain improves the flow of information on hazardous substances and helps to sort out the (sub)products containing hazardous substances and direct them towards proper treatment. The rest of the waste material would, hence, be better suited for recovery.

The producer can't always fully decide on the substances used in the process, as customer demands play a significant role (e.g. in surface treatment and textiles production). Sometimes the downstream partners consider the use of more environmentally friendly substances to be contradictory to the desired product properties. Therefore, it is important that comprehensive information on the environmentally friendly substances and substitution possibilities are made available to the customer by the producer. The customer should be aware of the environmental and health risks and the functionality of the chosen substances.

The importance of different phases of the value chain in promoting CE objectives vary from sector to sector. For example, in the textile sector the most important phase is the design phase as 80% of the environmental impact of textiles is determined there. For other sectors, for example STM, the design of the production process has more potential to promote CE objectives than the product design. Currently, the CE elements in the regulation of product and process are mostly lacking and this gives some leeway for including circular design aspects in BREFs.

Logistical reasons often limit circular material flows: the transportation costs may prevent the utilization of secondary raw materials. The location of production sites is crucial to support industrial symbiosis and circular material flows. A large integrated site usually has much more options to use side streams, by-products etc. internally. For example, in a company in Finland, the oil refinery and polymer production are on the same site, which enables efficient material flows between different companies.

The following subchapters describe measures that could be incorporated into the BREF process. The proposed measures are listed under the three HAZBREF CE approaches. It must be acknowledged that the proposed measures are not necessarily limited under a single approach, but in order to avoid repetition are only listed under one approach.

Ways to promote CE aspects and non-toxic material circles in BREFs

- The provisions of the IED and BREF guidance give the possibility to promote CE aspects in the BREF process, but, thus far, it has not been systematic. The IED evaluation offers an opportunity to refine the BREF guidance and the way in which CE aspects are promoted in BREFs.
- The IED and BREFs should not lay down provisions that are already set out in other CE promoting legislation, but BREFs could include references to other legislation and set specific targets considered as BAT. This would make the general targets set in other legislations more concrete at an industrial activity level.
- Systematic and transparent collaboration with upstream and downstream partners in the value chain improves the flow of information on hazardous substances and helps to sort out the (sub)products containing hazardous substances and direct them towards proper treatment.
- The importance of different phases of the value chain in promoting CE objectives vary from sector to sector.

Production waste approach

The Production waste approach fits well into the current installation focus of BREFs and many BREFs already include BATs on waste recovery and treatment. However, actions promoting non-toxic cycles should be given more focus than currently. Cross-contamination of waste materials should be prevented through requirements on source separation in BREFs. The Waste treatment (WT) BREF and sectoral BREFs could require a separate collection and storage of different waste fractions in cases where combined collection hinders promotion of CE. This requirement would offer better prerequisites for the application of EoW criteria and more efficient waste recovery by preventing cross-contamination and enabling fulfilment of different product requirements and standards. The WT BREF has a distinctive role in that it can apply to all wastes treated in IED sized WT plants, whereas sectoral BREFs can only affect specific waste streams.

Waste hierarchy is the leading principle supporting efficient material cycles in waste management. The hierarchy is already referred to in many existing BREF documents, although, in practice, it has rarely had any binding effect. Thus, more emphasis should be put on the practical implementation of waste hierarchy within industrial sectors. For example, BREF could include a requirement for the operator to regularly consider the recoverability of each waste type produced (e.g. quality of waste, available techniques). As a minimum, good CE-related practices within the sector should be listed in the BREF documents. A more ambitious implementation would be to set quantitative performance levels. However, this would require evidence from operators supporting the determination of such levels and this may not be feasible for all sectors.

Production waste approach possibilities

- Many BREFs already include BATs on waste recovery and treatment, but more focus should be given to actions promoting non-toxic material cycles.
- Cross-contamination of waste materials should be prevented through requirements on source separation in BREFs.
- The practical implementation of waste hierarchy within industrial sectors should be emphasized.

Secondary raw material approach

The second of the HAZBREF approaches to CE requires incorporating value chain thinking into the BREF process. Circulation of waste-based materials between installations or sectors demands a better connection of upstream and downstream processes. Sectoral BREFs should refrain from making statements that can discourage application of CE-promoting solutions, and, instead, introduce examples of successful practices for waste recovery and use of secondary raw materials. Sectoral BREFs should also be used to indicate the most common by-products and their possible further uses in industrial processes. Product requirements may limit the use of secondary raw materials and quantitative BATs (BAT-AEPLs) are rarely feasible, but increased information on possible uses in the form of narrative BATs in BREFs would support the use of by-product criteria of WD and prevent waste generation.

The current LVIC-AAF BREF states that it is BAT to market the by-product phosphogypsum, but also that this is challenging due to impurities, transportation costs and competition with natural resources. The BREF has little opportunities to influence current market and transportation costs, but it could influence the possible contamination of by-product phosphogypsum. The next LVIC BREF should take this variation of quality into account when describing the properties and possible uses of by-products. In a wider perspective, a similar approach should be used with by-products in different BREFs.

Valuable metals from the STM industry can be extracted from the wastewater, sludge or other waste materials and they are used in other sectors. For example, certain metals are essential plant nutrients and added to fertilisers. The new fertiliser product legislation, however, hinders the use of waste derived raw materials in inorganic fertilisers.

One of our findings points out that some operators do not utilize waste-based materials (by-products, EoW) because they would need to register the material according to REACH. The operators consider the registration process to be too complicated and resource consuming.

Secondary raw material approach possibilities and challenges

- Circulation of waste-based materials between different industrial installations or sectors demands a better connection of upstream and downstream processes.
- Sectoral BREFs should introduce examples of successful practices for waste recovery and the use of secondary raw materials and refrain from making statements that can discourage application of CE-promoting solutions.
- Some operators do not utilize waste-based materials (by-products, EoW) because they would need to register the material according to REACH and they consider the registration process to be too resource consuming.

End-of-life approach

The End-of-life approach goes beyond the current scope of IED and BREFs. The idea of setting requirements on product quality or other characteristics in BREFs is not, as such, possible in the current BREFs. Yet one method to support non-toxic material flows would be to introduce BAT for chemical inventory in sectoral BREFs. An inventory BAT is already included in the waste treatment (WT) and Common Waste Water (CWW) BREFs, but it should be developed to specifically serve CE issues in sector BREFs. The purpose would be to get information to which extent hazardous substances end up in the product or waste from the installation. The inventory could be supplemented with information on how to prevent the accumulation of hazardous substances in waste and products. The inventory should be designed in such a way that it would facilitate the utilization of generated waste and by-products and generate better prerequisites also for the recovery of post-consumer waste.

In order to help the utilization of post-consumer waste, the information of the chemical content of the products should be available throughout the whole supply-chain, all the way from the production of raw materials until the waste treatment of the product**.** For example, the HAZBREF case study on the textile sector noted that due to the use of variety of chemicals in different life cycle phases, there is a need for a system to trace the chemical content in post-consumer textiles in order to promote the recovery of fibres. There are several ideas on how the tracking of chemicals could be executed, but none of them yet address the problem of undeliberate contamination. If the chemical composition of waste-based materials cannot be identified, they cannot be safely recovered. Acquiring data on the chemical composition is much harder in the end-of-life phase than in earlier life cycle phases.

The SCIP-database (Substances of Concern In articles, as such or in complex objects (Products)) currently developed by ECHA could be a suitable tool for supporting the transfer of the information on substances in the supply chain. The aim of the SCIP database is “to promote the substitution of hazardous chemicals and a circular economy” by providing information of hazardous substances to consumers and waste operators. To be able to submit the information to the SCIP-database, companies need the information flow from the whole value-chain. This could be supported by adding chemical inventory BAT in sectoral BREFs.

To state the obvious, new provisions in BREFs concerning product design cannot affect the quality of existing products. An option is to foster for a differentiated approach, depending on the maturity of products. Nevertheless, future BREFs could include new kind of guidance concerning CE design for new products.

Horizontal vs. sectoral BREFs

End-of-life approach possibilities and challenges

- The End-of-life approach goes beyond the current scope of IED and BREFs. The idea of setting requirements on product quality or other characteristics in BREFs is not possible at the moment.
- Introducing BAT for chemical inventory in sectoral BREFs could support non-toxic material flows.
- In order to help the utilization of post-consumer waste, the information of the chemical content of the products should be available throughout the whole supply-chain – all the way from the production of raw materials until the waste treatment of the product.

There has been some discussion on whether CE aspects can be promoted best in a horizontal BREF dedicated to CE aspects or by including CE aspects to the review of sectoral BREFs. For example, the Ricardo study on IED contribution to Circular Economy (DG Environment 2018), recommends an additional horizontal BREF on Circular Economy. Moreover, in the IED Forum some proposals to merge the horizontal Industrial Cooling Systems (ICS) BREF with the Energy Efficiency (ENE) BREF into one resource efficiency BREF have been presented, which could give the possibility to emphasize CE issues in more detail.

Horizontal BREF on Circular Economy	versus	**Circular Economy aspects in sectoral BREFs**
• Good for implementing overall CE aspects within the scope of application of the IED.		• Good for addressing the specific challenges of a certain sector more effectively.
• Not always used in permitting.		• Used in permitting.
• Provisions must be applicable to a wide range of industrial activities.		• Provisions tailor-made for the industrial sector in question.

Horizontal BREF could be one option for implementing overall CE aspects within the scope of application of the IED. However, sectoral BREFs can address the specific challenges of a sector more effectively.

To conclude, HAZBREF clearly supports including concrete CE aspects in sectoral BREFs, rather than preparing a horizontal CE BREF with vague general BATs that are difficult to implement in practise.

Definitions and abbreviations

BAT	Best Available Technique
BAT-AEL	BAT-associated emission level
BAT-AEPL	BAT-associated environmental performance level
BREF	Best Available Technique Reference Document
By-product	A production residue (a material that was not deliberately produced in a production process), which meets the cumulative conditions set out in the WD or the detailed criteria established on the basis of these conditions and which is to be used as a secondary raw material or product and is not to be considered a waste.
CE	Circular Economy
CMR	Carcinogenic, Mutagenic, toxic to Reproduction
Disposal	Any operation which is not recovery, even where the operation has as a secondary consequence the reclamation of substances or energy.
EEA	European Environment Agency
End-of-Waste	A material recovered from waste, which meets the cumulative conditions and requirements set out in the WD or the detailed criteria established on the basis of these conditions and requirements, and which is to be used as a secondary raw material or product and no longer considered waste.
FDM	Food, Drink and Milk Industries
IED	Industrial Emissions Directive, Directive 2010/75/EU of the European Parliament and the Council on industrial emissions
IMPEL	The European Union Network for the Implementation and Enforcement of Environmental Law
KEI	Key Environmental Issue
LVIC	Large Volume Inorganic Chemicals
LVOC	Large Volume Organic Chemicals
POP	Persistent Organic Pollutant as defined in the Stockholm Convention
REACH	Registration, Evaluation, Authorisation and Restriction of chemicals, EC 1907/2006
Recovery	Any operation of which the principal result is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy (Art 3(15) WD)
Recycling	Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes (Art 3(17) WD)
Re-use	Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived (Art 3(13) WD)
SME	Small and Medium-sized enterprise
SRM	Secondary Raw Material
STM	Surface Treatment of Metals and Plastics
SVHC	Substance of Very High Concern according to the Candidate list of substances of very high concern for authorisation
TXT	Textile Industry
TWG	Technical Working Group
WD	Waste Directive 98/2008/EC
WFD	Water Framework Directive, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

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