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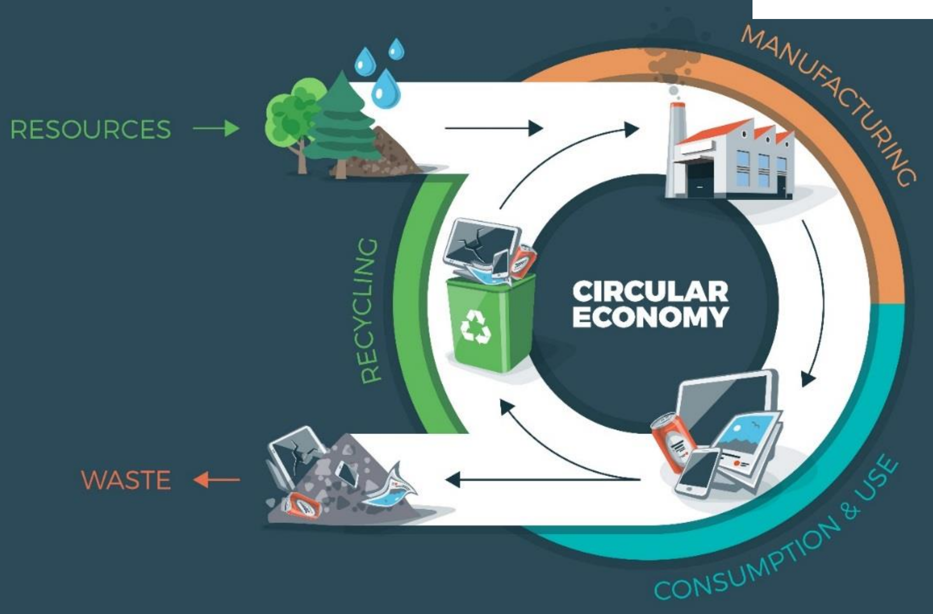

IED Contribution to the circular economy

Service Request 13 under Framework Contract **ENV.C.4/FRA/2015/0042**

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Abstract

This study assessed the contribution of the Industrial Emissions Directive (IED) to meeting circular economy objectives. The study gathered and analysed information on five circular economy topic areas of energy use, materials use, waste generation, use of hazardous chemicals and industrial symbiosis, to understand the contribution of IED sectors to each topic and their trends over time.

The Best Available Technique (BAT) conclusions for 17 sectors were reviewed to extract information on BATs relating to the five topic areas. Trends in energy use for the IED sectors over time was assessed using Eurostat data. The use of materials and waste generation by IED sectors was assessed using the EXIOBASE database. Five case studies highlighted examples of EU installations applying industrial symbiosis. The IED contribution to the circular economy was further assessed using indicators from the EU Circular Economy monitoring framework.

Following this analysis, the untapped potential for the IED to contribute further to the circular economy was assessed by reviewing circular economy topics in sectors where BAT reference documents (BREFs) have not yet been reviewed under the IED. A series of options to strengthen the IED's contribution to the circular economy were identified.

Cette étude a évalué la contribution de la directive relative aux émissions industrielles (IED) au respect des objectifs de l'économie circulaire. L'étude a rassemblé et analysé des informations sur cinq domaines de l'économie circulaire, à savoir l'utilisation d'énergie, l'utilisation de matériaux, la production de déchets, l'utilisation de produits chimiques dangereux et la symbiose industrielle, afin de comprendre la contribution des secteurs couverts par l'IED à chaque sujet et leurs tendances dans le temps.

Les conclusions sur les meilleures techniques disponibles (MTD) pour 17 secteurs ont été examinées afin d'extraire des informations sur les MTD relatives aux cinq domaines. Les tendances dans le temps de la consommation d'énergie dans les secteurs d'EEI ont été évaluées à l'aide de données d'Eurostat. L'utilisation de matériaux et la production de déchets par les secteurs couverts par l'IED ont été évaluées à l'aide de la base de données EXIOBASE. Pour la symbiose industrielle, cinq études de cas ont mis en évidence des exemples d'installations de l'UE appliquant des MTD liées à la symbiose industrielle. La contribution de l'IED à l'économie circulaire a également été évaluée à l'aide des indicateurs du cadre de suivi pour l'économie circulaire de l'UE.

À la suite de cette analyse, le potentiel inexploité de l'IED pour contribuer davantage à l'économie circulaire a été évalué en examinant des thèmes relatifs à l'économie circulaire dans des secteurs où les documents de référence MTD (BREF) n'avaient pas encore été examinés dans le cadre de l'IED. Une série d'options visant à renforcer la contribution de l'IED à l'économie circulaire a ensuite été identifiée.

In dieser Studie wurde der Beitrag der Richtlinie über Industrieemissionen (IED) zur Erreichung der Ziele der Kreislaufwirtschaft bewertet. Informationen zu fünf Bereichen der Kreislaufwirtschaft - Energieverbrauch, Materialeinsatz, Abfallerzeugung, Einsatz gefährlicher Chemikalien und industrielle Symbiose – wurden im Laufe dieser Studie gesammelt und analysiert um den Beitrag der IED-Sektoren zu jedem Bereich und die langfristigen Trends zu verstehen.

Die beste verfügbare Technik (BVT) Schlussfolgerungen für 17 Sektoren wurden überprüft, um Informationen zu BVT für die fünf Bereiche zu extrahieren. Die langfristigen Entwicklung des Energieverbrauchs für die IED-Sektoren wurde anhand von Eurostat-Daten bewertet. Der Materialeinsatz und die Abfallerzeugung in den IED-Sektoren wurden anhand der EXIOBASE-Datenbank bewertet. Für die industrielle Symbiose wurden Beispiele für EU-Anlagen, die eine industrielle Symbiose durchführen, in fünf Fallstudien hervorgehoben. Weiterhin, wurde der Beitrag der IED zur Kreislaufwirtschaft anhand von Indikatoren des Monitoringrahmens der EU für die Kreislaufwirtschaft untersucht.

Im Anschluss an diese Analyse wurde das ungenutzte Potenzial des IED für weitere Beiträge zur Kreislaufwirtschaft ermittelt, indem Bereiche der Kreislaufwirtschaft in Sektoren, in denen BVT-Merkblätter noch nicht im Rahmen des IED geprüft wurden, untersucht wurden. Anschließend wurden Optionen zur Steigenrung des Beitrags des IED zur Kreislaufwirtschaft ermittelt.

Executive summary

Introduction

In 2015, the European Commission published *Closing the loop- An EU action plan for the Circular Economy***,** setting out a transition to a circular economy where the value of products, materials and resources is preserved for as long as possible and waste generation is minimised. This was followed in 2018 by a Circular Economy package of measures which included a monitoring framework to track progress.

The Industrial Emissions Directive (IED) is the main instrument in the EU for mitigating environmental impacts of industry. The IED requires installations conducting activities listed in its Annex I to operate according to a permit issued by the relevant Member State authorities which extends to all environmental aspects of installations' operations including not only emissions but also energy consumption, resource use and waste generation. Permits must be based on Best Available Techniques (BAT) as set out in EU-wide BAT conclusions (BATC) within 4 years of adoption of the BATC. BATC are adopted for each sector following an exchange of information culminating in BAT Reference Documents (BREFs), which consider the key environmental issues (KEI) of a sector.

Given their use to support BAT-based permitting, BREFs could, where identified as KEI, contribute towards achieving circular economy objectives through encouraging reduced energy use, improved resource efficiency and minimisation of waste generation and use of secondary raw materials.

Aims and Methodology

This study aimed to provide an understanding of the extent of the IED's contribution to meeting circular economy objectives. This was to be achieved by gathering and analysing available information on the following topics in relation to IED activities:

- **Use of energy**, its reduction and where possible evolution over time;
- **Use of materials**, its reduction and where possible evolution over time;
- **Generation of waste**, its prevention or reduction; such as through recycling and reuse of materials
- **Reduction of use of hazardous chemicals** and chemical substances of high concern and their substitution with safer ones;
- **Industrial symbiosis**.

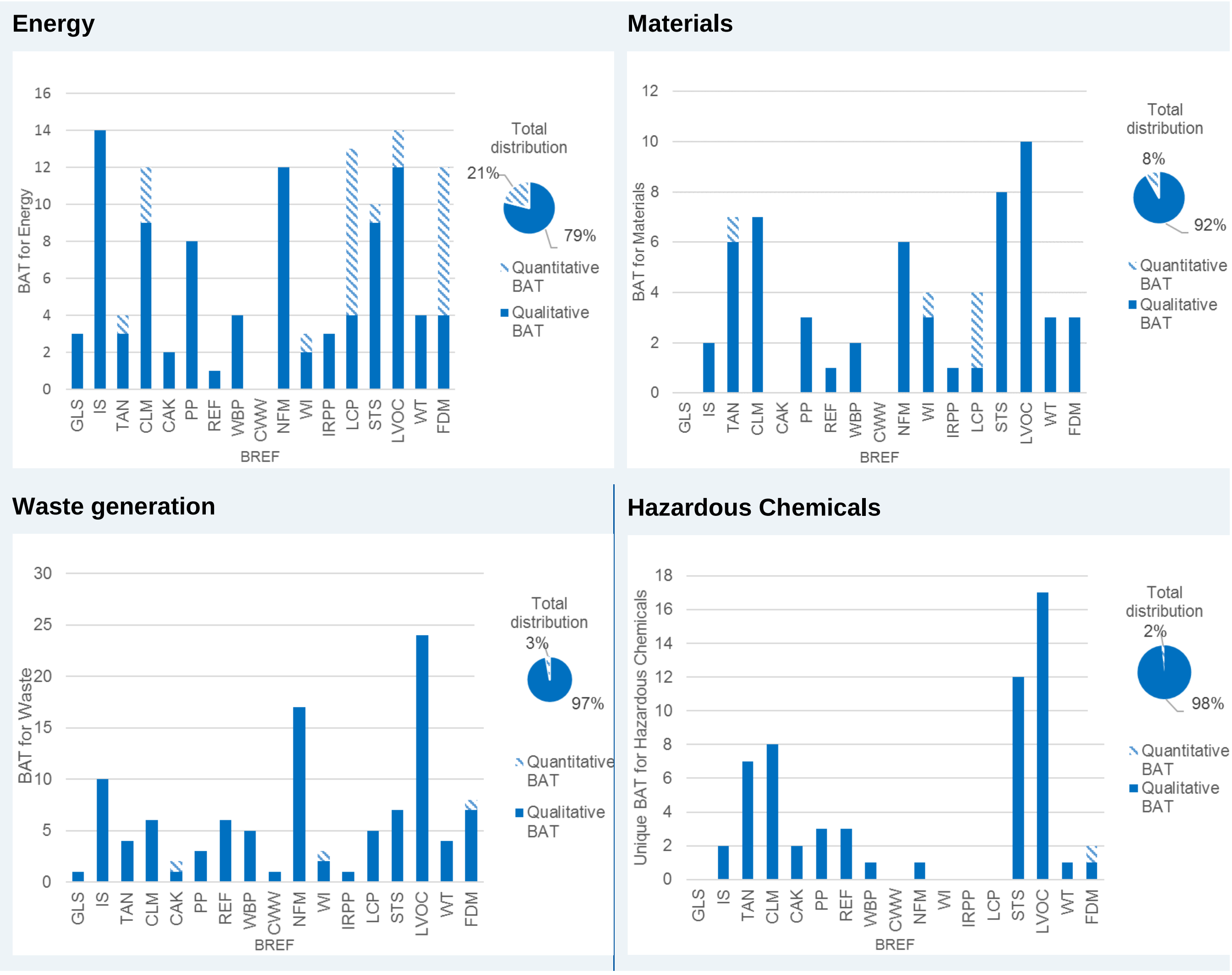
The research aimed to understand the contribution of IED sectors to each topic and their trends over time. As part of this step, 17 sectoral BATC were reviewed to extract information on BATs relating to the five topic areas and analyse the extent of the contribution of the IED to improvements in the five topic areas. BATs were identified as qualitative when only prescribing techniques and quantitative when associated performance levels such as BAT-Associated Environmental Performance Levels (BAT-AEPLs), or BAT-Associated Energy Efficiency Levels (BAT-AEELs) were present (although noting that these values are not legally binding values as is the case with BAT-Associated Emission Levels (BAT-AELs)).

Following this analysis, the untapped potential for the IED to contribute further to the circular economy was assessed. This included reviewing circular economy topics in sectors where BREFs have not yet been reviewed under the IED. A series of options to strengthen the IED contribution to the circular economy were then identified.

IED Contribution to circular economy

Figure 1 shows the results of the analysis of the BATC in BREFs that have been reviewed under the IED. Energy is the circular economy topic area most covered by BATC (117 energy related BAT across sectors) and also has the highest proportion of quantitative BATs. The quantitative energy sector BATs are particularly concentrated in the LCP and FDM sectors, which also have a large number of BATs specific to certain processes and sources rather than generic sector-wide measures. The fact that LCP and FDM are recently reviewed BREFs may indicate there is a shift in the Sevilla process towards more quantitative and process-specific BATs for energy. Energy-related BATs are mostly focused on process optimisation and energy/heat recovery. Waste generation is the second most commonly covered topic area in the IED BREFs, with the most in the LVOC, NFM and IS sectors. There are however almost no quantitative BATs relating to waste (3% of waste generation related BATs).

Figure 1 Number of BATs covering circular economy topic areas in the 17 reviewed IED BREFs



Untapped potential for IED to contribute further to the circular economy

Since the IED has come into force, not all sector BREFs have been revised. Those BREFs that are currently being revised or have not yet begun to be reviewed provide an opportunity to contribute further to circular economy topic areas. The following circular economy topics for these sectors were identified of most relevance (highest priority in bold):

a. Ferrous metals processing: **waste generation**, energy use;
b. Ceramic manufacturing: energy use, waste generation, use of hazardous chemicals;
c. Surface treatment of metals and plastics: energy use, materials use
d. Textiles industry: energy use, **waste generation**, materials use, **use of hazardous chemicals**
e. Smitheries and foundries: energy use, **waste generation**, materials use;
f. Slaughterhouses and animal by-products: **energy use**, **waste generation;**
g. Waste gas in chemicals (to cover POL/OFC/SIC sectors): **energy use**, **waste generation**;
h. Large volume inorganic chemicals: **energy use**, waste generation, **materials use**, use of hazardous chemicals.

The following findings were also identified regarding the untapped potential of the IED to contribute to the circular economy:

- There is potential to make the text of the BREFs and BATC more explicitly targeting circular economy objectives and strategies. This would raise awareness of circular economy issues as well as allow better identification of the circular economy related BATs in the future.
- There is potential to include BATs on materials use, hazardous chemicals use and industrial symbiosis more systematically across the BATC, through as a minimum deriving BAT for each circular economy topic identified as KEI. Hazardous chemicals use was rarely referred to in the description of KEIs in the BREFs.
- One of the limitations of current BATs on topics relevant to circular economy is lack of quantitative targets.
- Data collection on circular economy topics from individual operators and of a magnitude that is conducted during BREF development are rare, and thus there is potential for the process to significantly increase the knowledge base on circular economy topic areas.
- The Circular Economy Monitoring Framework only includes a few indicators relevant to the IED. Indicators within the CE Monitoring Framework where the IED has the highest potential to contribute to the circular economy objectives are waste generation, recycling rates, contribution of recycled materials to raw materials demand and innovation. There may be more that can be done on the opportunities to link the IED and the Environmental Technology Verification (ETV) programme which is mentioned in the CE Action Plan. As the IED was adopted several years before the CEAP, there is no clear framework to measure contribution of the industry regulated under the IED to circular economy. Given the upcoming evaluation of the IED, there is an opportunity to consider the way in which circular economy objectives can be integrated in the IED to a greater degree and how the contribution made could be measured.

Conclusions and recommendations

Findings of the review of current and potential contribution of the IED to circular economy objectives were used to produce an assessment of contribution with respect to the circular economy monitoring framework indicators. The results of this comparison are shown in Table 1. The current contribution is assessed to be low or very low, with potential for greater contribution in waste generation, recycling rates and contribution of recycled materials to raw material demand, and innovation.

Table 1 Contribution of the IED to meeting circular economy monitoring framework objectives.

Relevant indicators in the circular economy monitoring framework	Current contribution	Potential contribution
EU self- sufficiency for raw materials	Very low	Low
Waste generation	Low	Medium
Food waste	Low	Low
Recycling rates	Low	Medium
Recycling rates for specific waste streams	Very low	Very low
Contribution of recycled materials to raw materials demand	Very low	Medium
Innovation	Very low	Medium

The IED has been found to have in general a low contribution to achieving a circular economy. Indeed, the IED as an instrument, according to the DG ENV webpages “aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques (BAT)”.

The European Trade Union, in its plea for ‘An industrialised circular economy - policy brief 2016-03’, states that ‘by feeding the industrial production system with re-used, repaired or upgraded products, or with recycled materials, industrial systems keep the value, materials and energy embedded in industrial products longer in use’. The link between the use of re-used, repaired or upgraded products or recycled materials, will only indirectly affect industrial emissions, and probably not even in a positive way (since such products or materials are likely to be less reliable or pure then new products and primary materials. The main focus of circular economy strategies is on longevity, which produces environmental benefits by avoiding mining and production activities.

As a policy which was implemented prior to the formalising of the EU's latest policies to move the bloc towards a circular economy, and which has an expressed aim differing from the circular economy, it is perhaps not unsurprising that the IED is not the ideal instrument to deliver circular economy objectives.

More can be done however to make better use of the IED's existing mechanisms. In defining KEI and subsequently the BAT conclusions for industrial sectors, Technical Working Groups often identify energy use as a KEI in intensive industries; however material use and waste generation are less often identified, and normally dealt with in generic management BATC. The following recommendations have been made to increase the IED's contribution to circular economy objectives.

Nevertheless, it is noted that in the current Sevilla process the TWG decides the KEIs. It would therefore be for the TWG to consider whether the aspects suggested below are appropriate for the sector under consideration. The TWGs have limited resources and must make decisions to prioritise their work.

Consider possible changes to the IED:

- There is potential for the IED to contribute further to innovation in the field of circular economy by promoting better uptake of emerging techniques in industry that have a focus on the circular economy. This could be through the existing testing underway on an innovation observatory.
- The upcoming IED evaluation should be used as an opportunity to consider the way in which circular economy objectives can be integrated in the IED to a greater degree and how the contribution made could be measured.

Consider changes <u>in general</u> to the content/structure of BREFs:

- Include BATs on materials use, hazardous chemicals use and industrial symbiosis more systematically across the BATC where applicable.
- Increase the number of BATs on circular economy topics set with quantitative targets. Address any limitations on lack of quantitative data through the BREF data collection process.
- Mainstream circular economy topics through direct references and use of key words on circular economy related policies, topics, indicators and opportunities.
- Align with REACH, by for example adopting general BATC that promote the elimination and substitution of chemicals that are required to be reported under REACH. (e.g. it is BAT to use chemicals that are not listed as carcinogenic, mutagenic or as having reproductive effects as per their REACH registration). This may be more effective than describing specific chemicals, for which the BREF documents with their 10 year lifespan may not be suitable.

Consider changes to the BREF process exchange of information:

- **The BREF process** could be enhanced by broadening the pool of experts nominated by Forum members to participate in Technical Working Groups to include circular economy experts and experts from other sectors providing materials or receiving by-products/wastes.
- **Switch the way of thinking in BREFs:** Avoid over-focussing on determining BATs for each industrial activity separately. Instead, consider cross-sectoral effects, and determine the value chain BAT through collaboration with upstream and downstream partners to also identify techniques that will reduce environmental impacts elsewhere in the value chain.

Consider changes for reviews of specific BREFs:

- TWGs may decide that hazardous chemicals are a Key Environmental Issue for those sectors where the quantity of chemical use is relatively high (LVOC, PP, TXT, STS/STM, CLM and CAK) and/or where the potential risk from exposure is high (FDM, TXT), to enable BAT conclusions to reference the use of a chemical, rather than only its presence in emissions.
- Circular economy is important for IED sectors currently at an early stage of BREF development process or for which the review has not yet started. These BREF reviews provide an opportunity to address the following high priority circular economy topics with BATs *and ideally quantitative performance levels*:

  - Ferrous metals processing: waste generation;
  - Textiles: waste generation, use of hazardous chemicals;
  - Smitheries and foundries: waste generation;
  - Slaughterhouses and animal by-products: energy use, waste generation;
  - Waste gas chemicals (to cover POL/OFC/SIC sectors): energy use, waste generation.
  - Large volume inorganic chemicals: energy use, materials use.
- Consider an additional horizontal BREF on circular economy.
- When considering the economic viability of available techniques for the reduction of use of hazardous chemicals (or releases of such chemicals), further consideration should be given to alternative business models that may make such techniques viable. An example is the business model of chemical leasing.

Improve how the contribution of the IED to the circular economy can be tracked and monitored:

- Refine the Circular Economy Monitoring Framework to make sure that indicators are relevant to IED industry
- Consider whether existing EU monitoring tools such as the raw materials and/or resource efficiency scoreboards can be expanded on.
- At the level of the individual installation or sector, build on existing indicators such as the Material Circularity Indicator.

Abbreviations

Throughout the report the following abbreviations are being used:

BATC	Best Available Technique conclusions
BREF	Best Available Technique Reference Document
CAK	Production of Chlor-alkali
CER	Ceramic Manufacturing Industry
CLM	Production of Cement, Lime and Magnesium Oxide
CWW	Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector
EFS	Emissions from Storage
ENE	Energy Efficiency
FDM	Food, Drink and Milk Industries
FMP	Ferrous Metals Processing Industry
GLS	Manufacture of Glass
ICS	Industrial Cooling Systems
IED	Industrial Emission Directive
IRPP	Intensive Rearing of Poultry or Pigs
IS	Iron and Steel Production
LCP	Large Combustion Plants
LVIC-AAF	Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers
LVIC-S	Large Volume Inorganic Chemicals – Solids and Others Industry
LVOC	Production of Large Volume Organic Chemicals
OFC	Manufacture of Organic Fine Chemicals
NFM	Non-ferrous Metals Industries
POL	Production of Polymers
PP	Production of Pulp, Paper and Board
REF	Refining of Mineral Oil and Gas
SA	Slaughterhouses and Animals By-products Industries
SF	Smitheries and Foundries Industry
SIC	Production of Speciality Inorganic Chemicals
STM	Surface Treatment Of Metals and Plastics
STS	Surface Treatment Using Organic Solvents (including Wood and Wood Products Preservation with Chemicals)
TAN	Tanning of Hides and Skins
TXT	Textiles Industry
WGC	Common Waste Gas Treatment in the Chemical Sector
WI	Waste Incineration
WT	Waste Treatment
WBP	Wood-based Panels Production

Table of contents

1 Introduction

1.1 This report

This is the final report for project *"IED Contribution to the circular economy"*, which is Service Request 13 under framework contract ENV.C.4/FRA/2015/0042. The specific contract number is 07.0201/2018/785987/SFRA/ENV.C.4. The specific contract entered into force on 2 August 2018 lasting 7 months. This report presents results of the analysis of the contribution of the Industrial Emissions Directive 2010/75/EU to the circular economy.

1.2 Background: Circular Economy and Industrial Emission Directive (IED)

'Closing the loop - An EU action plan for the Circular Economy' (COM(2015) 614 (European Commission, 2015), further referred to as CEAP, **aims to stimulate Europe's transition to a more circular economy** "*where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised*". This transition, covering the whole cycle from production and consumption to waste management and secondary raw materials, is expected to increase the EU's global competitiveness, lead to economic growth and generate new jobs. EU industry is recognised in CEAP to have a key role in transitioning to a circular economy, particularly with regard to sustainable sourcing and cooperating across the value chain.

The CEAP implicitly focuses on materials (resources), by outlining targeted actions in areas such as '*chemicals, plastics, food waste, construction, critical raw materials, industrial and mining waste, consumption and public procurement*'. In this context, the CEAP addresses five main areas:

- Production, including product design and production processes;
- Consumption, including labelling, reuse, repair, planned obsolescence and public procurement;
- Waste management, including extended producer responsibility, recycling and harmonisation of methodologies;
- Supporting markets for secondary raw materials, including quality standards for secondary raw materials, and addressing water reuse and fertilisers;
- Horizontal measures, including innovation, investment and monitoring.

In January 2018 the Commission continued with the implementation of the CEAP through the adoption of a new Circular Economy Package of measures. This includes, among others, an important monitoring framework on the progress towards a circular economy; a circularity potential assessment of critical raw materials; an assessment on how the rules on waste, products and chemicals relate to each other; and a European strategy on plastics in a circular economy.

The primary mechanism to measures EU progress towards achievement of circular economy objectives is the **EU Circular Economy Monitoring Framework** (European Commission, 2018). The monitoring framework consists of a set of ten indicators grouped into four stages and aspects of the circular economy: (1) production and consumption, (2) waste management, (3) secondary raw materials and (4) competitiveness and innovation.

The primary instrument in place to mitigate the environmental impacts from EU industry is the Industrial Emissions Directive 2010/75/EU (IED), which entered into force on 6 January 2011 and had to be transposed by the Member States into national legislation by 7 January 2013. The IED was largely based on pre-existing legislation (such as the IPPC Directive) and predates the Commission's efforts on the circular economy.

The IED stipulates that Member States adopt an integrated approach in the process of permitting (or applying general binding rules to) industrial installations. All installations conducting activities listed in Annex I to the IED are required to operate according to a permit – issued by the relevant Member State authorities and reflecting the principles and provisions of the Directive. The permit extends to all environmental aspects of an installation's operating activities, including not only control of emissions but also covering the consumption of energy (e.g. through energy efficiency measures), resource use and waste generation (i.e. some circular economy topics). All permit conditions must be based on **Best**

Available Technique (BAT) conclusions (BATC) within 4 years of their adoption. BATC are adopted by the European Commission following an exchange of information culminating in BAT Reference Documents (BREFs). BATs are the most effective and advanced methods and technologies to minimise emissions and overall environmental impacts from industrial installations, taking into consideration economic and technical factors. **While BREFs and permits rarely make an explicit reference to the "circular economy", they should embed the circular economy principles in the operation of the installation by encouraging reduced energy use, resource efficiency, waste minimisation and use of secondary raw materials through the application of BATs.**

The regulation of circular economy topics through the IED is important as unlike pollutant emissions which have a direct impact on human health and the environment, they have indirect impacts which must be taken into consideration. For example, the generation of energy through combustion of fuel produces emissions of greenhouse gases and air pollutants, and so increasing energy efficiency reduces the generation of these pollutants to meet the same energy demand. Extraction and production of raw materials such as metals, timber and petrochemicals uses energy and water, may be associated with destruction of habitats or degradation of natural resources. Generation of waste creates a burden of waste management and may also use/generate substances hazardous to people or local environments. Usage of hazardous chemicals introduces substances with risk to human health and the environment which can potentially be avoided. While emissions abatement is frequently centred around fitting end of pipe technologies, addressing circular economy topic areas is usually focused on primary i.e. process-level abatement.

The CEAP recognises that each industry sector is different when it comes to the use of energy and materials, waste generation and management and therefore **BREFs have been listed in the CEAP as a tool to further promote circular economy best practices in EU industry**. The CEAP also highlights the importance of promoting innovative industrial processes, and **industrial symbiosis** which allows waste or by-products of one industry to become inputs for another.

Recital 13 of the IED indicates the EC should aim to update BREFs not later than 8 years after the latest BREF document was published. Currently, there are 32 BREFs, of which three are relevant to all sectors (i.e. BREFs on emissions from storage, industrial cooling systems and energy efficiency) and the remainder are each focused on a specific sector. There are also two reference documents, on economics and cross-media effects and monitoring of emissions. The status of BREF review and BATC publication at the time of writing this report is presented in Appendix 1. Six of the agreed BREFs have been finalised after the EU Circular Economy Action Plan entered into force, however the development of questionnaires and information gathering for these BREFs would have occurred before the publishing of the CEAP, and this is also the case for the FDM BREF which will soon be finalised. With that said, there are currently a number of BREFs undergoing the review process where the process of information exchange began after 2016 and have circular economy goals reflected to a greater degree in the key environmental issues (KEIs). These sectors include the common waste gas treatment in the chemical sector, ferrous metals processing, surface treatment using organic solvents, and textiles.

While the contribution of IED and BATC to water policy objectives has already been studied (see (Ricardo, 2017)), **there is little knowledge of the impacts that the IED, specifically BREFs and BATC have on use of energy, materials and hazardous chemicals, waste generation, use of waste as a resource and promotion of industrial symbiosis**.

Waste is by definition one of the key concerns of the circular economy. Industrial waste is covered by two BREFs under the IED: Waste Treatment and Waste Incineration. The role of waste treatment in a circular economy is critical, but very different from its role in a traditional linear economy. It changes from efficiently treating a particular waste stream, to providing a safe sink for those substances that, because of health and environmental concerns, should be removed from our (more circular) production processes. Additionally, the remaining materials and substances should be efficiently converted into useful inputs for industrial production processes.

The potential contribution of the waste treatment sector to the circular economy can thus be determined by measuring its ability to efficiently concentrate unwanted materials and substances contained in the waste supply, and to dispose them in safe and final sinks. Currently, there are no BATs targeting such ability. Additionally, in a circular economy, more focus should be put on the implementation of measures that improve the performance of a particular treatment technology as to produce more and higher quality secondary raw materials from a given waste stream. This is complementary to the existing BAT that already target the minimisation of the use of energy and non-waste material inputs. It is observed that the generation of so-called secondary wastes (i.e. waste from waste treatments) cannot be avoided, but should be carefully balanced with the efforts required to achieve the highest possible quality recycled materials.

1.3 Aims and objectives of this study

The objective of this study was to **provide an understanding of the contribution of the IED to meeting EU circular economy objectives**. This was to be achieved by gathering and analysing available information on the following five topics in relation to IED activities:

- **Use of energy**, its reduction and where possible evolution over time;
- **Use of materials**, its reduction and where possible evolution over time;
- **Generation of waste**, its prevention or reduction; such as through recycling and reuse of materials
- **Reduction of use of hazardous chemicals** and chemical substances of high concern and their substitution with safer ones;
- **Industrial symbiosis**.

The data gathering, and analysis was conducted for the EU-28 and has covered all activities listed in Annex I to the IED.

1.4 Structure of this report

This report consists of the following sections:

- Section 2 explains the study methodology.
- Section 3 presents the results of the data gathering and analysis for five circular economy topic areas (i.e. energy use, materials use, waste generation and management, the use of hazardous chemicals, and industrial symbiosis). It concludes with an assessment of the IED's contribution to circular economy objectives to date.
- Section 4 summarises the coverage of circular economy topics in BREFs not yet reviewed under IED.
- Section 5 analyses whether there is an untapped potential for IED to contribute further to the circular economy and identifies potential obstacles and how those could be overcome.
- Section 6 describes final conclusions and recommendations from the study.

2 Methodology

2.1 Overview

To provide an understanding of the contribution of the IED to meeting EU circular economy objectives, the methodology for the study included the following steps:

- **Step 1 Assessing IED contribution to the circular economy:** this step involved literature research on the topics of energy use, materials use, waste generation and hazardous chemicals use in the IED sectors. The research was targeted at identifying quantitative data to understand the contribution of individual IED sectors to each topic, and trends over time. For an additional fifth topic of industrial symbiosis the literature research focused on identifying potential case study examples. As part of this step, BATC for 17 sectors have been reviewed to extract information on BATs related to the five topic areas. The data was then analysed to understand to what extent the BATC have contributed to the circular economy to date – this was conducted at sector as well as topic level. Finally, the information was systematised and presented against selected indicators from the circular economy monitoring framework to conclude on the overall contribution of the IED to date, and to identify areas where the IED can contribute further.
- **Step 2 Assessing the untapped potential for the IED to contribute further to the circular economy:** This step first involved a short literature review of circular economy topics for sectors for which BREFs have not yet been reviewed under the IED. This identified areas where the revised BREFs could contribute the most towards a circular economy. The findings were then combined with observations and conclusions from step 1 to identify key focus areas for the IED to contribute further to circular economy i.e. the untapped potential. A series of possible options to strengthen the IED contribution moving forward have been identified, covering: mainstreaming circular economy topics in BREFs and BATC, changes to the BREF development process and formulation of BATs, use of horizontal BREFs, tracking progress towards circular economy objectives and emerging techniques.

The sections below provide further detail on the methodology for each step.

2.2 Step 1: Assessing IED contribution to the circular economy

2.2.1 Collecting data on energy, materials and hazardous chemicals use, waste generation and industrial symbiosis

The identification of sources and data collection focused on information on energy, materials and hazardous chemicals use, waste generation and industrial symbiosis at the BREF sector granularity. This granularity was selected to match the findings from the data analysis with the findings from BREF data extraction. Data sources identified were reviewed to determine completeness of information they provide, how well they correspond to BREF sector granularity and the time series covered.

The full list of literature sources reviewed in this step is presented in Appendix 2.

2.2.2 Data extraction from BREFs and categorisation of BATs

All BREFs revised under the IED have been reviewed and the following data have been extracted:

- BAT-AEPLs set out in BATC concerning energy, materials and hazardous substances use and waste generation or prevention.
- Techniques and best practices set out in BATC.
- Baseline data concerning consumption of energy, materials and hazardous substances as well as waste generation where quantitative BAT were set.

The BREF extraction process was conducted by reviewing the BATC using searches for key words according to the different circular economy topic areas. The methodology applied is described in detail in Appendix 3. BATs identified as relevant for each topic were grouped according to their scope and nature of the techniques into different categories for each topic. In some instances BATs were categorised against more than one topic area. For example BATs related to hazardous chemicals use were generally also counted as materials use related BATs. Given that a single BAT often includes lists of multiple techniques, one BAT could also have been included in multiple categories within each topic. For example, a single BAT listing techniques for waste minimisation, recycling and re-use was counted towards three separate categories. Categories of BATs developed for each topic area are presented in Section 3. The number of BATs in each topic, category and sector were then counted to illustrate coverage of the circular economy topics across all BATC. The spreadsheet with all BAT extracted per sector and figures used in this report is included in Appendix 4.

2.2.3 Quantitative assessment of IED contribution

A very small number of quantitative BATs were identified as relevant to circular economy topics. This, together with the poor availability of information on the consumption/generation before entry into force of the IED did not allow detailed quantitative assessment of the contribution the IED has had on the circular economy for most sectors and topics.

Where sufficient information was available, i.e. BAT included a BAT-AEPL, and consumption/generation data before entry into force of the IED were available from the BREF, the scale of potential impacts was calculated. This was conducted for the LCP, FDM and STS sectors for the energy use topic, and for the FDM sector for the hazardous chemicals use topic. The calculation method first assumed a normal distribution of operators with two standard deviations between the mean and the 95th percentile. It then estimated the percentage of the population which is above the lower BAT-AEL and the percentage that is above the upper BAT-AEL. The midpoint of these two populations was then used to calculate best and worst reduction estimates (or estimates of increase in case of energy efficiency related BAT). This methodology is in line with the assessments conducted as part of the previous study 'Summary on IED Contribution to water policy' for DG Environment (Ricardo, 2017). Details of the assessment methodology are described in section 3.1.

2.2.4 Specific considerations for each study topic

While the steps described above have been followed for all topics, due to differences in the nature of topics and data availability, the specific approach differed for each study area.

Energy use

The energy use by industrial sectors covered by the IED and its contribution to the overall EU energy use was evaluated based on the energy use data[1] per sector and over time, obtained from Eurostat. For industrial sectors, Eurostat '*Simplified energy balances - annual data [nrg_100a]*' has been identified as the most appropriate record of energy use. Simplified energy balances use energy balance indicators which have their own classification codes but which are built on NACE Rev2 classification. These codes were mapped as closely as possible to the IED sectors in the same way it has been done in previous work for the Commission in study 'Industrial emissions policy country profiles' (Ricardo, 2018). The mapping and its limitations are shown in Appendix 5. The sectoral-level data on energy intensity was sourced from the IDEES database.

Materials use and waste generation

The assessment of the use of materials and waste generation by IED sectors was conducted using the EXIOBASE database. Environmentally extended multiregional input-output (EE MRIO) tables have emerged as a key framework to provide a comprehensive description of the global economy and its effects on the environment. Of the available EE MRIO databases, EXIOBASE stands out as a database compatible with the System of Environmental-Economic Accounting (SEEA[2]) with a high sectoral detail matched with multiple social and environmental satellite accounts[3]. EXIOBASE has a detailed, multiregional system of supply and use tables which are gathered from Eurostat in the case of the EU.[4]

[1] Statistical sources commonly refer to energy consumption. For consistency, energy use is used consistently throughout this report

[2] The System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework) is a statistical framework consisting of a comprehensive set of tables and accounts, which guides the compilation of consistent and comparable statistics and indicators for policymaking, analysis and research. It has been produced and is released under the auspices of the United Nations, the European Commission, the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, the International Monetary Fund and the World Bank Group. (From: https://ec.europa.eu/eurostat/documents/3859598/5936709/KS-01-14-120-EN.PDF/334d5c04-b630-4395-8008-94f36712bf6b)

[3] Satellite accounts provide a framework linked to the central (national or regional) accounts, allowing attention to be focused on a certain field or aspect of economic and social life in the context of national accounts; common examples are satellite accounts for the environment, or tourism, or unpaid household work. (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Satellite_account)

[4] Wood et al. (2015) https://www.mdpi.com/2071-1050/7/1/138/htm

The latest EXIOBASE version, EXIOBASE 3[5], provides a time series of EE MRIO tables ranging from 1995 to 2011 for 44 countries (28 EU Member States plus 16 major economies) and five rest of the world regions. EXIOBASE 3 uses rectangular supply-use tables in a classification of 163 industries by 200 products as the main building blocks.

Due to its sectoral detail, EXIOBASE was the preferred source of data on materials use and waste generation.

With regard to materials use, EXIOBASE contains information on 222 categories of raw materials used by and supplied to 163 industrial sectors which were mapped onto IED activities (see Appendix 6), and for the production of 200 products. This allowed analysis of absolute and relative quantities of materials use (e.g. relative to value added) by IED sector. For the ease of reading and interpreting the results, individual materials were grouped into nine material product categories described in section 3.1.2.

With regard to waste generation, EXIOBASE contains information on the generation of 17 different types of wastes across 163 industrial sectors. Again, for the ease of reading and interpreting the results, the waste types were grouped into 12 waste categories described in section 3.1.3.

The main limitation of using EXIOBASE is that the latest data available is for the year 2011. However for the purpose of measuring the IED contribution, this is acceptable as it is taken to illustrate the status pre-implementation of the IED and any of the BATC.

Use of hazardous chemicals

As data on consumption of hazardous chemicals across IED sectors does not exist, no quantitative analysis was performed for this topic area. Instead, several sectors whose production processes rely heavily on hazardous chemicals have been analysed qualitatively in more depth, to illustrate potential impacts that BATC has had on the use of hazardous chemicals.

Industrial symbiosis

As no quantitative data on industrial symbiosis exists, no quantitative analysis was performed for this topic area. Instead, examples of plants applying BATs related to industrial symbiosis were identified and developed into five case studies. This aimed to illustrate the impacts (in terms of costs and benefits) on operators participating in the symbiotic relationship. In order to gather more comprehensive information for the case studies, operators of the selected plants were contacted and invited to provide further information.

2.2.5 Measuring IED contribution to the circular economy

To provide an overall conclusion on the IED contribution to the circular economy the assessment across individual sectors was summarised and presented against the circular economy indicators used to monitor the EU's progress towards achieving circular economy objectives. The EU circular economy monitoring framework (European Commission, 2018) consists of the following 10 indicators:

1. **EU self-sufficiency for raw materials**
2. Green public procurement
3. **Waste generation (including municipal but also other waste)**
4. **Food waste**
5. **Recycling rates**
6. **Recycling rates for specific waste streams**
7. **Contribution of recycled materials to raw materials demand**
8. Trade in recyclable raw materials
9. Private investment, jobs and gross value added related to circular economy
10. **Number of patents related to recycling and secondary raw materials**

Indicators selected for the assessment (**in bold** above), and justification for exclusion of some of the indicators, is presented in section 3.2. The assessment for each selected indicator has been based on the data gathered in the earlier steps as described above.

[5] http://www.exiobase.eu/

2.3 Step 2: Assessing the untapped potential for the IED to contribute further to the circular economy

2.3.1 Sectors pending BREF review under the IED

Research on the relevance of circular economy topics for sectors with BREFs not yet reviewed under the IED utilised the following data sources:

- For the BREF sectors of textiles manufacturing, smitheries & foundries, slaughterhouses and animal by-products industries and ceramic manufacturing, information on the relevance of circular economy topics have been assessed based on a previous study for the Commission 'Preliminary determination of Key Environmental Issues (KEI) for industrial sectors in BREF reviews under the IED' (Ricardo, 2018).
- For the BREF sectors of ferrous metals processing, surface treatment of metals and plastics and the various chemical sectors, the relevance of circular economy topics has been assessed based on the information in IPPCD BREFs.

Across all sectors, the assessment made use of consumption/generation data compiled in step 1.

2.3.2 Defining the untapped potential

The findings from the review of sectors pending the BREF review were combined with observations and conclusions from step 1 to identify key focus areas for the IED to contribute further to circular economy i.e. the untapped potential. A series of possible options to strengthen the IED's contribution moving forward have been identified, covering: mainstreaming circular economy topics in BREFs and BATC, changes to the BREF development process and formulation of BATs, use of horizontal BREFs, tracking progress towards circular economy objectives and emerging techniques.

3 IED contribution to circular economy

Section 3.1 of this chapter summarises the coverage of circular economy topics in the IED BATC. The topics assessed are energy use, materials use, waste generation, hazardous chemicals use and industrial symbiosis. For each topic, this section first summarises the significance of each topic to the industrial activities covered by the IED, and then presents the coverage of each topic in BREFs and BATC reviewed under the IED (including those BREFs for which reviews are close to being finalised). While all efforts were made to ensure consistency in the analytical approach and presentation of the results, due to the different nature of topics and diversity in the data sources used, the type of information presented for each topic varies from one to another.

Section 3.2 then shows the assessment of the IED's contribution to EU circular economy objectives using selected indicators from the EU Circular Economy Monitoring Framework.

3.1 Coverage of circular economy topics in IED BATC

3.1.1 Energy use

3.1.1.1 Contribution of IED sectors to the overall EU energy use

The energy use by industrial sectors covered by the IED and their contribution to the overall EU energy use has been evaluated based on Eurostat energy use[6] data per sector and over time. Energy balance indicators have been mapped as closely as possible to the IED sectors. The mapping and its limitations are shown in Appendix 5. This same data source also includes total national energy use, which was taken as the 'gross inland consumption'[7], as per Ricardo (2018).

Energy use and energy efficiency in industrial sectors

Figure 2 shows the energy use of industrial sectors together with all other sectors marked as 'non-IED sectors' (calculated as the national total minus the energy use of industrial sectors). It shows that **industrial sectors make up about 15% of gross inland energy use**. Between 2007 and 2016 the overall energy use shows a greater decline than that of industrial sectors.

[6] Statistical sources commonly refer to 'energy consumption'. For consistency, energy use is used consistently throughout this report

[7] Gross inland consumption includes consumption of industry and households; = Primary production + primary product receipt + Other Sources (recovered products) + Recycled products + Imports + Stock Changes – Exports – Direct Use

Figure 2 Energy use by IED sectors and non-IED sectors (source: Eurostat *nrg_100a*)

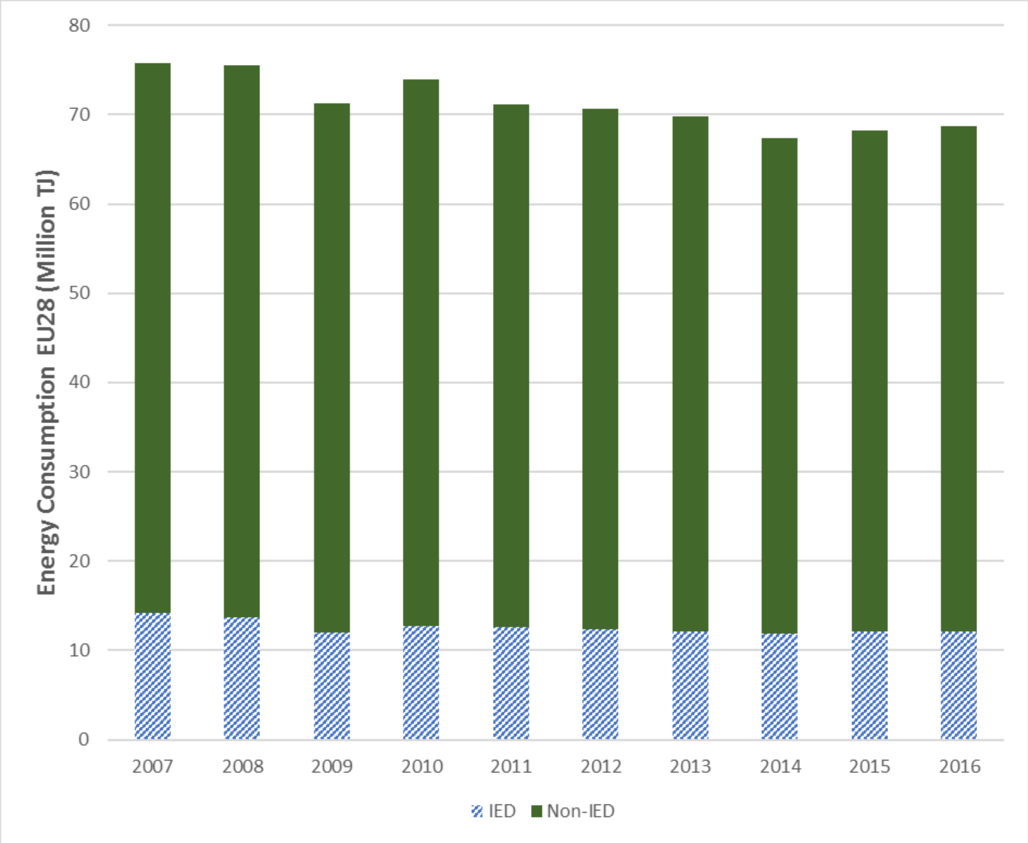


Figure 3: Energy use by IED sectors (source: Eurostat *nrg_100a*)

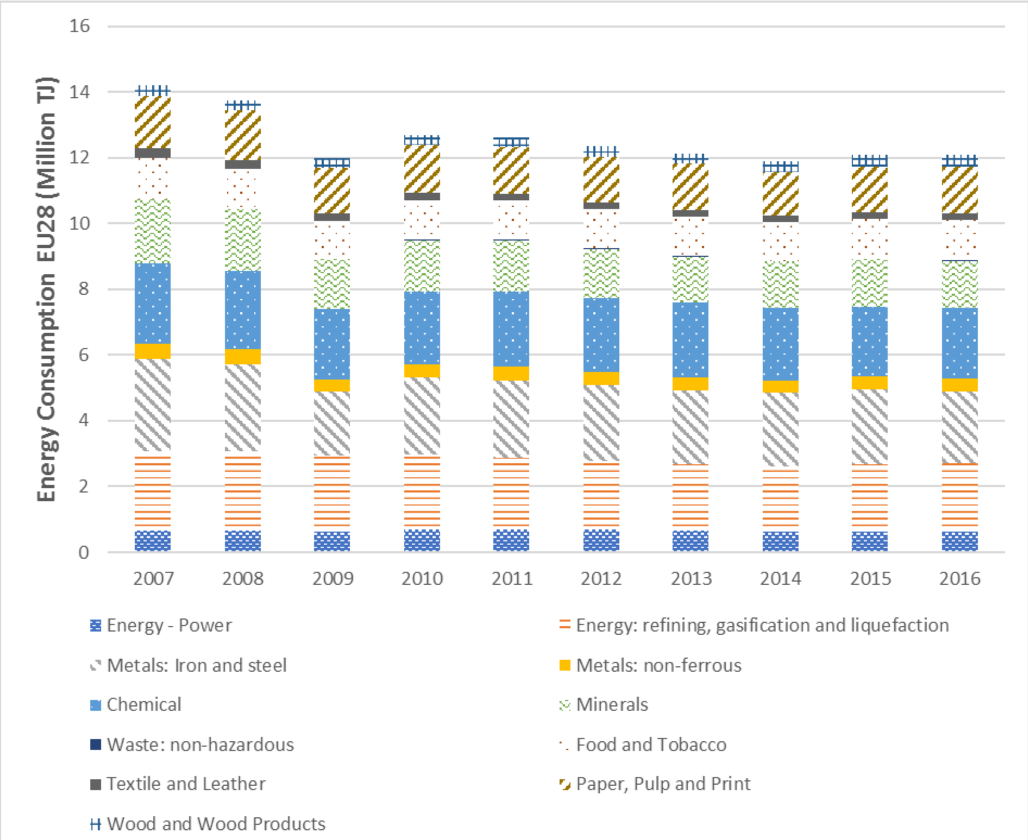


Figure 4 presents the energy use by IED sectors from 2007 to 2016 and Figure 5 shows the change in energy use in this period indexed to 2007 to illustrate more clearly trends over time. The iron and steel, chemicals, and energy refining sectors are the largest users of energy. Energy use has decreased for most sectors over time, in particular for the textile and leather, minerals and ferrous metals sectors. Wood and wood products is the only sector for which energy use has increased in the analysed time period. The decrease in energy use in most sectors in 2008 is likely associated with decreased economic activity during the financial crisis. Analysis of the Eurostat data by fuel type reveals that renewable energy use makes up 13% of energy products directly used in the EU28 economy as a whole in 2016 while for industrial sectors this proportion is just 0.08%[8].

While the above data analysis cannot on its own attribute reductions in consumption to energy efficiency improvements, some decline in energy use can be attributed to gains in energy efficiency. The Odyssee energy efficiency index (ODEX) measures energy efficiency progress of industry, transport and households as well as for the whole economy. The index is a weighted average of sub-sectoral indices of energy efficiency progress (EEA, 2018). EU final energy efficiency increased by 28% between 1990 and 2014 based on the ODEX index (EEA, 2018). During this time period, energy efficiency in industry improved the most: 36%, averaging at +1.8 % per year, compared to +1.7% in households and +1.4% per year overall. The fastest rate of improvement occurred between 1990 and 2000 (-2.5% per year), after which improvements slowed. There have also been reductions in energy consumption, with the greatest reductions in energy intensive industries, particularly steel (-3.2% specific energy consumption per year), chemicals (-1.5%), cement (-1.3%) and paper (-0.9%).

[8] https://ec.europa.eu/eurostat/en/web/products-datasets/-/NRG_100A

Figure 4 Energy use by industrial sectors between 2007-2016 (source: Eurostat nrg_100a)

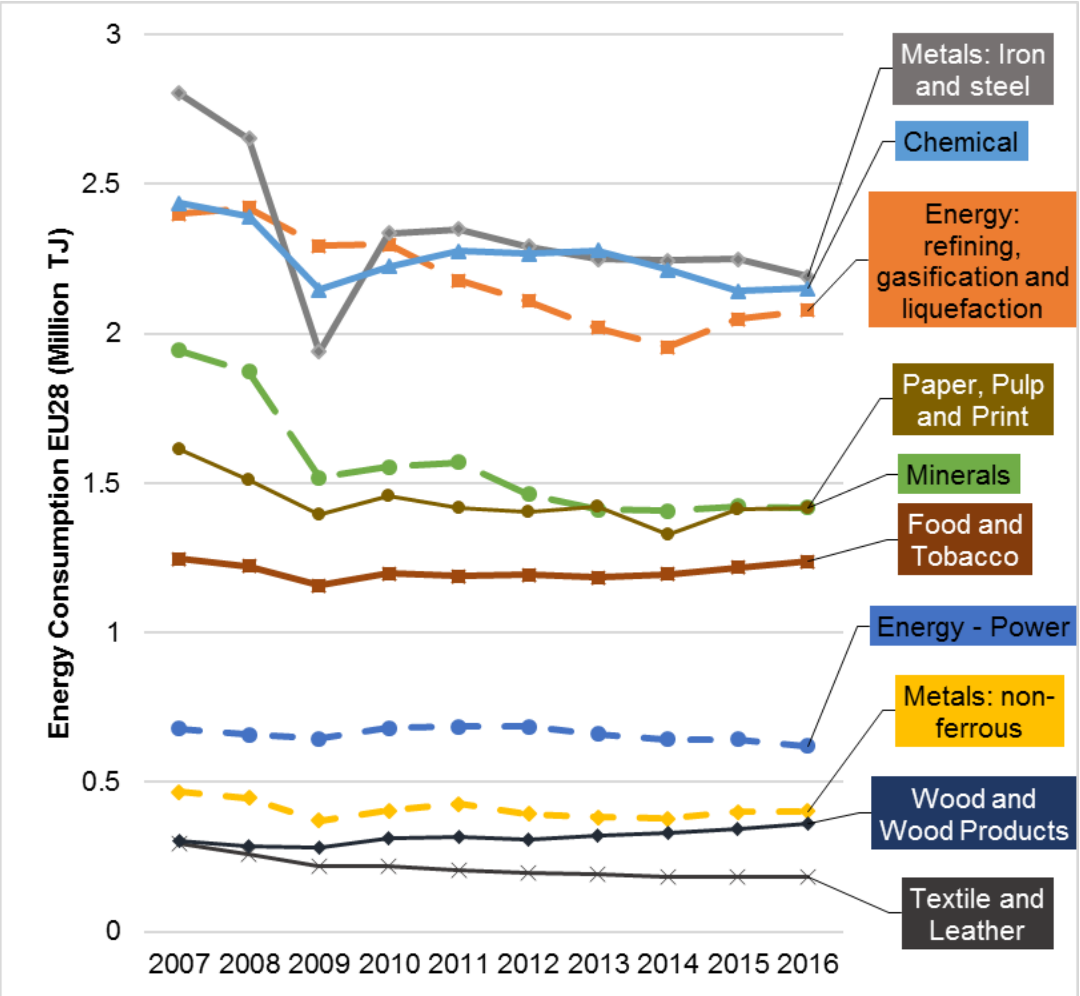
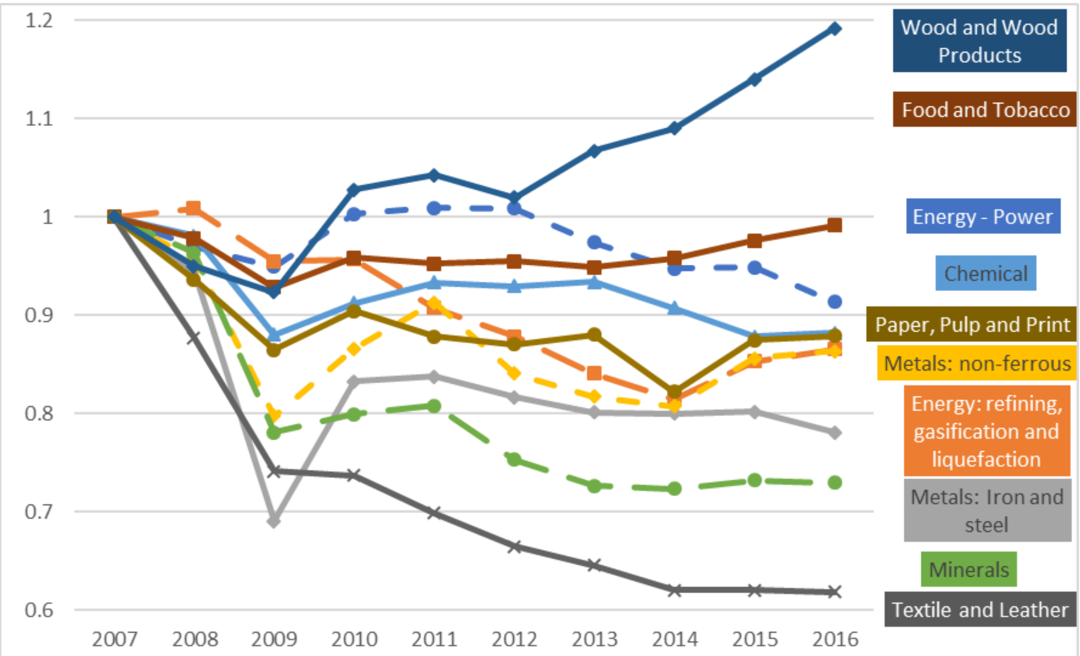


Figure 5 Energy use by industrial sectors between 2007-2016, indexed to 2007=1 (Source: Eurostat nrg_100a)

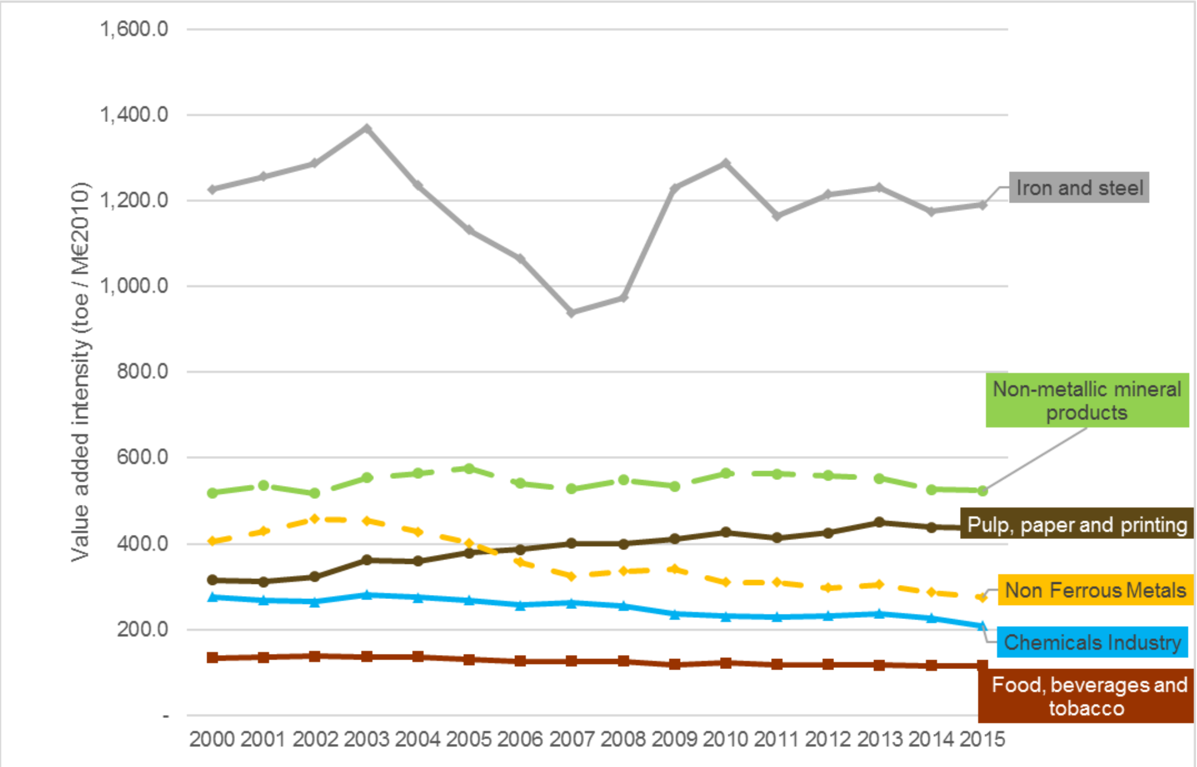


Energy intensity

The intensity of total final energy consumption in the EU decreased by 17.5 % between 2005 and 2016 averaging at 1.7% per year, indicating a decoupling of energy consumption from economic growth (EEA, 2019). **The largest decrease in that time period was achieved in the industry sector in which the energy intensity decreased at an average rate of 2.3 % per year**. This was driven both by improvements in energy efficiency but also a shift towards industries that are less energy intensive (EEA, 2019).

The sectoral-level data on energy intensity is available from the IDEES database[9] which combines Eurostat data on energy use with data on value added, to give a metric for energy intensity described as *'value added intensity in tonnes of oil equivalent (toe) per millions of Euros'*. This indicator shows the amount of energy utilised to produce a unit of output in €, with lower values indicating the same value of product created using less energy. Trends in the value-added intensity between 2000 and 2015 are presented in Figure 6 for six sectors (those included in the IDEES database). The iron and steel sector has the highest value added intensity. Value added intensity was lowest in 2007; in 2015 intensity was similar to 2000 levels. Value added intensity of non-ferrous metals and chemicals industry have gradually decreased over time, while the value-added intensity of pulp, paper and printing has increased. It can be seen that the trends differ from those showing absolute changes in energy consumption in Figure 4. In the iron and steel sector, there was a decrease in energy consumption from 2007-2009 while value-added intensity increased. This indicates that not only did energy use fall but that the amount of energy needed to generate each unit of output increased in this period for the sector. While the amount of energy use decreased in the non-metallic mineral sector, this was not due to a decrease in value added intensity and therefore decreased energy use is due to reduced production or reduced price of goods. The chemical sector saw a decrease in absolute energy use from 2007-2015 while value added intensity also decreased, meaning that some of the decrease in energy use may be due to increases in energy efficiency (although it may also be due to an increase in the price of goods).

Figure 6 Value-added intensity (tonnes of oil equivalent per m€) of industrial sectors



[9] https://ec.europa.eu/jrc/en/potencia/jrc-idees

3.1.1.2 BATs related to energy use in BATC

Overview

As illustrated in Figure 7 BATs on energy use are the most frequent across the circular economy topics covered in this study (32% of all BATs from all BATC[10]). The review has identified 117 energy use related BATs across the BATCs. Distribution of these BATs across sectors is presented in Figure 8. All BATCs contain at least one BAT relating to energy use with the exception of the CWW BREF. The sectors with the highest number of energy use-related BATs are the IS (14), LVOC (14), LCP (13), CLM (12), FDM (12) and NFM (12). The sectors with the lowest number of energy use-related BATs are: REF (1), CAK (2), GLS (3), WI (3), and IRPP (3).

Figure 7 The largest proportion of BATs on circular economy topics from across all the BATC published at the time of writing, is on energy

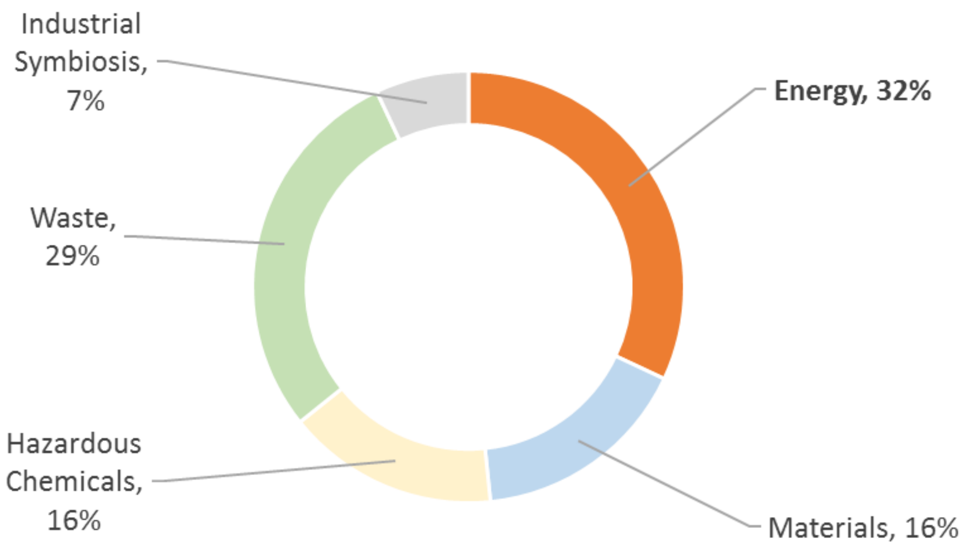
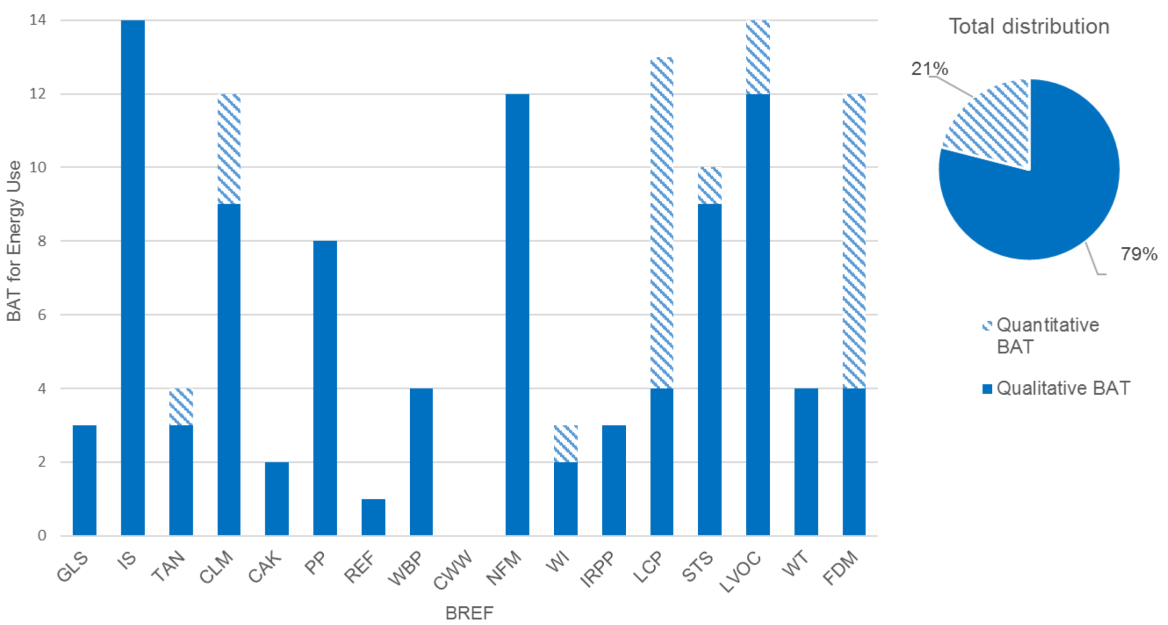


Figure 8 Number of energy use related BATs in IED BREFs, split into quantitative and qualitative BATs



[10] This percentage is calculated using the total number of BATs included in the BATC across all sectors, at the time of writing this report

Qualitative and quantitative BATs

Across all BATs related to energy use, 79% of BATs are narrative, i.e. no associated quantitative performance levels are set (BAT-AEPLs) (Figure 8). These qualitative BATs are often worded in one of the following ways:

- In order to reduce the specific/thermal/primary energy consumption…
- In order to increase energy efficiency…
- BAT is to reuse process gases as a fuel…
- BAT is to recover the energy of…

21% of all energy-use related BATs are quantitative, i.e. they include BAT-AEPLs. This is the highest number of quantitative BATs among the 5 circular economy topics covered in this study. It is important to note that Article 15 of the IED which requires competent authorities to set emission limit values associated with BAT, does not specifically refer to BAT-AEPLs. As such, there may be no apparent obligation to include BAT-AEPLs in permits. BATC for the LCP sector includes BAT associated energy efficiency levels (BAT-AEEL) which are a variation of BAT-AEPLs. They relate to electrical efficiency and net fuel utilisation for different fuel types in boilers, engines and turbines[11].

Across the BREFs, the highest proportion of quantitative BATs have been set for the LCPs (9 BAT-AEELs), FDM (8) as well as the CLM (3). Specifically in the FDM sector, the BAT's on energy efficiency include indicative environmental performance levels [12] set for specific sub-sectors.

Energy efficiency BREF (ENE)

The horizontal energy efficiency BREF published under the IPPC Directive contains guidance and conclusions on techniques for energy efficiency considered to be compatible with BAT for installations covered by the IPPC Directive, and now the IED. The horizontal approach is based on the premise that energy is used in all installations and that common systems and equipment occur in many sectors.

With that said, no associated energy savings or energy efficiency values are included in the horizontal energy efficiency BREF. The BREF states that BAT for energy efficiency and associated energy consumption levels are therefore given in the appropriate sector-specific (vertical) BREFs, and that BAT for specific installations is therefore a combination of specific BAT in the relevant sector BREF, specific BAT for associated activities found in other vertical BREFs (e.g. LCP BREF for combustion), and generic BAT presented in the energy efficiency horizontal BREF.

Generic BAT included in the BREF include energy efficiency management, benchmarking, energy efficiency design, increased process integration, and monitoring and measurement.

Types of BATs on energy use

The BATs related to energy use have been reviewed and categorised in this study into those relating to **energy efficiency, energy recovery** and **use of renewable energy**. Table 2 presents further division of these two broad categories of BATs. Energy efficiency involves measures which reduce energy use per unit of output, or in the case of generation increase electricity generated per unit of fuel. Energy recovery involves the harnessing of waste heat for use or using process gases as fuel to generate heat.

[11] BAT-AEELs are defined by the ratio between the combustion unit's net energy output(s) and the combustion unit's fuel/feedstock energy input at actual unit design. The net energy output(s) is determined at the combustion, gasification, or IGCC unit boundaries, including auxiliary systems (e.g. flue-gas treatment systems), and for the unit operated at full load.

[12] Note: BAT-AEPLs are a broad term encompassing different types of environmental performance levels. In the FDM BREF, energy efficiency values are referred to as indicative environmental performance levels.

Table 2 Categories of BATs related to energy use

Energy efficiency	Energy recovery	Use of renewable energy
• Energy management • Energy monitoring • Process optimisation • Use of energy efficient equipment • Change of fuel/feedstock	• Heat recovery/CHP • Use of process streams as fuel	• E.g. Solar energy

Figure 9 shows the different types of energy use-related BATs in each BATC. It indicates that across all sectors, *process optimisation* is the most common form of technique, followed by use of *process streams as fuel* and *energy efficient equipment*. The least common BATs relate to the *use of renewable energy* and *change of fuel / feedstock*. Renewable energy use makes up 13% of energy products used in the EU28 economy as a whole in 2016 while for industrial sectors this proportion is just 0.08%[13]. The low number of BATs relating to renewable energy in the BATC means that the BATC are unlikely to drive change in this area.

Figure 9: Spread of energy use BAT across different categories (source: analysis in this study)

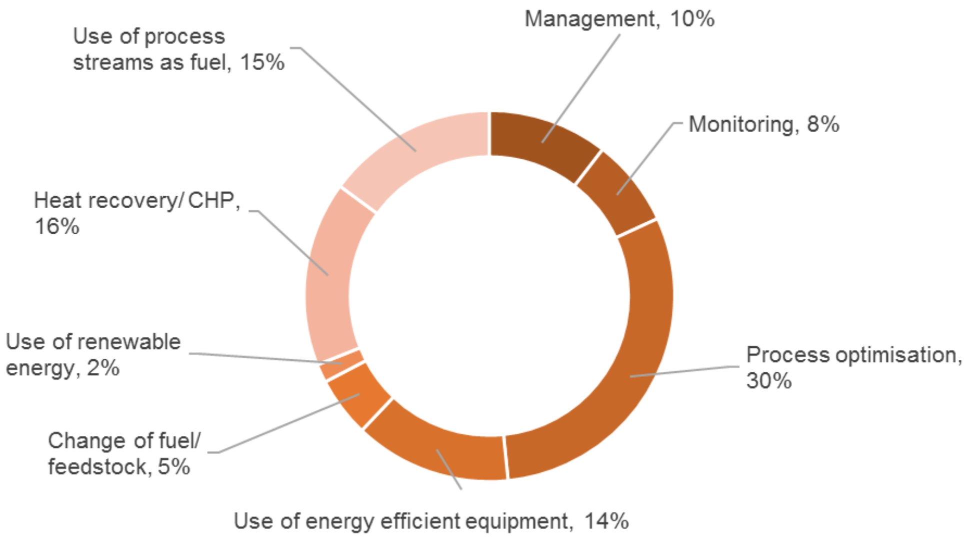
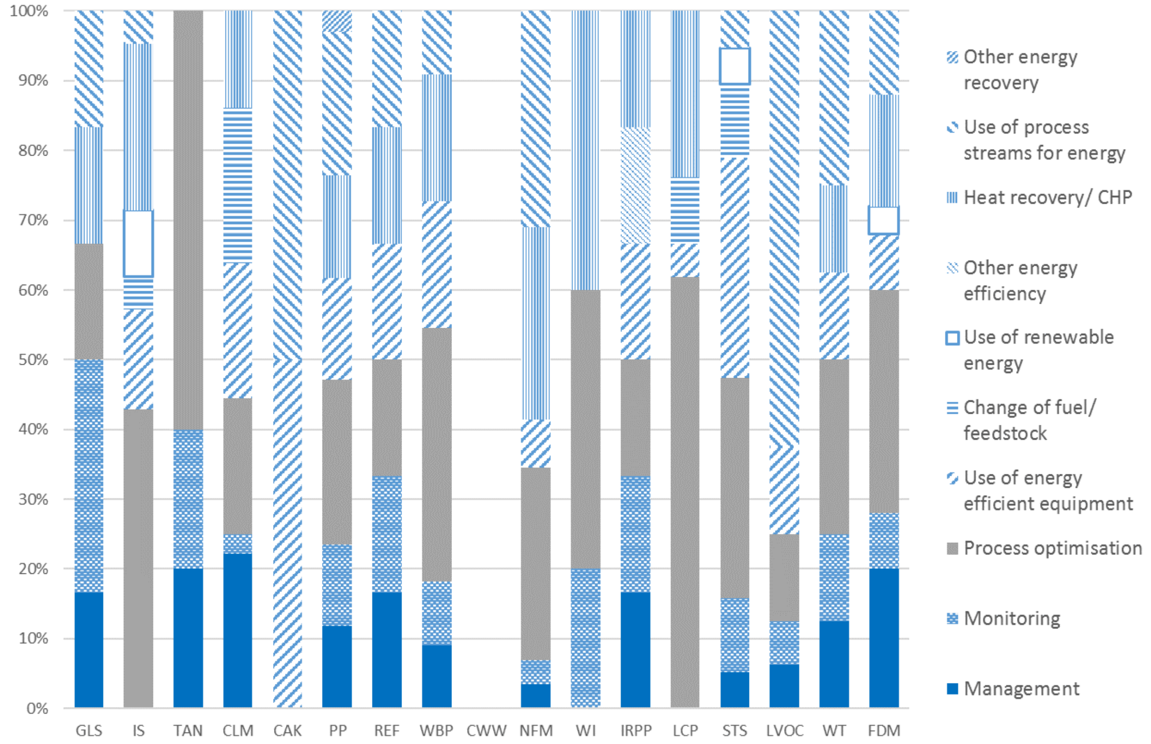


Figure 10 illustrates the spread of the different types of energy use-related BAT in each BATC and shows that:

- All BATC with energy use-related BAT contain at least one BAT related to *process optimisation* (to improve an overall energy efficiency), with the exception of the CAK. This type of BAT is the most common in the LCP and TAN BREFs.
- 13 BATC contain at least one BAT relating to *energy recovery*, involving *heat recovery/CHP* or *the use of process streams as fuel* to generate energy.
- 13 BATC contain at least one BAT on *monitoring of energy use*, and at least one on *energy management*.
- All BATC with the exception of the GLS, TAN, and WI include BATs related to the *use of energy efficient equipment.*

[13] https://ec.europa.eu/eurostat/en/web/products-datasets/-/NRG_100A

Figure 10: Types of energy BAT categorisations in IED BATC



Further detailed information on BATs for each sector is presented in Appendix 7.

3.1.1.3 Contribution of the IED to more efficient use of energy

Analysis of the energy use, energy efficiency and energy intensity data suggests that since the adoption of the IED and its predecessor legislation, energy use by industry has decreased and improvements have been made in industrial energy efficiency. However, it is not possible to determine whether these changes can be attributed to the IED and/or IPPCD, or to other legislation targeting industrial energy use such as the EU ETS which also applies to several of the IED sectors, or due to other factors such as changes in energy prices. Energy makes up a large proportion of operational costs of industrial installations, thus reductions in energy use and improved energy efficiency are also common-sense measures in the effort to increase profit margins in a competitive economic climate. While such investments from industry have contributed to the overall reduction in energy use and improvements in energy efficiency, industrial sectors make up a relatively small proportion of the overall EU energy use (around 15%).

All BATC, with the exception of CWW, include energy use related BATs. Iron and steel, chemical and energy refining sectors have the highest energy use across the IED sectors. Analysis of their respective BATC reveals that:

- **IS sector has the highest number of total BATs associated with energy use out of all sectors, and this corresponds with the sector's high energy use.** However, none of these BATs are quantitative thus it is difficult to estimate their actual impact. Most of the qualitative BATs are considered relatively easy for the industry to comply with as they often include a range of different techniques / practices that could be used to comply with BAT (and were not considered important in the recent Ricardo study on ex-post impacts of the iron and steel BATC).
- There are 5 qualitative generic BAT in the IS sector which are targeted at reducing thermal and electrical energy consumption, including measures on power management, optimisation of energy flows and utilisation of extracted process gases and heat recovery. There are also 12 qualitative process specific BAT which target reduction in energy consumption and energy recovery in sinter strands, coke ovens, blast furnaces, basic oxygen furnaces.

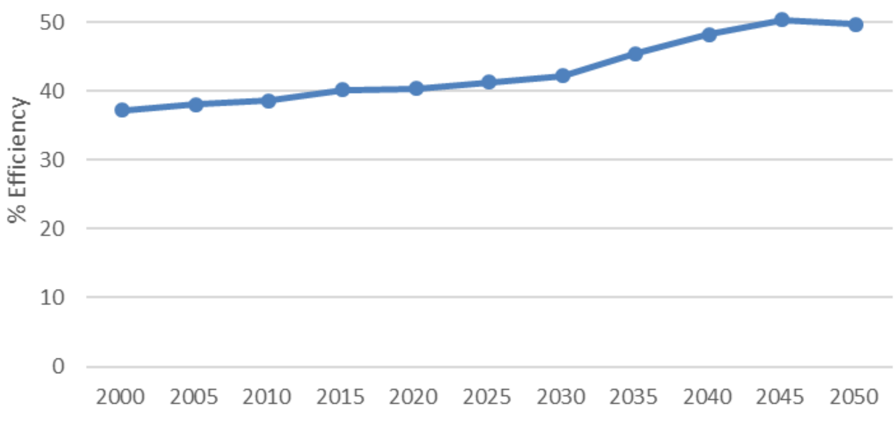
- The **LVOC** sector has 14 BATs addressing energy use, which corresponds with the sector's high energy consumption. However only 2 BATs are quantitative. There are 2 generic BAT that apply to the whole sector, on general energy management and the use of waste residues as fuel. The remaining BATs are process specific, with the diverse range of chemical processes in the BREF to some extent explaining the high number of BATs. Process-specific BATs target energy efficiency and energy recovery, with a large focus on the use of process streams as fuel (9 process-specific BATs).
- The BATC for the **REF** sector, has only one qualitative energy use-related BAT. This is a generic BAT applicable to the whole sector and measures include design techniques including heat integration of process streams, process control and optimisation, and energy efficient production techniques. Given that refineries are a sector with one of the highest energy consumption across industry (See Section 3.1.1.1), it is noteworthy that the BATC for this section contain only one generic, qualitative BAT.
- **The BATC with the most quantitative energy-use related BATs are for the LCP and FDM sectors.** The BATC for these sectors are some of the most recent (LCP BATC was published in July 2017, while at the time of writing this report the FDM BREF was at final review stages, awaiting adoption). Thus the larger number of quantitative BATs for these sectors may be associated with:
  - Overall greater emphasis placed on energy use during the BREF review process (provided energy use is a KEI for the sector), including increased emphasis on deploying quantitative rather than just qualitative BATs for those topics identified as key environmental issues.
  - Better quality of data collected during the review process through the information exchange, allowing the BAT-AEPLs to be derived.

Quantitative estimates of improvements in energy efficiency and reduction in energy use in these two sectors (and a more limited assessment for the STS sector) are presented below.

Large Combustion Plants

An assessment of the energy efficiency gains associated with the BAT-AEELs in the LCP sector was made. This drew on DG ENER's EU Reference Scenario energy modelling based on PRIMES[14] which contains data on the efficiency of gross thermal power generation over time in the EU-28, projected forward in 5-year increments to 2050 (see Figure 11). The improvement in energy efficiency from 2010 (38.6%) to 2020 (40.4%) was applied to the efficiencies presented in the LCP BREF section on current consumption levels by applying a 1.05 multiplier. This reflects the impact of anticipated business as usual changes in the sector since the time of the information exchange during the BREF review process and the deadline for compliance with BATC (July 2021). The adjusted baseline energy efficiency levels were then compared to the BAT-AEELs using the formula and methodology described in Section 2 to obtain an estimate of potential improvement that could be considered attributable to the IED. The increased efficiencies over time may, however, be driven by market forces as well as the IED.

Figure 11 Efficiency of gross thermal power generation to 2050 (source: EU 2016 Reference Scenario)



[14] https://ec.europa.eu/energy/en/data-analysis/energy-modelling

The estimated improvements in energy efficiency of the LCP sector per BAT are as follows:

- For BAT 19 on net electrical efficiency in coal and lignite plants, estimated improvements are 7-9% (% improvement i.e. 7-9% of baseline efficiency) for existing coal and lignite plants under 1000MW, however no improvements are estimated for large plants >1000MW, which are an important (high emitting) category of plants. Small improvements in net fuel utilisation are predicted for these plants however, of approximately 10%.
- For BAT 40 on net electrical efficiency in gas fired plants, existing closed cycle gas turbines (CCGT) are predicted to have small improvements of ~6% for plants of 50-600 MW, and ~10% for plants >600MW.

These represent the most significant plant types across the EU. While no improvement is estimated for the largest coal and lignite plants, improvements for coal and lignite pants <1000MW and CCGT plants are significant and outstrip the improvements in efficiency across industry as a whole (EEA, 2018).

It should be noted that despite efforts taken, these calculations may still present overestimates in the contribution of the IED to improvements. In the LCP sector, improvements in efficiency are likely to be driven by improved design of new plants, which may not be driven by the IED. An alternative way to calculate improvement in energy efficiency would be to refer to footnote 8 of Table 10.2 in the LCP BREF containing the BAT-AEELs for BAT 19 which states that:

> *The achievable electrical efficiency improvement depends on the specific unit, but an increase of more than three percentage points is considered as reflecting the use of BAT for existing units, depending on the original design of the unit and on the retrofits already performed.*

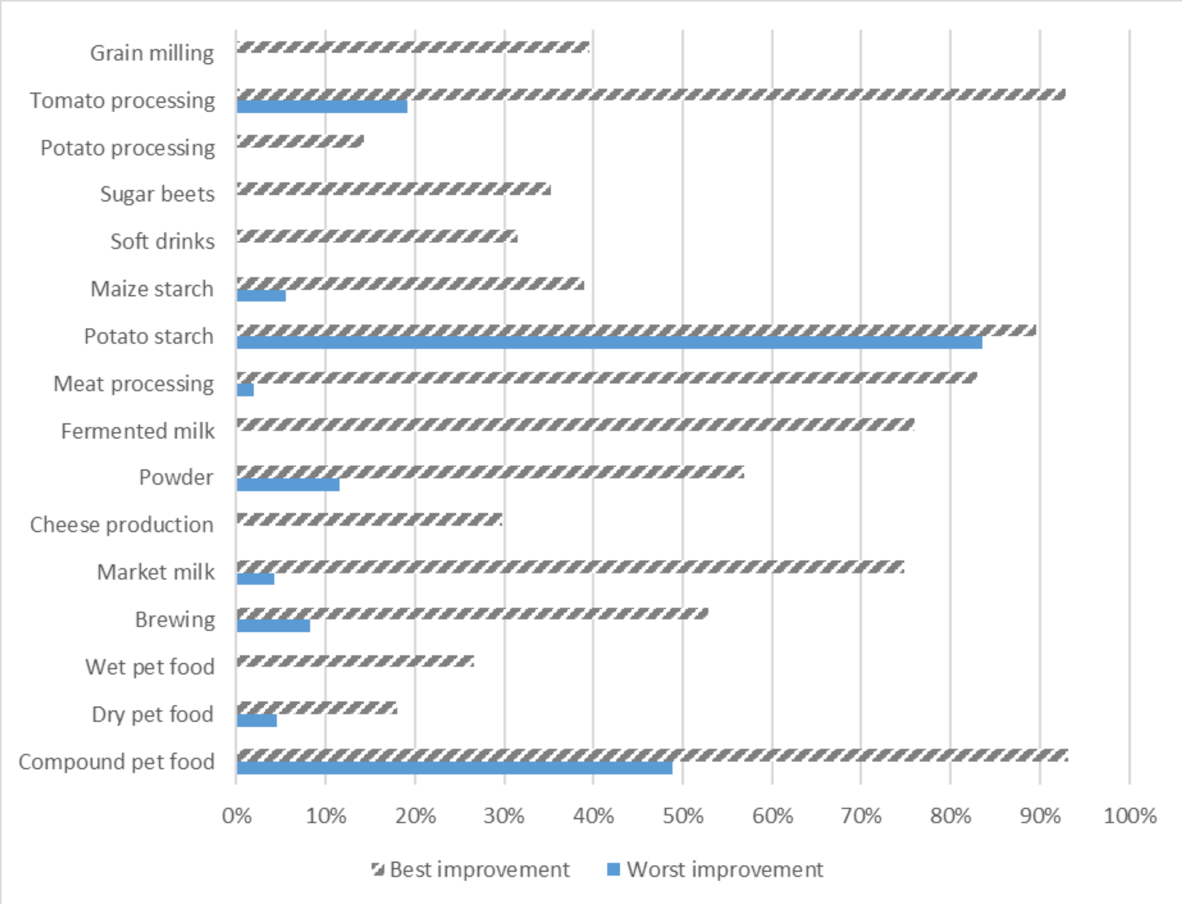
In the report of the final meeting of the LCP BREF, notes on this footnote state that the scale of improvement depends “on the original design of the plant and on the retrofits already performed”. As such, a 3 percentage point improvement could be used as a lower bound of energy efficiency improvement estimates for all BATs. This leads to the assumption that the 3 percentage point improvement is applicable to all types of combustion plant, which may over-estimate improvements in some cases and under-estimate it in others.

Food, drink and milk

In the June 2018 Draft FDM BREF, there are 16 BAT-indicative environmental performance levels defined at subsector level. These are either associated with the application of generic measures outlined in BAT6 (energy management plan, energy efficiency equipment e.g. motors, heat recovery, process optimisation, heat recovery) or through specific process-level BATs such as for dairy, oil seed processing, soft drinks and sugar beet processing.

Improvements in energy efficiency were estimated by comparing indicative environmental performance levels with energy efficiencies from the current consumption and emissions chapter of the BREF using the methodology and formula described in Section 2 (Figure 12). Improvements are the % improvement in efficiency going from current levels to efficiencies in the lower and upper indicative performance levels. The largest improvements are predicted in the production of compound pet food and potato starch. The lowest improvements are estimated in potato processing. In the case of some subsectors, the upper (best case) estimate of energy efficiency improvements is very high, particularly in the production of compound pet food, tomato processing, potato starch, meat processing, fermented milk and market milk. This is because the lower end of the indicative performance range is significantly lower than the sub-sectors’ efficiencies stated in the current consumption chapter of the BREF. For some subsectors the range of improvements is also very large, for example in the case of meat processing, fermented milk and tomato processing. This reflects the relationship between current efficiency levels and the indicative environmental performance levels. For example, current efficiency levels for meat processing are 0.25-3.3 MWh/tonne, while the BAT indicative environmental performance levels are 0.25-2.6 MWh/tonne. This produces a very large range of projected improvements.

Figure 12 Range of improvements in energy efficiency estimated to be driven by application of BAT in draft FDM BREF



Note: Improvements are in % improvement of current levels. Best and worst improvement estimates compare upper and lower ranges of current efficiencies as well as BAT-associated indicative performance levels and are based on the formula presented in the methodology section developed with the EIPPCB in the recent study 'Summary on IED Contribution to water policy study' (Ricardo, 2017).

Surface treatment using organic solvents

The STS BREF BAT 21 targets energy efficiency: "*In order to increase energy efficiency, BAT is to use an appropriate combination of the techniques given below."* The techniques mentioned include thermal insulation of tanks and vats, combined cooling heat and power, heat recovery, and flow adjustment of process air and off-gases. BAT 21 includes BAT-AEELs for specific processes in the BREF. It was possible to compare the BAT-AEELs with values presented in the current consumption chapter. For the coating of passenger cars, the BAT-AEEL of 0.5 – 1 MWh/unit coated produces an estimated reduction of 5-41% in specific energy consumption. For other processes it was not possible to estimate improvements due to incomparable metrics on energy being used in the current consumption chapter and in the BAT-AEELs. The results of the analysis for coating of cars indicates that the application of BAT has the potential to drive significant reductions in energy consumption in the sector.

Other BREFs with quantitative BATs relating to energy

With regards to other BREFs with quantitative BATs relating to energy:

- The LVOC sector has 2 quantitative BATs which include measures on:
  - Energy recovery and use of process streams as fuel in formaldehyde production
  - Recovery of gas for combustion in the production of phenol

  These measures relate to energy by reducing the use of primary fuel. They are part of a BAT that is targeted at reducing emissions of organic compounds and so the quantitative target relating to them are AELs for organic compounds. As such, quantitative estimates of energy savings attributable to the IED were not undertaken.

- In the CLM BREF, there are 2 BATs targeting the reducing of thermal energy consumption, with BAT-AEELs in GJ/Tonne of product. However, the upper and lower BAT AEELs are the same as the values provided in the current consumption and emissions chapter of the BREF suggesting a lower level of ambition in the AEELs. As such no improvements have been estimated.
- The TAN BREF contains BAT-AEELs. However, the current consumption and emissions chapter of the BREF only contains data on energy use of processes as a proportion of overall energy consumption at the installation. As such, it was not possible to estimate energy use improvements in this sector.

3.1.2 Materials use

3.1.2.1 Contribution of IED sectors to the overall EU materials use

Data on the material use by IED sectors and compared to other sectors (e.g. households) are not possible to present because raw materials are embedded in substances and intermediate and final products that move over different sectors towards households.

The materials use by industrial sectors covered by the IED and its contribution to the overall EU industrial materials use is evaluated based on the **direct use of materials (i.e. direct input of raw materials and goods**) per sector and over time, obtained from the EXIOBASE database.

For the ease of reading and interpreting the results, raw materials, material goods and products used by the industrial sectors have been grouped into the following nine categories:

- **food products:** agricultural and fish products, processed meat, processed vegetables, dairy products, sugar (related products), beverages and other food products;
- **textiles:** textiles, wearing apparel, furs and leather (products);
- **paper and wood products:** products of forestry, logging, wood and products of wood and cork, straw and plaiting materials, pulp, paper (products), printed matter and recorded media;
- **energy (related) products:** fossil and bioenergy derived and refined products, including fuels;
- **plastics and chemicals:** plastic and rubber (products), chemicals and fertilisers;
- **mineral products:** mineral resources (e.g. sand and clay), glass (products), ceramic goods, bricks, tiles, cement, lime, plaster, other construction products and construction work;
- **metal products:** metal resources (e.g. iron ores), ferrous metals, precious metals, aluminium (products), lead, zinc and tin (products), copper (products), other non-ferrous metal products, machinery and equipment, motor vehicles, trailers and semi-trailers and other transport equipment;
- **electronics:** office machinery, computers, electric machinery and apparatus, radio, television, communication equipment and apparatus, medical, precision and optical instruments, watches and clocks; and
- **others:** other not categorised products (e.g. furniture, tobacco, retail and services).

Use of Critical Raw Materials (CRM)

Due to growing concern over access to certain raw materials, the European Commission has created a list of Critical Raw Materials (CRMs) which is regularly reviewed and updated. The latest list of CRMs was published in 2017 and includes 27 raw materials. The 2018 report by the European Commission on the CRMs and circular economy identified key sectors for the supply and demand of critical raw materials. The only sector regulated by the IED and featured in this report is chemicals and fertilisers production sector, which uses CRMs in the production of catalysts (using platinum group metals), fertilisers, polymers and pharmaceutics and dyes. Some examples of the level of use include:

- fertilisers production consumes 86% of phosphate rock
- detergents and other chemicals production consumes 90% of white phosphorus
- pharmaceuticals and other chemicals production uses 60% of bismuth
- production of silicone and silicates consumes 54% of silicon metal

In order to address high consumption of CRMs in the chemical sector, the report recommends *support for the development of new or optimisation of existing chemical processes and/or technologies that enable/enhance the safe recycling and/or reuse of CRMs*.

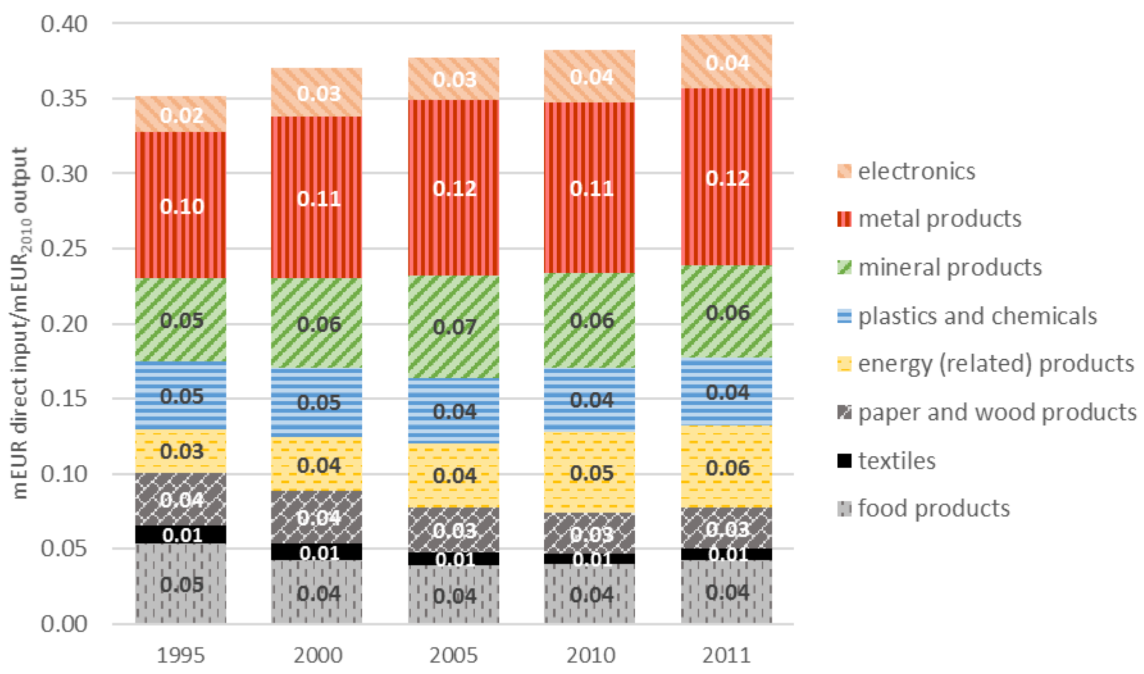
Use of materials

The reduction of the use of primary raw materials is one of the core objectives of any circular economy strategy. The use of primary materials by industries is to be reduced in relative terms, i.e. per unit of industrial output, in units of mass and/or product value. An alternative mechanism for reducing primary raw material consumption is to substitute, to the extent possible, primary with secondary materials that result from the treatment of waste. It is particularly important, for reducing supply risks, to substitute those primary raw materials that are sourced outside the EU.

In the latter case of substitution, and particularly in a context of industrial emissions, appropriate measures should be taken in order to avoid that the replacement of virgin, pure raw materials by recycled inputs -or of newly produced parts by used or remanufactured components- is associated with increased levels of impurities, hazardous substances and waste, and/or with a decrease in value or quality of the industrial output.

Figure 13 shows the direct use of materials and goods by the primary[15] and secondary[16] sectors in the EU-28 between 1995 and 2011. The direct use is expressed as the monetary value of the yearly purchases of material resources by a sector(group), per million EUR_{2010} of output. The figure shows that, per monetary unit of output, the value of the material inputs is increasing. This means that, in terms of costs, the use of semi-finished products, intermediate goods and raw materials is increasingly significant for EU-28 industries. This trend can be caused by several factors, such as a relative decrease of labour cost, lower profit margins, lower fixed capital costs, higher input value of materials as compared to other resources, the use of intermediate or semi-finished products at higher finishing levels, shifts in European industrial production output characteristics, among other. Furthermore, the contributing factors will differ per sector, and probably even per industrial region, Member State or geographical area.

Figure 13 Direct use of materials, divided into eight material categories (excl. others) by the primary and secondary sectors in the EU-28 per million EUR_{2010} output, 1995-2011. *Source: own calculations using EXIOBASE 3*



[15] NACE section A: Agriculture, forestry and fishing to B: Mining and quarrying

[16] NACE section C: Manufacturing, D - Electricity, gas, steam and air conditioning supply, E - Water supply; sewerage; waste management and remediation activities and F - Construction

Across the primary and secondary sectors, most of this monetary value is related to metal, mineral and energy (related) products. It means that, on average, the primary and secondary sectors relatively spend more money on the purchase of metal, mineral and energy (related) raw materials and (intermediate) goods. The higher spending on energy products is explained by their use across all sectors. The shares of other material categories in the purchase of materials is often sector specific and illustrative for the material use intensities of different sectors (groups e.g. FDM). Another explanation is found in the mass-based share in the material input in which metal products represent 8%, mineral products 45% and energy (related) products 30% (2011 data). For metal products the unit-price is dominant, while the share of mineral and energy (related) products is high due to the use of large quantities. The monetary value of the direct use of materials by the primary and secondary sectors in the EU-28, per unit of added value, increased in the period 1995-2011, demonstrating a growing average cost of material resource use per monetary unit of output.

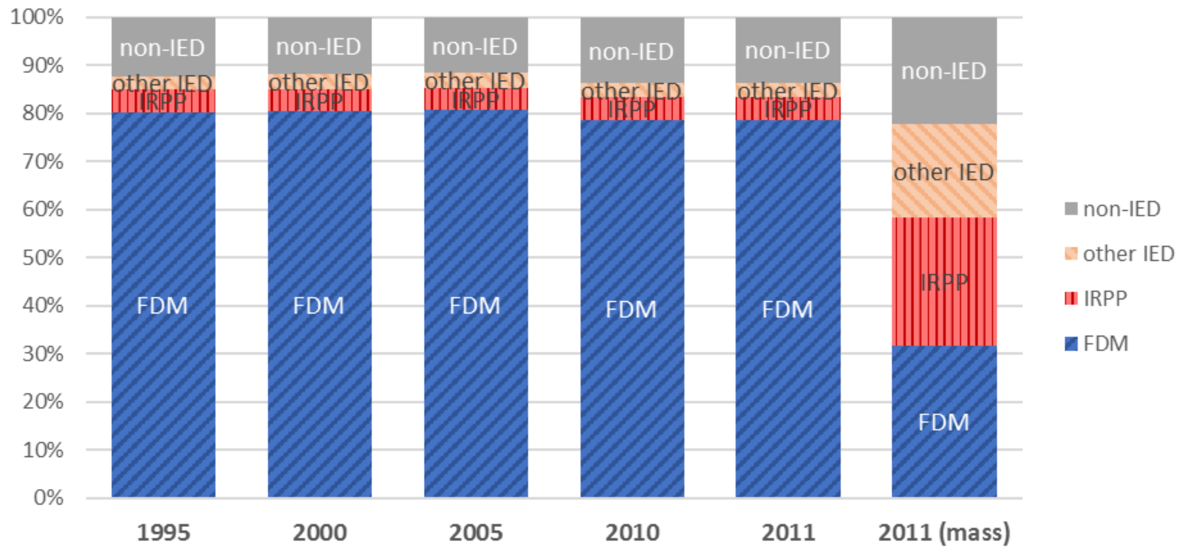
Figure 13 thus represents the use of the eight different materials' categories by all primary and secondary sectors, both IED and non-IED. The distribution of these categories is indeed very specific for each individual industrial sector, while also the share of the cost of materials in the total cost of production will differ according to the sector.

Figure 14 to Figure 21 show the direct material use of the IED-sectors in 2011 (expressed in monetary units and tonnes) for the eight material groups, relative to the total direct material use by all primary and secondary sectors in the EU-28. For interpreting these figures, it is important to observe that the IED-sectors' share is likely to be an overestimation, due to the imprecise correlation between IED activities and NACE codes, and capacity and production thresholds applied in the IED to some activities. It should be emphasised that all figures refer to material used by industry, excluding tertiary sectors and households. The first five bars show the monetary value of direct material use, while the last bar shows the direct material consumption in physical units (i.e. tonnes). The difference between both reflects the price per mass unit of the used materials.

Use of food products

Figure 14 presents the direct use of **food products** for industrial food production, for (consecutive) activities of food processing and, in general, as an input for industrial activities, such as the rearing of pigs and poultry. Food products can however be consumed, wasted, or processed in many different industries. At the end of industrial food production chains, the food products that are ready for consumption are destined to wholesale and retail sectors, and finally consumed by households and animal breeders. In 2011, 75% of the value of all industrial purchases (i.e. by NACE divisions A-F) of food products in the EU-28 were attributed to the FDM sector. The same sector purchased only 32% of the weight of all purchased food products in the EU-28. This share is remarkably lower compared to the 75% share in monetary units, showing that the FDM sector is mainly buying high-value food products. The opposite is true for the IRPP sector which has a monetary share in direct food products input of 4%, compared to a physical share of 27%. This demonstrates that the IRPP-sector is mainly consuming low-value food products. In mass-based units, the IED-sectors cover almost 80% of the total industrial use of food products. The shares of the FDM and IRPP sectors in the total monetary value of food products consumed by EU industrial sectors, has remained practically unchanged over the period 1995-2011.

Figure 14 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of food products by the main IED-sectors, other IED-sectors and non-IED-sectors[17] in the EU-28. Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



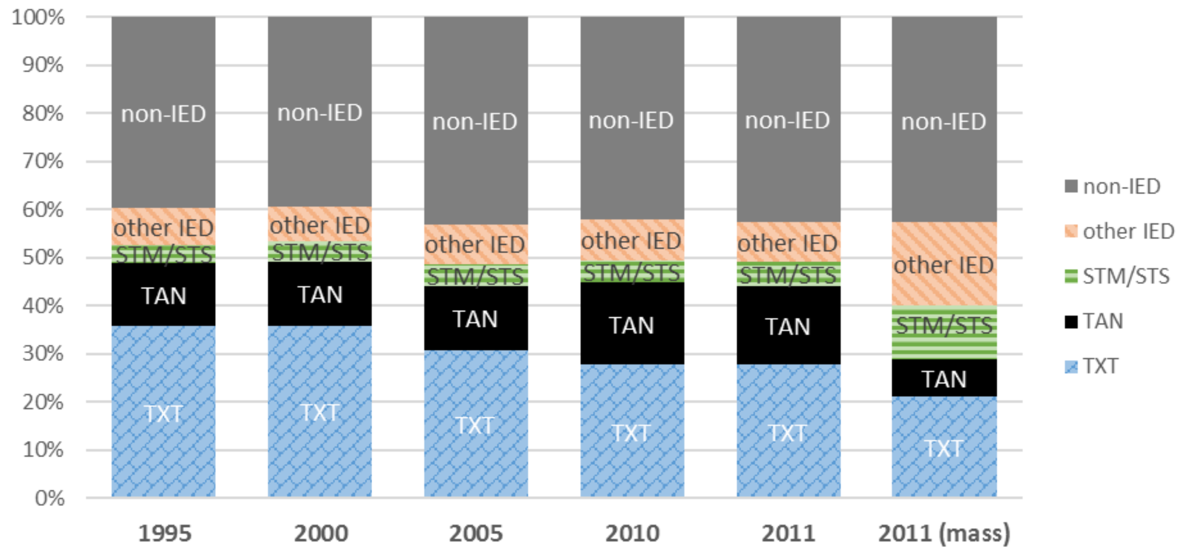
The main road for achieving reductions in the use of food products by food producing and processing industries is the improvement of processing and conversion efficiencies. Such strategies could consist of (i) using lower quality inputs, maybe by-products, or even waste, in order to decrease the (relative) monetary cost of food product purchases, or (ii) the reduction of the production of food waste per unit of food product output (see section 3.1.3). It is however doubtful whether and in which cases both strategies can be applied simultaneously, while a sector-specific and quantitative or qualitative analysis of how different waste stream volumes relate to the corresponding input material volumes per material category, reaches beyond the scope of the present study. Altogether, the enforcement of reduction measures such as those outlined above, by using the tools and mechanisms provided by the IED and the BATC, seems to be fairly complex and challenging.

[17] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of textile products

Figure 15 presents the direct material use of **textile products** for industrial textile production, for (consecutive) activities of textile processing and, in general, as an input for many different industrial activities in both primary and secondary economic activities. In each of these industries, different shares of these inputs of textile products are consumed, wasted, and processed. In 2011, 28% of the value of all purchases of textile products in the EU-28 are attributed to the TXT sector and 21% of the weight of all purchased textile products in the EU-28 are bought by the TXT sector. This share is lower compared to the share in monetary units. The same is true for the TAN-sector which has a monetary share of direct textile products consumption of 16%, compared to a physical share of only 8%. This demonstrates that both the TXT and TAN sectors are mainly consuming high-value textile products. In mass-based units, the two IED sectors cover almost 30% of the total use of textile products, while this is almost 50% in monetary-based units. The share of non-IED sectors in the total value of textile products consumed by EU industrial sectors, has slightly increased between 1995-2011.

Figure 15 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of textiles by the main IED-sectors, other IED-sectors and non-IED-sectors[18] in the EU-28. Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



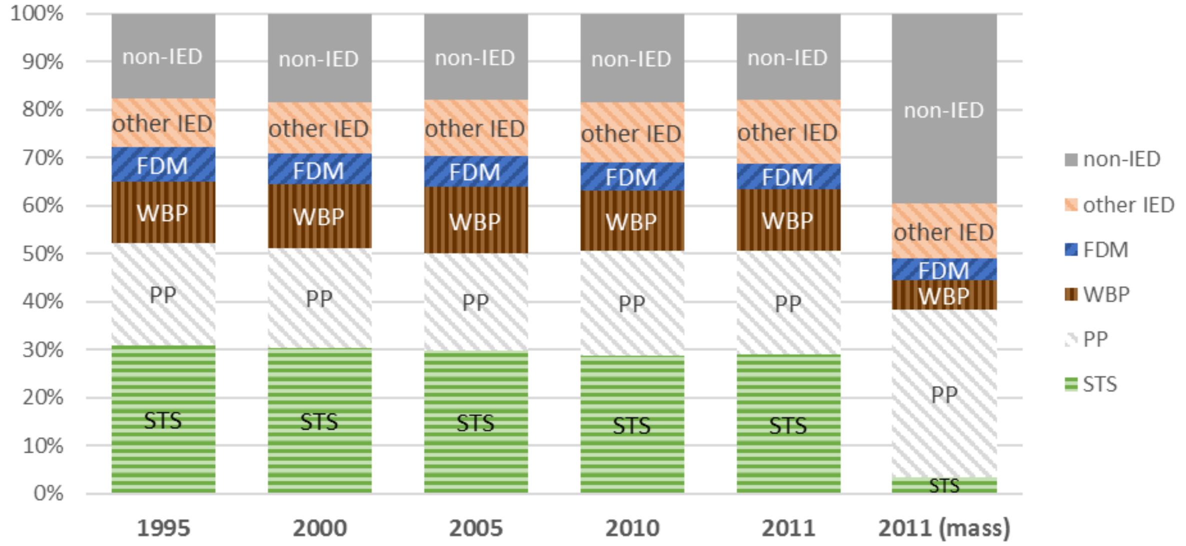
[18] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of paper and wood products

Figure 16 presents the direct material use of **paper and wood products**, as an input for industrial activities. Since end-of-life paper and wood products are commonly recycled and reused as a secondary material, it is important to observe that the paper and wood products category also considers 're-processing of secondary wood material into new wood material', 'secondary paper for treatment' and 're-processing of secondary paper into new pulp'.

In 2011, 29% of the value of all purchases of paper and wood products in the EU-28 were attributed to the STS sector, but only 3% of the weight of all purchased paper and wood products in the EU-28 are bought by the STS sector. The same is true for the WBP sector which has a monetary share in direct paper and wood products input of 13%, compared to a physical share of only 6%. This demonstrates that both the STS and WBP sectors are mainly consuming high-value paper and wood products. The opposite is true for the PP sector, which has a monetary share in direct paper and wood products of 22%, compared to a physical share of 35%. In mass-based units, the IED-sectors cover around 60% of the total use of paper and wood products. The share of the IED sectors that contribute most to the total value of products from paper and wood that are consumed by EU industrial sectors, has remained fairly stable over the period between 1995 and 2011.

Figure 16 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of paper and wood products by the main IED-sectors, other IED-sectors and non-IED-sectors[19] in the EU-28. Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



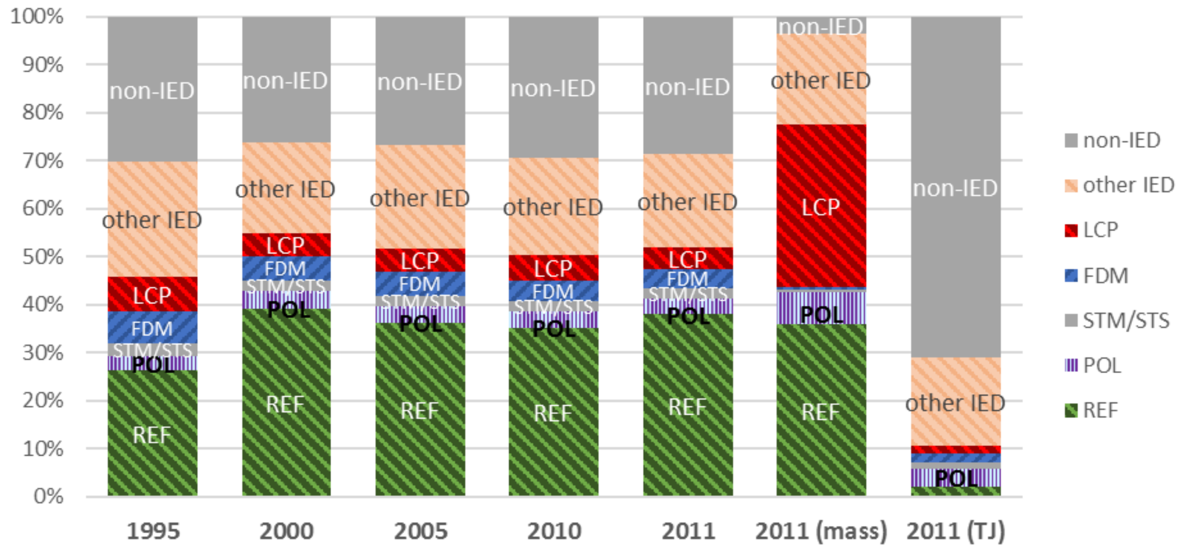
[19] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of energy products

Figure 17 presents the direct material use of **energy (related)** products by all industries that are categorised under primary and secondary economic sector activities. Many different industries use these products as a source of energy, or further process and refine them into higher value products. The monetary value bars represented in the figure refer to the use of all energy (related) products, including those products for which the physical mass cannot be determined, such as electricity, steam, hot water, distribution services and nuclear energy. The latter are thus not included in the '2011 (mass)' bar. Additionally, a 2011 (TJ) bar is included in the figure that includes electricity, steam, hot water and nuclear fuels.

In 2011, 38% of the value of all purchases of energy (related) products in the EU-28 are attributed to the REF sector, and 36% of the weight of all purchased energy (related) products in the EU-28 are bought by the REF sector. Although the LCP sector has a monetary share in direct use of energy (related) products of only 5%, this sector has a substantial physical share of 34%. This demonstrates that the LCP sector is mainly consuming low-value energy (related) products. In mass-based units, the IED-sectors cover almost 100% of the total use of energy (related) products. Although the aggregated contribution of the IED sectors in the total monetary value of energy (related) products consumed by EU industries has remained stable, relevant variations in the relative shares of both REF and minor IED energy consumers can be observed between 1995-2011.

Figure 17 The monetary value (1995-2011) and physical quantity mass (2011) and energy content (2011) of direct material uses of <u>energy (related) products</u> by the main IED-sectors, other IED-sectors and non-IED-sectors[20] in the EU-28. Note that one IED-sector can be in multiple sector groups



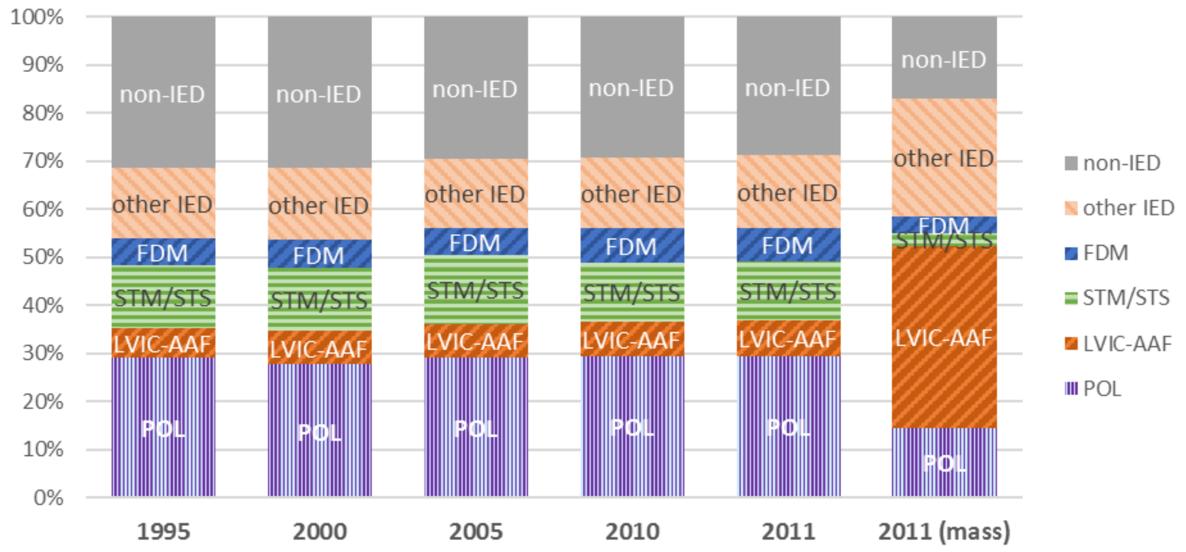
Source: own calculation based using EXIOBASE 3.
Note: the 2011-mass composition excludes the direct material use of nuclear fuels, steam, hot water and electricity. The use of electricity, steam, hot water and nuclear fuels is included in the '2011 (TJ)' bar.

[20] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of plastics and chemicals

Figure 18 presents the direct material use of **plastics and chemicals** as an input for all industrial activities that are categorised under the primary and secondary economic sectors, IED as well as non-IED. These plastics and chemicals can be either processed and turned into finished and semi-finished products, wasted or consumed, in proportions that will differ among different activities. In 2011, 29% of the value of all purchases of plastics and chemicals in the EU-28 were attributed to the POL sector, but only 14% of the weight of all purchased plastics and chemicals in the EU-28 were bought by the POL sector. The same is true for the STM/STS sectors which have a monetary share in direct use of plastics and chemicals of 12%, compared to a physical share of only 2%. This demonstrates that both the POL and STM/STS sectors are mainly consuming high-value plastics and chemicals products. The opposite is true for the LVIC-AAF sector which has a monetary share in direct use of plastics and chemicals of 7%, compared to a physical share of only 38%. In mass-based units, the IED-sectors cover around 80% of the total use of plastics and chemicals. The monetary value share in the total EU industrial consumption of plastics and chemicals in the non-IED sectors decreased slightly between 1995-2011.

Figure 18 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of plastics and chemicals by the main IED-sectors, other IED-sectors and non-IED-sectors[21] in the EU-28. Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.

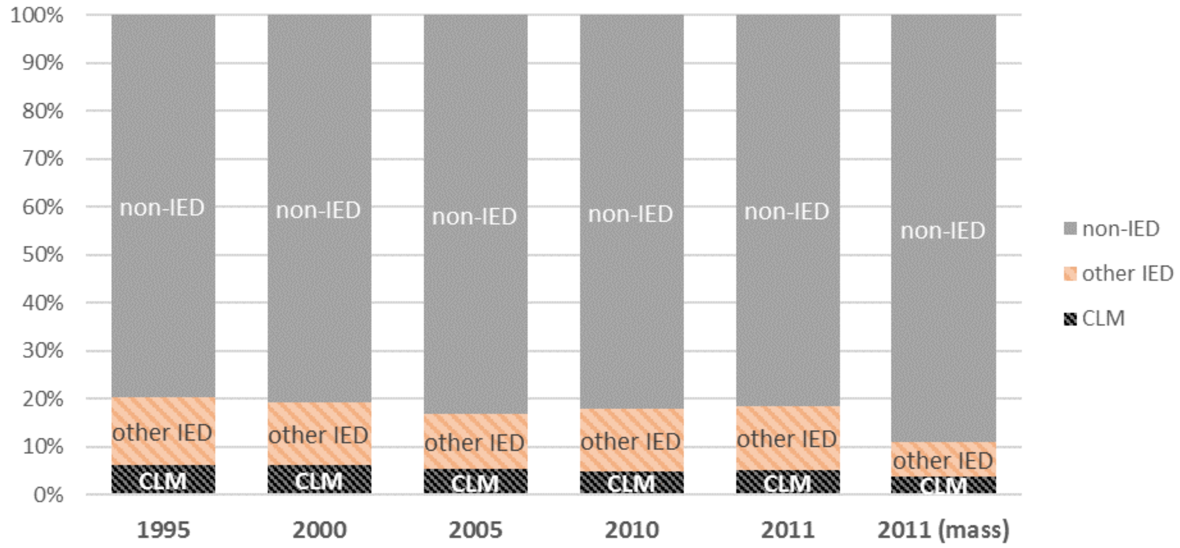


[21] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of mineral products

Figure 19 presents the direct material use of **mineral products, i**ncluding raw materials, as an input for all industrial activities that are categorised under the primary and secondary economic sectors, IED as well as non-IED. These mineral raw materials and products are processed and turned into finished and semi-finished products, wasted or consumed, in proportions that will differ among different activities. The non-IED sectors' share in the total value of mineral products is 80%. The physical share is even greater – 90%. This is driven by large consumption of mineral products by the construction industry which is grouped within the "non-IED sector" category. The largest single consumer of the mineral products among the IED sectors is CLM. In 2011, around 5% of the value of all purchases of mineral products in the EU-28 were attributed to that sector.

Figure 19 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of mineral products by the main IED-sectors, other IED-sectors and non-IED-sectors[22] in the EU-28. Note that one IED-sector can be in multiple sector groups.



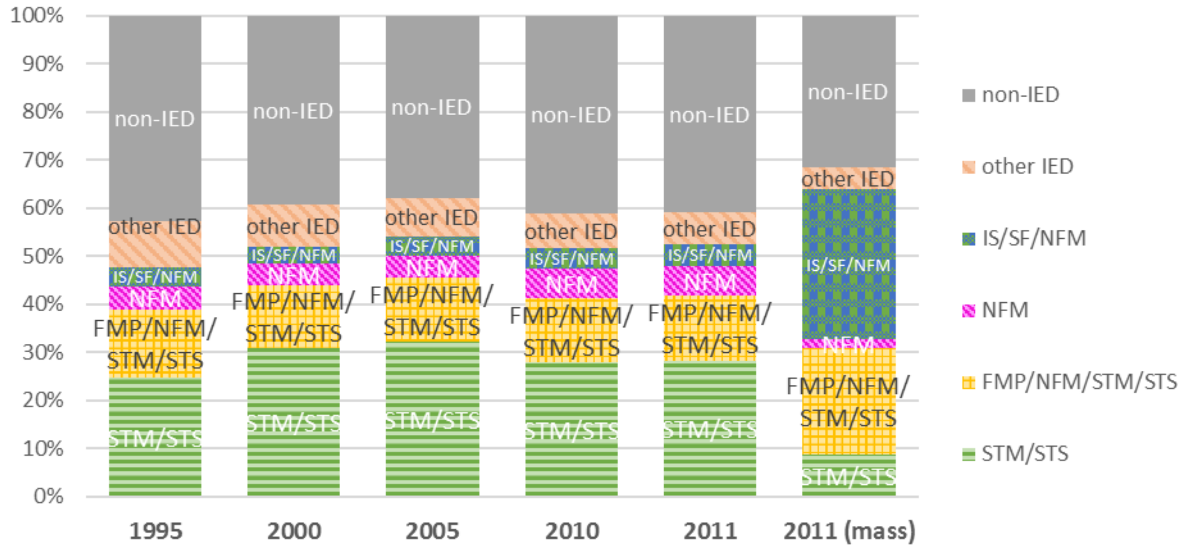
Source: own calculation based using EXIOBASE 3.
Note: the 2011-mass composition excludes the direct material use of construction works.

[22] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of metal products

Figure 20 presents the direct material use of **metal products**. The use of metal products is dispersed across both the IED and non-IED sectors. In 2011, 28% of the value of all purchases of metal products in the EU-28 were attributed to the STM/STS sector, but only 9% of the weight of all purchased metal products in the EU-28 were bought by the STM/STS sector. The opposite is true for the grouping comprising FMP/NFM/STM/STS sectors[23], which has a monetary share in direct use of metal products of 11%, compared to a physical share of 22%. In mass-based units, the IED-sectors cover around 70% of the total use of metal products. The overlapping NACE-sector linked to the IS/SF/NFM-sectors has a low monetary share of <5%. However, the physical weight-based share is much higher, at 31%. The monetary bars show a stable trend in the non-IED sectors' share between 1995-2011.

Figure 20 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of metal products by the main IED-sectors, other IED-sectors and non-IED-sectors[24] in the EU-28. Note that one IED-sector can be in multiple sector groups.



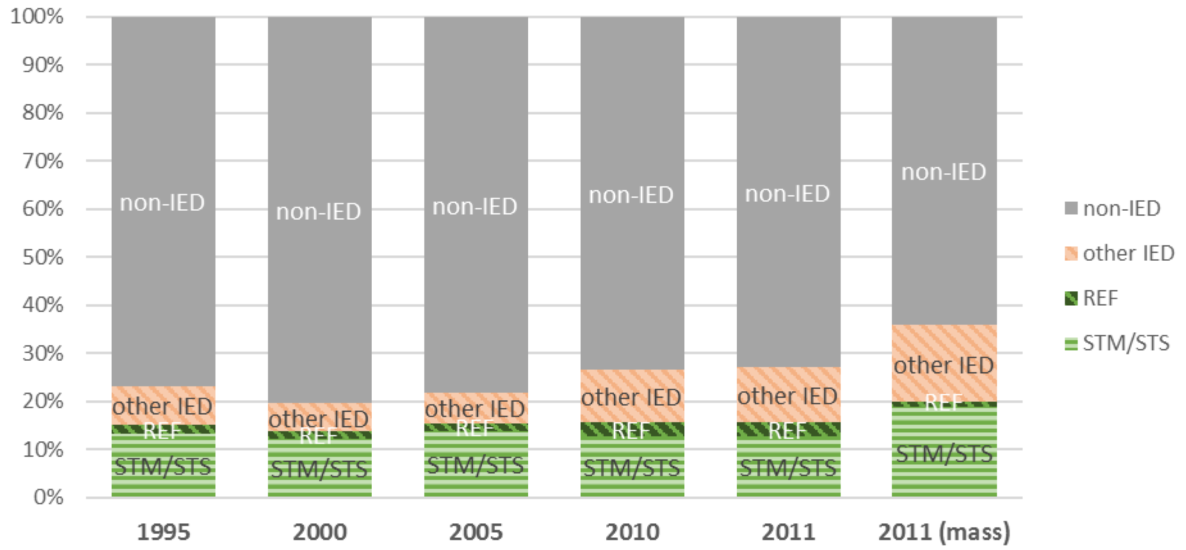
Source: own calculation based using EXIOBASE 3.
Note: the 2011-mass composition excludes the direct material use of motor vehicles, trailers and other transport equipment.

[23] This grouping is due to the imprecise match between the NACE and IED sectors
[24] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Use of electronics

Figure 21 presents the direct material use of **electronics** as an input for all industrial activities that are categorised under the primary and secondary economic sectors, IED as well as non-IED. These electronics can be either used in production processes and other industrial operations, assembled, built into finished and semi-finished products, or wasted, in proportions that will differ among different activities. The non-IED sectors' share in the value of electronic products is around 75%, with the physical share of around 65%. This is driven by the electronics sector (producing electronic equipment for industries and consumer electronics products) forming part of the non-IED sectors. Across the IED sectors the most significant consumers of electronic products are STS/STM and REF sectors.

Figure 21 The monetary value (1995-2011) and physical quantity (2011) of direct material uses of electronics by the main IED-sectors, other IED-sectors and non-IED-sectors[25] in the EU-28. Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



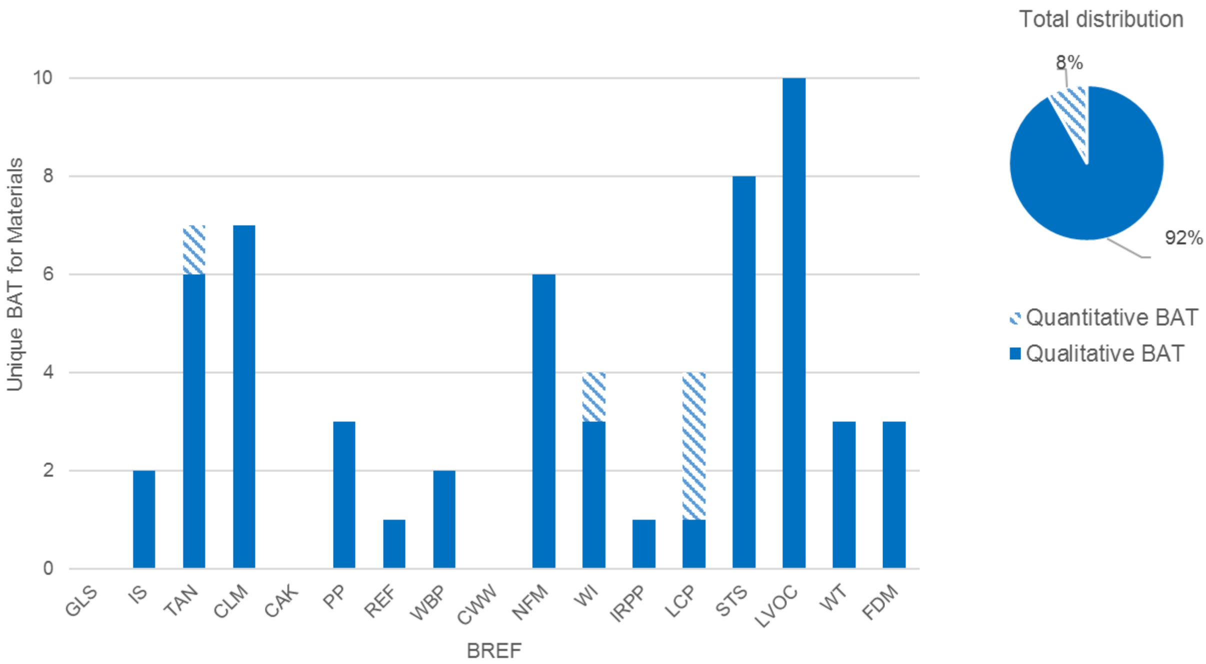
3.1.2.2 BATs related to materials use in BATC

Overview

BATs related to material use are less frequent (16% of all BATs) compared to other circular economy topics covered in this study. The review has identified 61 BATs related to materials use across the BATCs. Distribution of these BATs across sectors is presented in Figure 22. The sectors with the highest number of materials use-related BATs are the LVOC sector (10), followed by the STS-sector (8), the CLM-sector (7), the TAN-sector (7) and the NFM-sector (6). For three IED sectors, there are no BAT relating to materials use: GLS, CAK and CWW. All other sectors have BATCs that contain at least one BAT relating to materials use (Figure 22).

[25] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Figure 22 Number of materials use related BATs in IED BREFs



Qualitative and quantitative BATs

As shown in Figure 22 across all BATs related to materials use, 92% is narrative, i.e. no associated quantitative performance levels are set. These qualitative BATs are usually referring to one of the following types of measures, in very general terms:

- increase resource efficiency through recovery of residues;
- minimise the materials use;
- optimise material flows;
- use waste as a resource; and
- monitor process parameters.

Across all BATC there are five quantitative BATs related to materials use (8% of all materials use-related BATs). It is important to highlight that fuels, or energy carriers in general, indeed are considered as a material category[26]. Typical energy carrier materials such as fossil fuels can be found under energy resources, although they also have uses in material applications, e.g. as feedstock for the chemical industry (plastics). Also biomass is commonly used in both material (e.g. as paper and construction wood) and energy applications, and is thus categorised accordingly.

- Three of these quantitative BATs are for the LCP sector and relate to net fuel utilisation. The BATs are targeting increased energy efficiency through design improvements, with BAT-AELs set for plant output efficiencies. While the BAT-AELs are not set directly for the quantity of fuel used, these BATs will contribute to minimisation of **energy products** use in the sector.
- The quantitative BAT for the TAN sector (for processing bovine hides from raw to wet blue or wet white) focusses on the use of short floats in order to reduce the energy consumption for wet processes.
- The quantitative BAT for the WI sector applies to the blending and mixing of waste (which are considered a material input to the waste incineration process). The BAT-AEPL is set on the TOC-content in slags and bottom ashes. This AEPL can be considered as material related, since it is about TOC content associated to a waste input. This kind of BAT will clearly not have

[26] Further information , definitions and categorizations can be found under the JRC Raw Materials Information System (RMIS)

any effect on the quantity of used materials (in this case waste materials), but might have an effect on the quality of waste, by targeting lower TOC content.

Types of BATs on materials use

The BATs related to material use were grouped into the following four categories:

- **Material minimisation:** Lowering the amount of material needed to produce a unit of product or output flow.
- **Material elimination:** Completely phasing out the use of certain material in all applications, processes and products, for reasons that are not solely related to its toxic/hazardous characteristics (which belongs to the topic of hazardous chemical use)
- **Material substitution**: Replacing materials in certain applications, processes or products, with other ones that have a lower environmental impact, for reasons that are not solely related to its toxic/hazardous characteristics (which belongs to the topic of hazardous chemicals use).
- **Material "other":** This includes for example management, characterisation, separation and sorting of materials.

Figure 23 shows the categorisation of material use related BATs across all BATC. It indicates that across all sectors, material minimisation is the most common type of BAT, followed by materials substitution. Material elimination is less common. Just under one third of all BATs were categorised as "other" and concerned measures related to overall management and preparation of materials.

Figure 23 Spread of materials use BAT across different categories

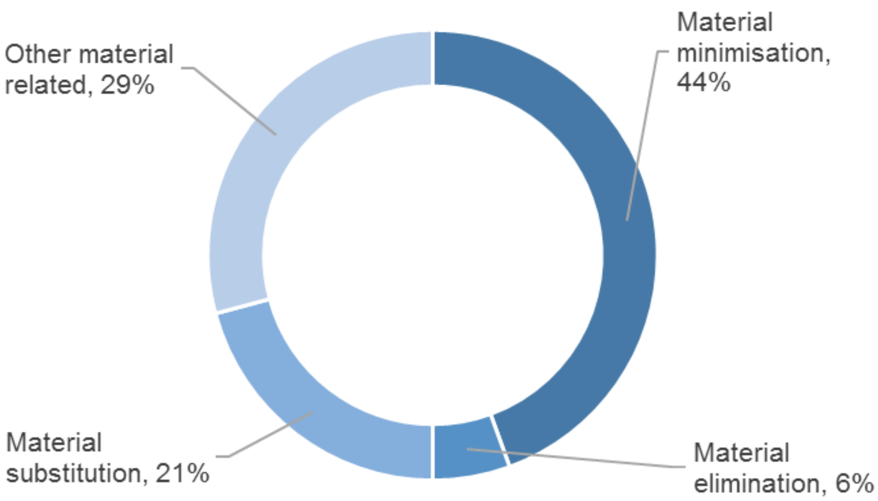
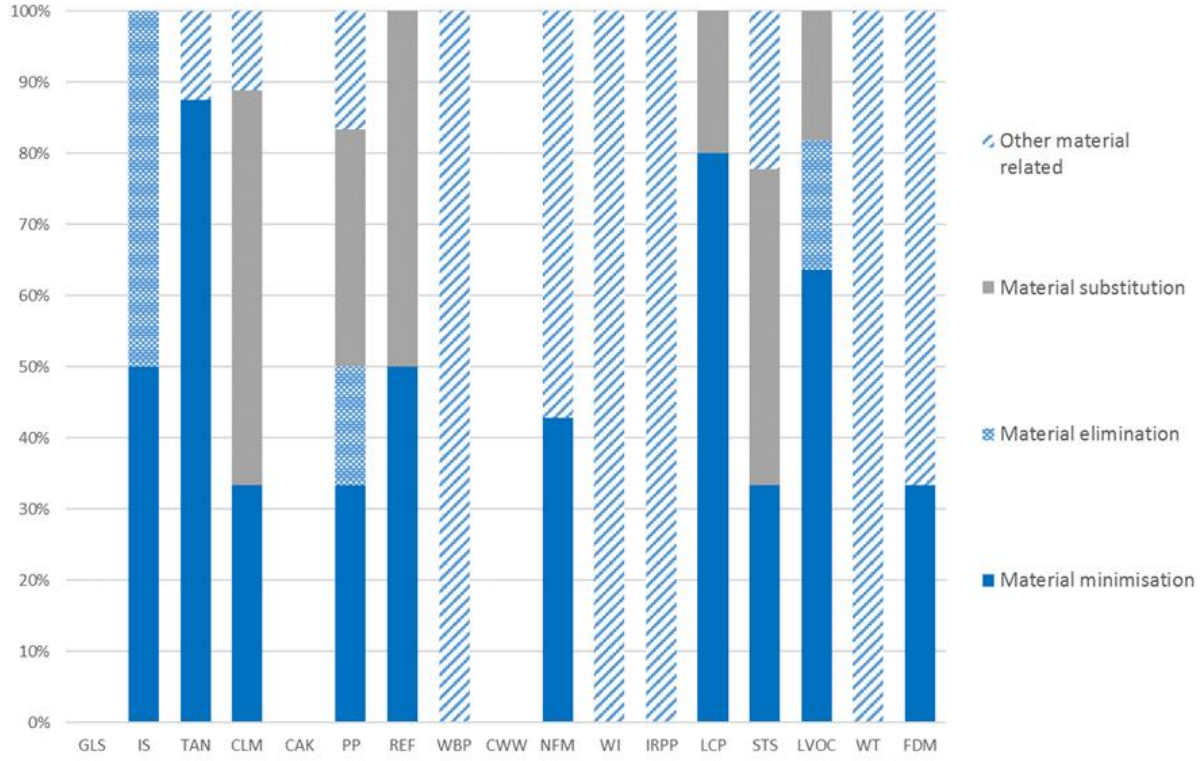


Figure 24 illustrates the different types of materials use-related BATs in each BATC and shows that:

- 14 BATC contain at least one BAT related to material minimisation. It is the most common type of BAT in the TAN, LCP and LVOC sectors;
- Material elimination BATs feature only in three sectors: IS, PP and LVOC;
- 6 BATC contain BAT on material substitution and
- 10 BATC contain at least one BAT categorised as other (i.e. related to management or preparation of materials). All BATs in WBP, WI, IRPP and WT sectors belong to this category, and it is also a dominant type of measure for NFM and FDM.

Figure 24 Types of materials use BAT in IED BREFs.



Further detailed information on BATs for each sector is presented in Appendix 2.

3.1.2.3 Contribution of the IED to more efficient use of materials

Based on the analysis of direct materials use by the IED sectors using the EXIOBASE data, the IED sectors are the major users (more than 50% by value) of food, textile, paper and wood, energy, plastics and chemicals and metal products compared to other industries. They use relatively small amounts of electronics and mineral products (less than 30% by value). Pharmaceuticals and chemicals production are considered priority sectors due to the use of significant quantities of CRMs.

Across the IED sectors, the intensity of use of specific product groups closely relates to the nature of their activity. Industrial activities purchase materials and products for many reasons: for further processing or refining them; as an input that will be consumed in the production process; to convert them in semi-finished products to be further processed or assembled in other industrial facilities, or; to make finished products that can be offered to households and services. Part of the purchased materials will be converted into waste and emissions. Among IED activities, the FDM sector dominates use of food products; POL and STS/STM sectors are relevant purchasers of plastics and chemicals; PP, WBP and STS sectors use important quantities of paper and wood products.

Across all product groups, STM/STS sectors use the largest variety of products in a significant amount (more than 10 % of EU industrial consumption for each group): plastics and chemicals, metal products and electronics.

EU circular economy strategies target a reduction of materials consumption, in order to ensure the secure and sustainable supply of raw materials. Currently, the circular use of raw materials in the EU economy is, however still below 10%[27]. This percentage is expected to increase by improving the supply of secondary raw materials, for example by increased recycling rates, or by extending the lifetime of products – for example through repair and re-use.

[27] https://publications.europa.eu/en/publication-detail/-/publication/117c8d9b-e3d3-11e8-b690-01aa75ed71a1

The latter strategy will inevitably result in a reduced need for production and thus for a decrease of mining and product manufacturing activities. It will however boost the industrial activities related to repair, reuse and remanufacturing, that currently do not contribute significantly to the added value of the overall EU economic activity.

The first strategy, of increased supply of secondary raw materials, intends to simultaneously increase the corresponding use of recycled materials by industry, as a substitute for primary raw materials. Such a strategy, however, will not necessarily have a direct positive effect on industrial emissions and waste generation, since recycled materials might be less pure or of lower quality as compared to feedstock from primary sources. However this would bring environment benefits through the reduced supply of raw materials.

An alternative strategy for reducing material use by industry consists of improving the efficiency of conversion of raw material to product, the so-called material productivity. However, this is difficult to achieve in practice and is already incentivised by other economic factors.

The BATC address the materials use across the IED sectors to varying extent:

- **The FDM and IRPP sectors dominate the industrial use of food products**. In the FDM-sector two BATs on environmental management systems and monitoring specify to monitor raw material usage. Another BAT focuses on increased resource efficiency. As the input (and output) of food products is at the core of both the FDM and IRPP sectors, probably all BAT will have a positive impact on the foodstuff consumption of these sectors. Still we find that none of these BATs set specific guidelines or targets or specifically focus on the use of food products as a material input for industrial activities. In the IRPP, only one BAT is addressing material use. This qualitative BAT concerns monitoring of the process parameters of feed consumption and the number of animals. While this BAT addresses consumption of food products by this sector, no quantitative targets are set and due to the nature of the measure, setting such targets would be very difficult.
- **The use of textile products is dominated by the TXT, TAN, STM and STS sectors**. BREFs for TXT and STM have not yet been reviewed under the IED – relevance of these sectors to the circular economy are discussed in further detail in section 4.1. 7 BATs related to material use apply to the TAN sector, but none of them addresses material usage, except one general qualitative BAT addressing the minimisation of environmental impacts of the production process. BAT24 relates to recovery of chromium (motivation for this BAT is to reduce content of chromium in sludge sent for disposal but it also promotes resource efficiency). BAT2, BAT7 and BAT23 aim to minimise the use of, or ensure the most efficient use of, **chemical products**. The materials use related BATs for the STS focus on the minimisation of raw material consumption and substitution of certain materials with others in order to reduce the environmental impacts of the processes.
- In physical units, the use of **paper and wood products** is dominated by the PP-sector. As the input (and output) of paper products is at the core of the PP sector, all BAT will have a positive impact on the paper consumption of this sector. However, the PP-sector has no BAT specifically addressing the use of paper or wood products. Only one BAT is mentioning the principles of good housekeeping for minimising the environmental impact and focusses on the use of chemicals and additives.
- The use of **energy products** in physical units is dominated by the sectors REF and LCP. The LCP sector has 3 quantitative BATs which promote more efficient fuel utilisation and are associated with BAT-AEPLs. The other materials use related BAT for the LCP or the REF sector do not address the use of energy products (e.g. recovery of used solvents).
- 50% of the weight-based use of **plastics and chemicals** is used by the sectors POL and LVIC-AAF. BREFs for both of these sectors have not been reviewed yet under the IED.
- 65% of the weight-based use of **metal products** is used by the sectors FMP, IS, SF, NFM, STM and STS. However, BREFs for the FMP, SF and STM sectors have not yet been reviewed under the IED. The materials use by IS, NFM and STS sectors is addressed by 2, 6 and 8 BATs, respectively. These BATs refer to metal consumption and production in general terms, for example by:
    - applying techniques that optimise the management and control of internal material flows in order to improve the process efficiency and optimisation of the metal yield,

    - increasing the raw or secondary materials' yield via the separation of non-metallic constituent and metals via different techniques,
    - minimising the process raw material consumption.
- IED sectors are not major consumers of **mineral and electronics products**. CLM is the largest consumer of mineral products across the IED sectors. Respectively it contains two BATs directly targeting materials use: BAT35 aimed at minimisation of limestone consumption and BAT54 which refers to "saving" raw materials.
- **Production of fertilisers and chemicals have been identified as large consumers of CRMs**. Specific examples included:
    - Production of fertilisers - this activity is covered by the LVIC-AAF BREF which has not yet been reviewed under the IED
    - Production of detergents – manufacturing of inorganic phosphates used in detergents is within the scope of the LVIC-S BREF which has not yet been reviewed under the IED.
    - Production of pharmaceuticals – this activity was covered within the scope of the OFC BREF but this BREF will not be reviewed under the IED.

Relevance of the circular economy topics in the above sectors is discussed further in section 4.

3.1.3 Waste generation

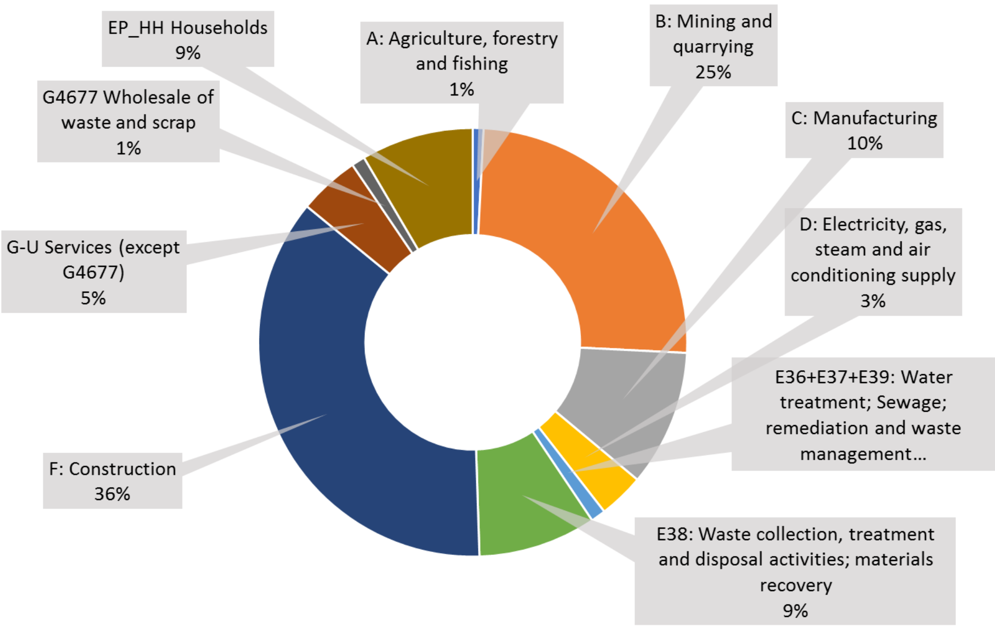
3.1.3.1 Contribution of IED sectors to the overall EU waste generation

Waste generation indicators in general do not refer to the amounts of waste in absolute terms, but relative to GDP and to materials consumption. If this analogy is extended to industrial sectors, waste minimisation would target waste quantities per unit of sectoral added value, and per unit of materials consumed by the sector. The primary and secondary sectors in the EU-28 (NACE Division A – F) generate a gross value added of 2,818 billion EUR (2011-value). This represents **27.7%** of the total gross value-added creation by all NACE-activities (NACE Division A-U; total value = 10,145 billion euro). The same primary and secondary sectors (NACE Division A – F) in the EU-28 generate **89.8%** of the total waste by all NACE-activities (NACE Division A – U), including the tertiary sectors of services and wholesale of waste and scrap. When considering all waste generated in the EU-28, waste from households only accounts for a share of 8.5% on a mass basis, as is shown in Figure 25. This share is of the same order of magnitude as the share of manufacturing industry waste. This is not unexpected, since at the end of their lifecycles, all manufactured consumer products, except for food, will turn into household waste. It should be noticed that most circular economy policies on waste, however, primarily focus on the reduction of consumer wastes and End-of-Life products from households, such as (plastic) packaging, food waste and Waste Electrical and Electronic Equipment (WEEE). This means that most of the GDP (72%) is generated in non-industrial activities. In contrast, the same primary and secondary sectors in the EU-28 account for almost 90% of the total waste generation from all economic activities[28]. In other words, EU industrial sectors (IED and non-IED) have a higher impact on total waste generation than on EU GDP.

The quantities of specific categories of waste generated by IED industry per EUR million of added value, are extremely diverse. For example, more than 85 tonnes of manure are generated per EUR 1 million of added value, while the sectors that generate textile waste produce only 40 *kilograms* of waste for the same added value. This would favour targeting manure rather than textile wastes. This makes an indicator on waste generation relative to the added value generated by a sector of limited applicability, since it would introduce a bias towards reductions of large waste streams in sectors that generate limited added value.

[28] Based on analysis Exiobase 3

Figure 25 Waste generation by economic activities and households, mass-based shares, EU-28, 2016.



Source: Eurostat[29].

Figure 26 shows the total waste generation in the EU-28, of all economic activities and households, per category of waste, on a mass basis. Most wastes concern mineral and solidified wastes, a category that includes heavy wastes, such as soils, dredging spoils, mineral wastes from waste treatment and stabilised wastes, mineral waste from construction and demolition, and combustion wastes (ashes).

Figure 26 Waste generation by waste category, mass-based shares, EU-28, 2016.

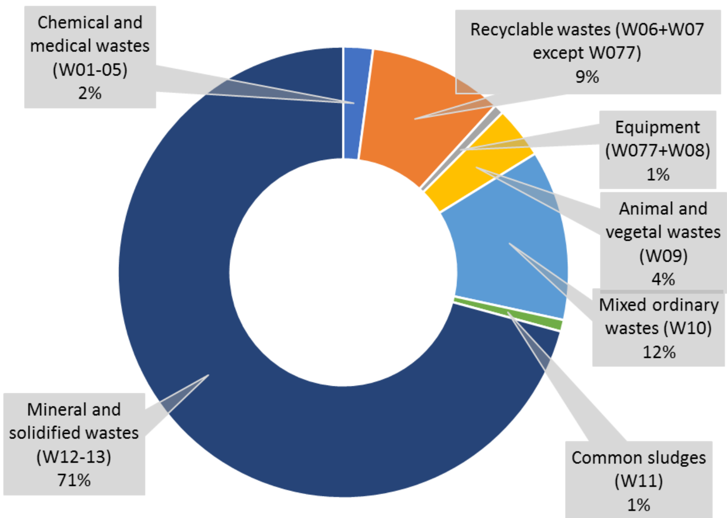
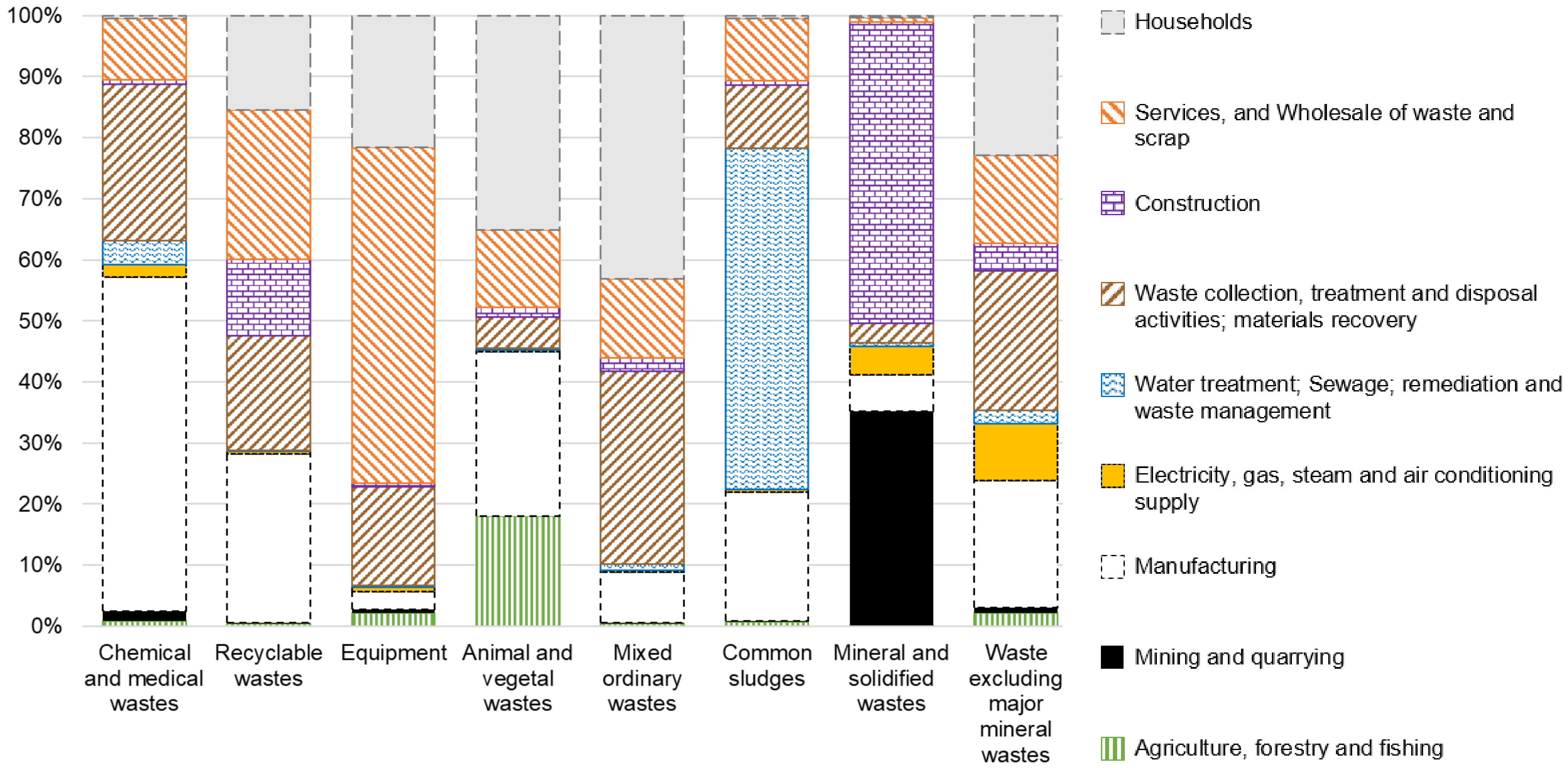


Figure 27 represents, for each waste category, the economic sectors that contribute most to its generation (Including households). This figure does not take into account whether waste can be recycled.

[29] https://ec.europa.eu/eurostat/statistics-explained/images/6/64/Waste_generation_by_economic_activities_and_households,_EU-28,_2016_(%25).png

Figure 27 Generation of waste by waste category and NACE Rev. 2 activity.



Source: Eurostat.

In the rest of this section, the waste generation by industrial sectors covered by the IED and its contribution to the overall EU waste generation is evaluated using data obtained from the EXIOBASE database. The waste is categorised into the following waste fractions: food, manure, textile, wood, paper, plastics, glass, ashes, metals, construction materials, oils and hazardous materials, sewage and mining and quarrying waste.

Waste in EXIOBASE refers to the materials, processed or not, that are utilised in activities but that are not incorporated in outputs or discharged as emissions. Therefore, waste in this context includes both waste residuals and waste products. Waste is defined as 'material to be treated' that includes all the materials that need further processing in order to be turned into new products, or into emissions, or into stock addition on landfills. This treatment thus includes the conversion of scrap into new, secondary materials that can substitute for primary raw materials; as well as waste incineration, landfill, waste water treatment, composting, or just storage of uncontrolled discharge of waste in the environment involving emissions from degradation (Stadler et al., 2018).

The following subsections present the waste generation per waste category and show the relative contribution of IED sectors to the total waste generation by primary and secondary sectors in the EU-28. It is important to observe that industrial waste streams, even in the same waste category, are extremely heterogeneous. This heterogeneity makes it challenging to associate a single waste stream with a particular waste treatment or with an application of the materials derived from this waste stream. For example, coal fly ash from electricity production is a homogeneous waste stream with typical applications. One of the primary uses for coal fly ash is in the cement industry because fly ash easily combines with calcium hydroxide to form compounds needed in the cement production process. However, there are thousands of different ash types from incineration activities, with varying composition and possible applications.

Food, manure and textile waste

Figure 28 presents generation of food, manure and textile wastes and demonstrates that industrial food waste and textile wastes are almost entirely generated by single IED-sectors:

- 96% of industrial food waste is attributed to the FDM sector;
- 43% of the industrial manure waste is from the IRPP sector; and
- 76% of the industrial textile waste is generated by the TXT sector and 11% by the TAN sector.

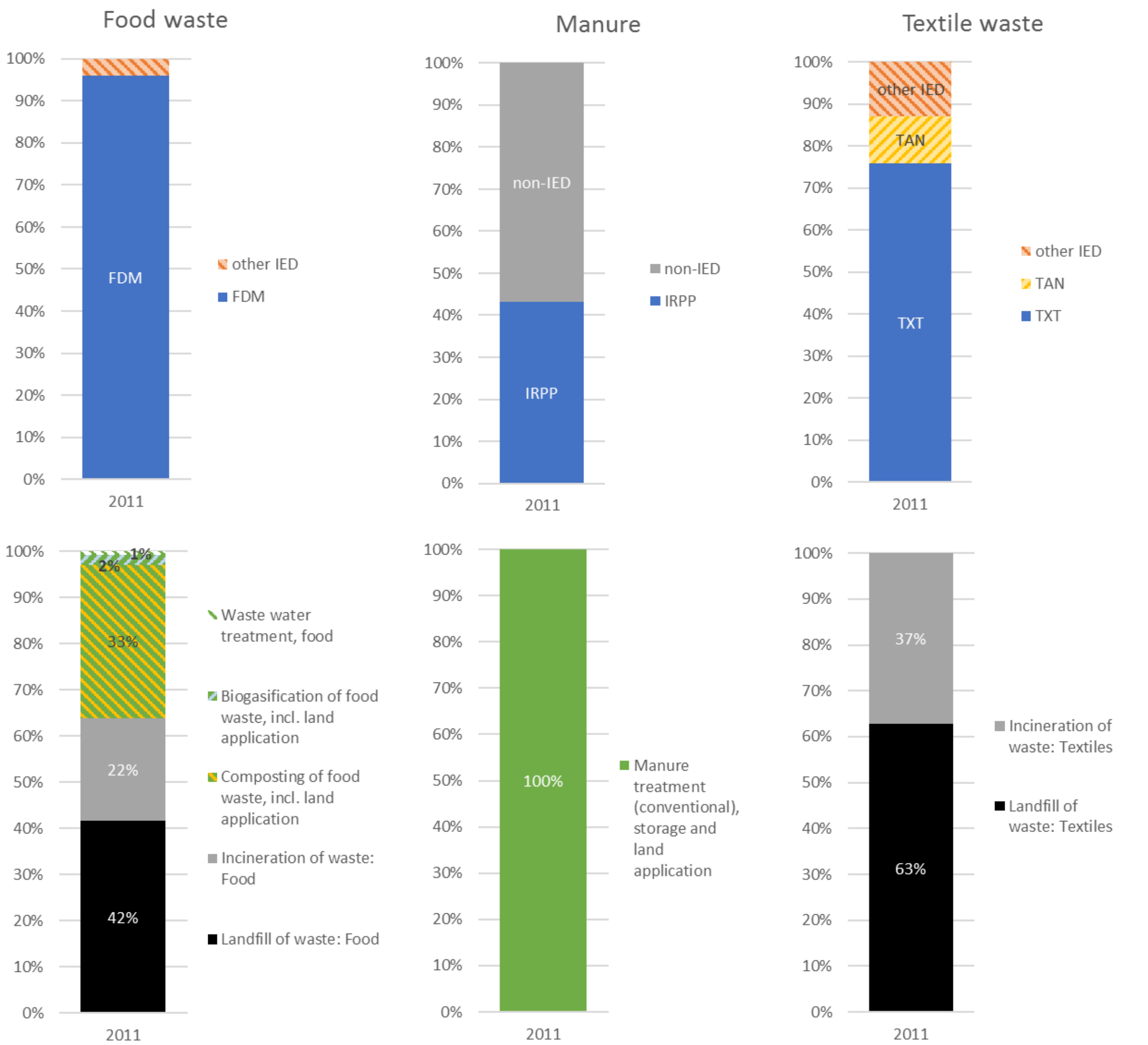
All data in this section refers to **food waste** resulting from industrial food production and (consecutive) industrial activities of food processing. Some milk, vegetables or other inputs will be wasted during production and processing. Further downstream in the food value chain, stored, packaged, cooled and otherwise treated finished food products are distributed and purchased by wholesalers and retailers, and finally bought by consumers. All these consecutive steps, including household consumption, generate food waste. There are many causes for food losses and wastage at each stage of the supply chain. Very different figures are available on the contribution of households in the total food waste generation, ranging from 71%[30] to 42%[31].

Manure is generated by industrial activities in the food supply chain that consider animal rearing. This manure has different useful applications, such as biogas production for the provision of energy, and the recovery of carbon and soil nutrients on agricultural land. Eurostat has however observed a clear lack of data on manure management at European level derived in a data coverage that was found to be an insufficient basis for solid analyses.[32]

A detailed analysis of the composition of different sector-specific waste streams, and the quantification of the shares of these streams that are recycled and/or used within industry as well as in other industrial sectors, falls beyond the scope of this study. A brief analysis of the destination of different waste streams is however included in Figure 28 below. It should however be highlighted that figures on waste treatments do refer to the total amount of a particular waste category, generated by all industrial activities. It is not possible to link a waste application with the specific industrial source of that waste. It cannot thus be derived from the figure how much of the composted food waste comes from FDM, and what share was generated in other IED or non-IED sectors.

[30] http://www.wrap.org.uk/sites/files/wrap/Estimates_%20in_the_UK_Jan17.pdf
[31] https://www.eea.europa.eu/signals/signals-2014/articles/from-production-to-waste-food-system
[32] https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Agri-environmental_indicator_-_manure_application

Figure 28 Industrial waste generation of food waste, manure and textile waste in 2011 by the main IED-sectors, other IED-sectors and non-IED-sectors[33] in the EU-28 (weight-based composition). Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



Wood, paper and plastic wastes

Figure 29 presents generation of wood, paper and plastic wastes and demonstrates that:

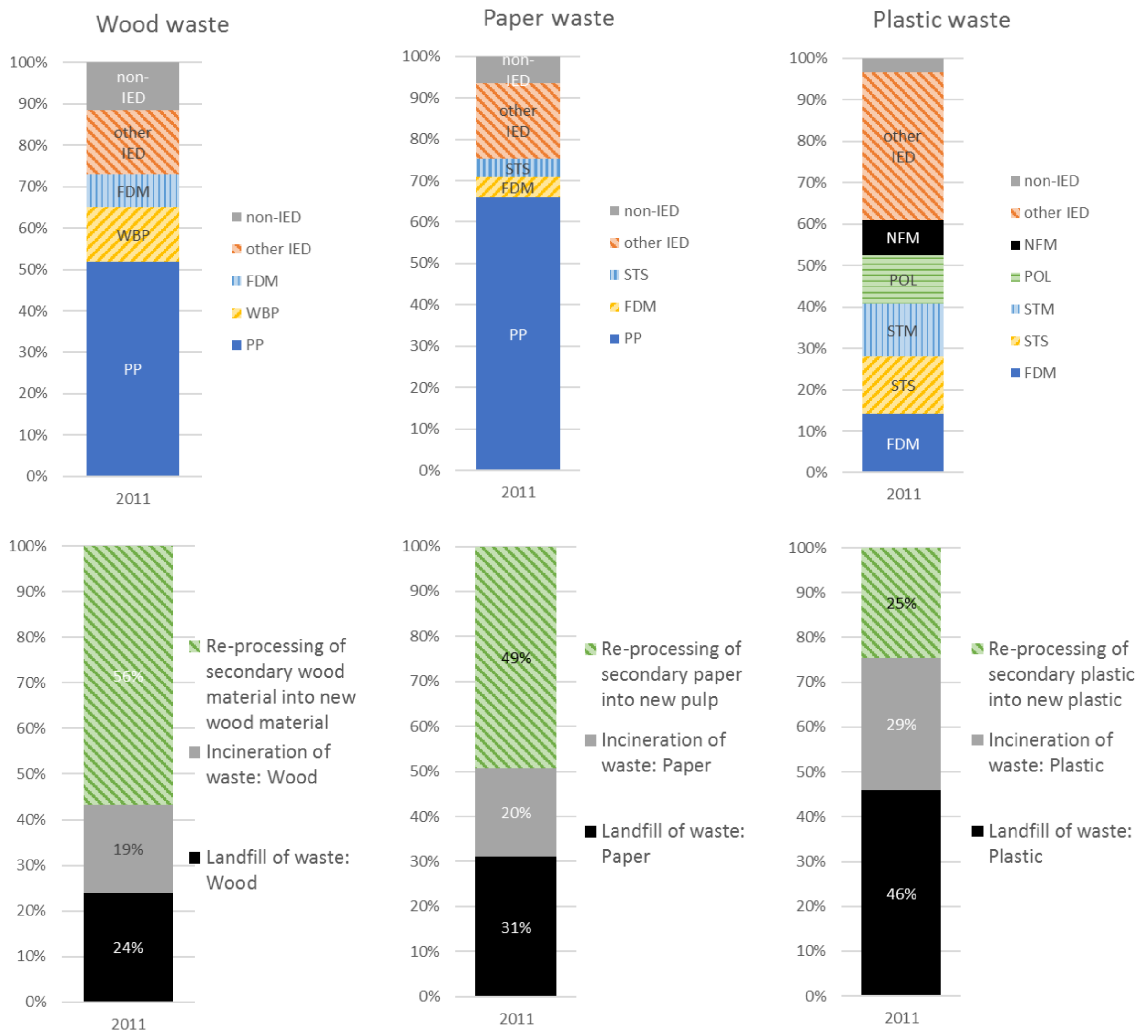
- 52% of the wood waste is attributed to the PP sector, 13% to the WBP sector and 8% to the FDM sector, while 11% is wood waste from non-IED sectors;
- 66% of the paper waste is attributed to the PP sector, 6% to the FDM sector and 5% to the STS sector. A small share, 5%, is paper waste from non-IED sectors; and
- Generation of plastic waste is dispersed across the IED-sectors, with 16% generated by the FDM sector, 14% by the STS sector, 13% by the STM sector, 12% by the POL sector and 9% by the NFM sector. Over a third of all plastic waste is generated by other IED-sectors.

A brief analysis of the destination of these waste streams is provided in Figure 29 below. It should again be highlighted that figures on waste treatments refer to the total amount of a particular waste category generated by all industrial activities. It cannot thus be derived from the available data how much plastic waste from STM is incinerated, as compared to the STM share in the landfilled plastic waste, or in relation to the STS or other sectors' plastic waste that is treated by incineration. Regarding the re-

[33] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

processing of paper waste into new pulp it is reasonable to assume that it is only performed by those industries that classify as PP. In this sector, the pulp from secondary sources is a relevant input material, that is included as such in the section on materials use.

Figure 29 Industrial waste generation of wood waste, paper waste and plastic waste in 2011 by the main IED-sectors, other IED-sectors and non-IED-sectors[34] in the EU-28 (weight-based composition). Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



Glass, ashes and metal waste

Figure 30 presents the generation of glass, ashes and metal waste and demonstrates that IED sectors generate considerable share of ashes and metal wastes:

- 32% of the glass waste originates from the FDM sector and 14% from the IRPP sector, while 33% is from non-IED sectors;
- 46% of the ashes waste is from the WI sector, 35% is from the LCP sector
- 76% of the metal waste is from the IS-sector, 8% from the NFM-sector, 7% from the STM-sector and 7% from the STS-sector.

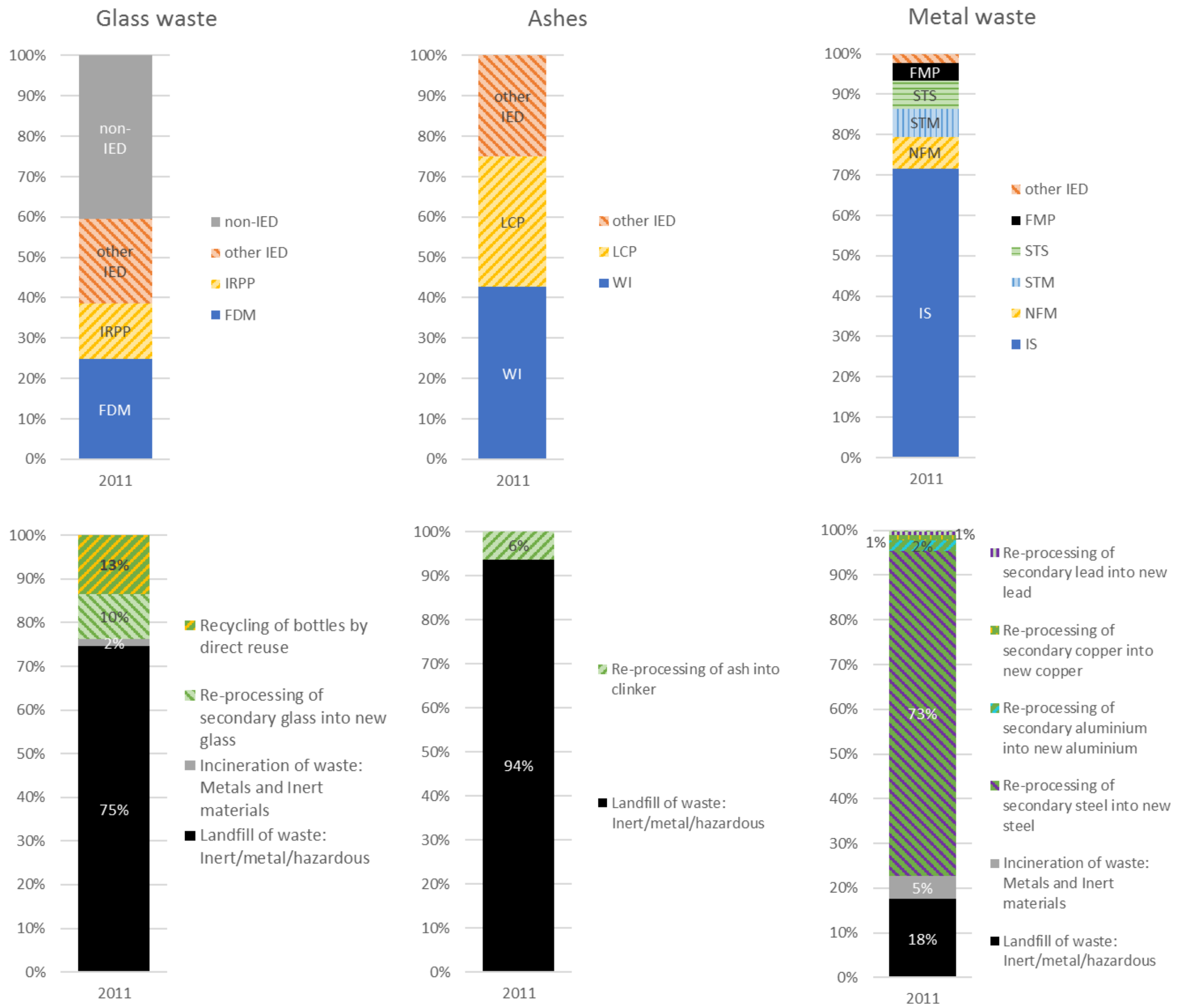
Figure 30 includes a brief analysis of the destination of these waste streams. Also here, it is highlighted that the waste treatment figures are not source-specific. Some waste streams, such as **metals containing wastes**, indeed constitute a valuable source of secondary materials. This involves a large

[34] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

series of applications following the re-processing of metal scrap. However, it should be observed that reducing waste generation is one of the most relevant circular economy objectives, independently of whether the generated waste is completely or partly recycled or recovered. A recent study concluded that the highest valorisation potential for steel slag from the Iron and Steel sector is represented by the use of slag in road construction. 48% of the steel slags are used in this application, whereas 6% was used as secondary raw material in manufacturing of concrete. Additionally, distinctive types of steel slags arise at different stages of the steel making process, such as Electric Arc Furnace and Ladle Furnace slags, and are suited as secondary raw materials in different applications.[35]

A similar situation as with metal waste is observed for **ashes**. One of the primary uses for LCP coal fly ash is in the cement industry. However, also in this case, different kinds of ashes are picked up at different points in the incineration process and are disposed of and used in different ways. Moreover, ashes from industrial incineration activities often have to be treated and disposed of as hazardous waste due to the toxic characteristics of a number of chemicals and compounds found in them.

Figure 30 Industrial waste generation of glass waste, ashes and metal waste in 2011 by the main IED-sectors, other IED-sectors and non-IED-sectors[36] in the EU-28 (weight-based composition). Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.

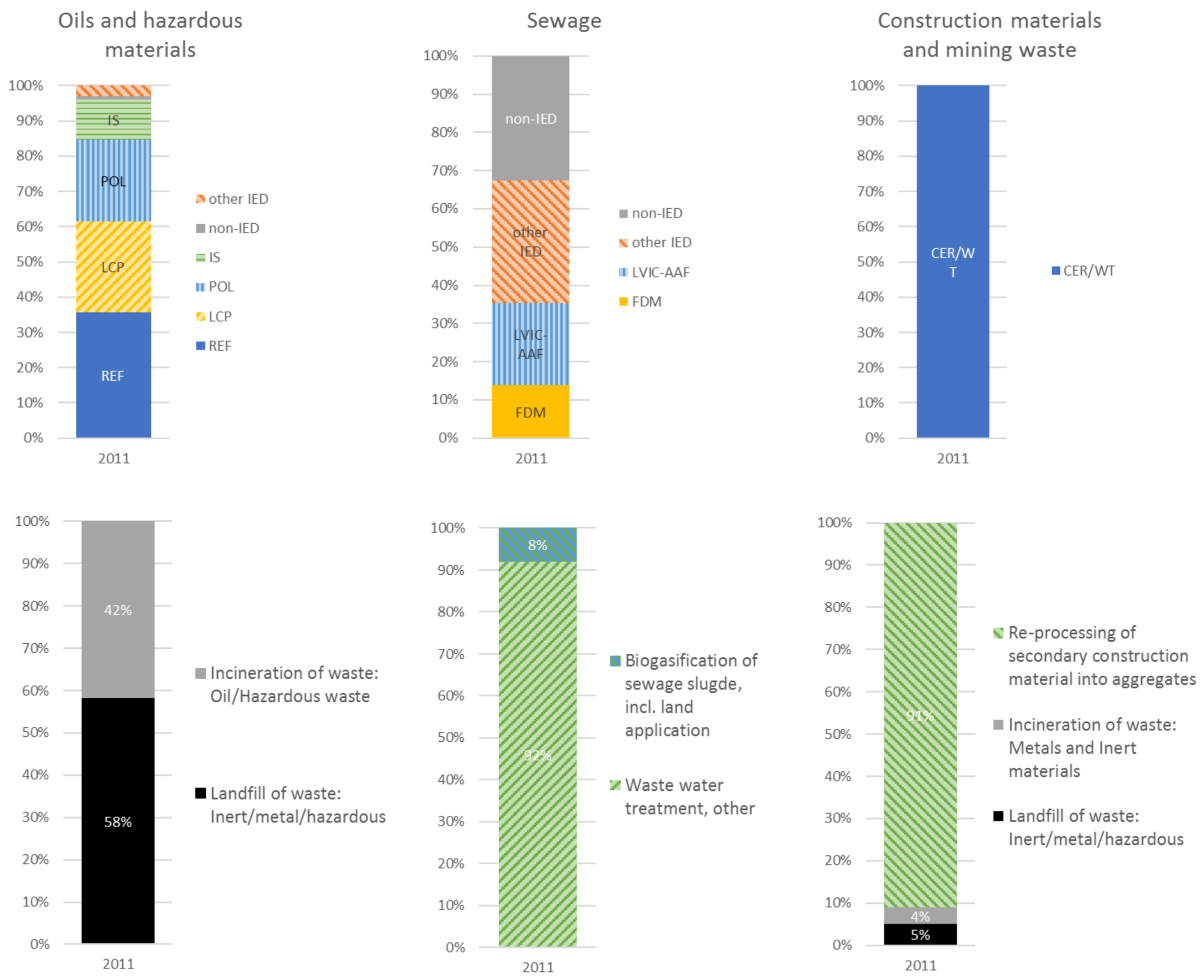


[35] http://fissacproject.eu/wp-content/uploads/2018/06/FISSAC-D1.3-Inventory-of-raw-materials-waste-and-energy-flows-in-industrial-sectors-Summary.pdf
[36] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

Oils and hazardous materials waste, sewage, construction materials and mining waste

Figure 31 presents generation of oils and hazardous material waste, sewage, construction materials and mining waste and demonstrates that generation of these wastes is almost fully covered by the IED sectors.

Figure 31 Industrial waste generation of oils and hazardous materials waste, sewage and construction materials and mining waste in 2011 by the main IED-sectors, other IED-sectors and non-IED-sectors[37] in the EU-28 (weight-based composition). Note that one IED-sector can be in multiple sector groups. Source: own calculation based using EXIOBASE 3.



From the figure, the following observations can be made:

- 38% of the oils and hazardous materials waste is generated by the REF sector, with over 20% by the LCP and POL sectors respectively;
- 19% of the total production of sewage waste from industrial sectors is generated by the LVIC-AAF sector and 14% by the FDM sector;
- Construction materials and mining and quarrying waste is entirely in the scope of the CER and WT sectors, because together they cover all '*re-processing of secondary construction material into aggregates*'-activities. Note that the mining waste from mining activities is excluded from this waste fraction.

Waste from oils and hazardous materials, sewage and construction materials and mining waste are completely covered by the IED-sectors and a high share is linked to a limited number of sectors.

[37] Other primary (NACE section A-B) and secondary sectors (NACE section C-F).

3.1.3.2 BATs related to waste generation in BATC

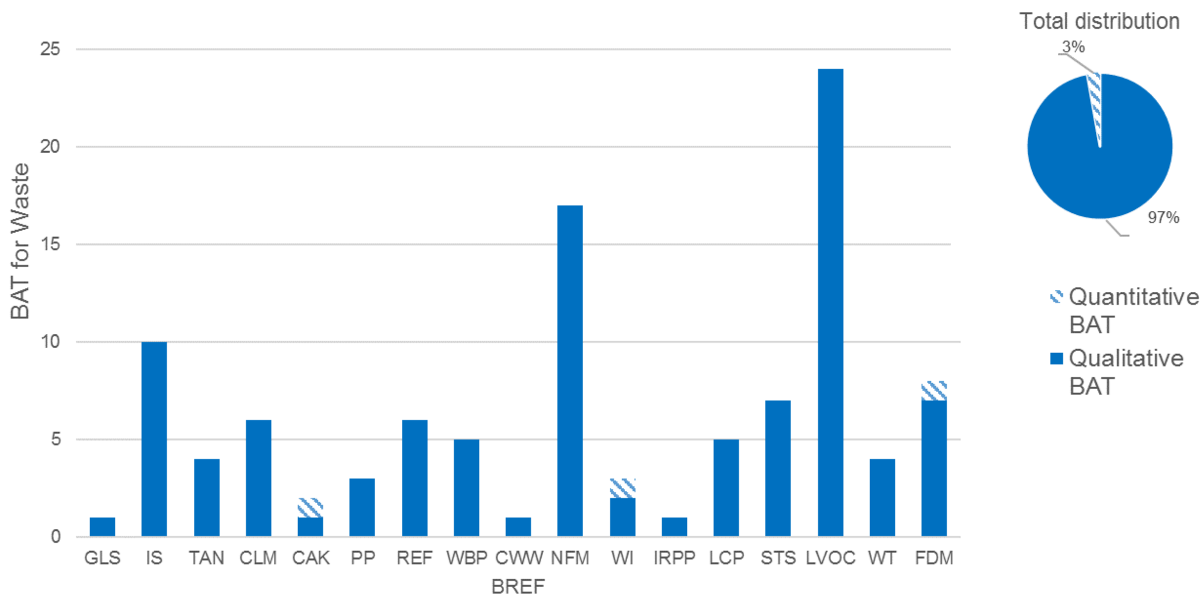
Overview

Waste generation in industrial processes can potentially be reduced in relative terms, i.e. relative to the mass and/or value of the industrial output products, by improving the material productivity of the processes. The production of waste in industrial processes is often unavoidable. The figures on materials use in section 3.1.2 already include, for each of the analysed sectors, all materials that are used by that sector, regardless of the source. This means that steel that is used as an input for an industry could have been sourced from scrap treatment facilities or from the processing of iron ores, in the EU or abroad. It is however a challenging task to identify and distinguish these original sources further up in sector-specific production and value chains. It is thus in practice difficult to determine the proportion of recycled content in finished products. Circular economy initiatives primarily focus on waste prevention measures to lower waste volumes to be treated or disposed, independently of the particular waste treatment that is applied **after** the waste has been generated.

Although circular economy strategies always aim for an increased supply of secondary materials, it would be difficult to impose minimum recycled content levels through BREFs. Moreover, this is the case when an increased substitution of primary resources by secondary materials, or by reused or remanufactured parts or products, will not necessarily reflect a decrease of the sector's emissions and waste generation.

BATs related to waste generation are second most frequent (29% of all BATs) across the topics covered in this study. The review has identified 107 BATs related to waste generation across the BATCs. Distribution of these BATs across sectors is presented in Figure 32. All BATCs contain at least one BAT relating to waste generation. The sectors with the highest number of BATs are the LVOC sector (24), followed by the NFM sector (17) and the IS sector (10). Only one waste related BAT was identified in IRPP, CWW and GLS sectors.

Figure 32 Number of waste generation related BATs in IED BREFs.



Qualitative and quantitative BATs

As shown in Figure 32 across all BATs related to waste generation, 97% are narrative, i.e. no associated quantitative performance levels are set. These qualitative BATs are usually referring to one of the following types of measures, in very general terms:

- On-site recycling;

- Recycling of residues;
- Techniques for waste minimisation;
- Controlled management of residues (e.g. waste streams management plans); and
- Ensure proper disposal of residues.

Across all BATC there are three quantitative BATs related to waste generation (3% of all waste generation related BATs):

- The quantitative BAT for the CAK-sector is to reduce the quantity of spent sulphuric acid sent for disposal. The BAT-AEPL is set for tonne of spent sulphuric acid sent for disposal per tonne of chlorine produced.
- The quantitative BAT for the WI sector requires use of advanced control system and/or optimisation of the incineration process in order to improve the overall environmental performance, to reduce the content of unburnt substances in slags and bottom ashes, and to reduce emissions to air from the incineration of waste. The BAT-AEPL is set for the TOC-content and loss on ignition of slags and bottom ashes.
- The quantitative BAT for the FDM sector which applies to the vegetable oil processing is to use techniques in order to reduce the hexane losses from oilseed processing and refining. The BAT-AEPL is set for kilograms of hexane loss per tonne of seeds/beans processed.

Types of BATs on waste generation

The BAT related to waste generation were grouped into the following five categories:

- **Waste minimisation**: Reducing the amount of material that is classified as 'waste' at the end of a process.
- **Waste management:** Concerning the overall approach to be taken to waste management, including limitations and obligations on waste destinations and the conversion of raw materials to waste.
- **Recycling:** Recovery of waste, converting it in secondary materials that can be used as inputs for the same or a different process, either on-site or external to the industrial installation. Only waste can be recycled, whereas production residues that are not waste, are considered as by-products[38].
- **Recovered material quality:** Improving the quality of recycled material[39].
- **Other:** other measures, mostly concerning waste post-treatment.

Figure 33 shows the categorisation of waste generation BATs across all the BATC. It indicates that across all sectors, waste minimisation and recycling are the most common type of BAT, followed by recovered material quality and waste management.

[38] EC (2007). Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on waste and by-products,

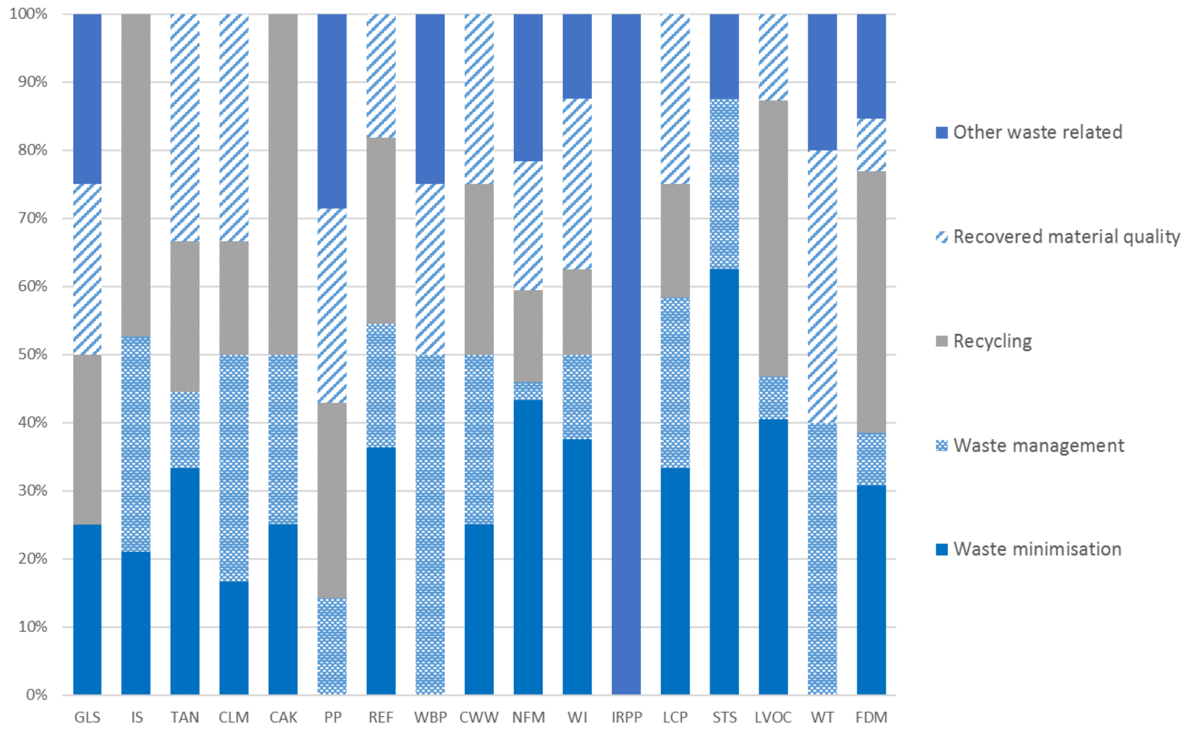
[39] Conventional recycling usually produces lower-grade material. Circular economy promotes closing material loops and maintaining quality of the raw materials in the loop. Thus any BAT that works to improve the quality of recycled material is directly contributing to circular economy objectives.

Figure 33 Proportion of waste generation BAT across BREFs.

Figure 34 illustrates the different types of waste generation related BAT in each BATC and shows that:

- 16 out of 17 BATC with waste generation related BAT contain at least one BAT on recycling. Only the IRPP-sector does not have a BAT on recycling. Recycling is the most common type of BAT in IS, CAK and FDM sectors;
- 15 out of the 17 BATC with waste generation related BAT contain at least one BAT on waste management. Only the IRPP and GLS sectors do not have a single BAT on waste management. This type of BAT is most common in the WBP sector;
- 14 out of the 17 BATC with waste generation related BAT contain at least one BAT related to waste minimisation. Only the IRPP, PP and WT sectors do not have a single BAT on waste minimisation. This type of BAT is most common in the sectors TAN, REF, NFM, WI, LCP, STS and LVOC;
- 13 out of the 17 BATC with waste generation related BAT contain at least one BAT on recovered material quality. This type of BAT is most common in the TAN-sector.

Figure 34 Types of waste generation related BAT in IED BREFs.



Further information on BATs for each sector is presented in Appendix 2.

3.1.3.3 Contribution of the IED to lower waste generation and better management of waste as a resource

Based on the analysis of waste generation by the IED sectors using the EXIOBASE data, the IED sectors are the major contributor to EU waste generation from industrial activities. Certain types of wastes are mainly generated by one or two IED sectors.

All BATC address the topic of waste generation and management, with a varying potential impact on specific waste types:

- The industrial generation of **food waste** is almost fully linked to the FDM-sector. The BATC for this sector include seven qualitative and one quantitative BAT. Most of the BATs concern waste minimisation. Generic BATs for the sector include BAT 1 on EMS and BAT 2 on inventories, which in the case of the FDM refer specifically to generation and use of waste. Process-specific BATs involve minimisation of waste generation and recovery techniques. Except for the production of vegetable oil, no BAT-AEPLs are set for this sector.
- 43% of the **industrial manure waste** is linked to the IRPP sector. BAT on waste generation for the IRPP-sector concerns monitoring the process parameters of manure generation. However, no specific quantitative targets are set.
- 87% of industrial **textile waste** is generated by the sectors TXT and TAN. The BREF for the TXT-sector is in the early stages of review. Four qualitative BATs are linked to the TAN-sector and aim to limit the quantities of wastes sent for disposal. Examples include the segregation of waste streams to allow for the recycling of certain waste streams, limiting the quantities of waste sent for disposal, waste recycling or other recovery techniques. None of the BATs sets quantitative targets nor do they specifically address textile waste.
- Half of the industrial **wood waste** generation is linked to the PP sector and 13% and 8% are linked to the WBP and FDM sectors respectively. The BATs for the PP sector aim to reduce the quantities of wastes sent for disposal, to prevent waste generation and to minimise the amount of solid waste to be disposed. Currently, there is a considerable surplus of waste wood on the North-West European market, so prices have fallen sharply, and in several countries,

such as Belgium and the Netherlands, even have turned negative[40]. Examples of BATs are fibre and filler recovery, separate collection of different waste fractions and pre-treatment of process residues before reuse or recycling. Also, the BATs on waste generation for the WBP-sector aim to prevent and reduce the quantity of waste being sent for disposal and to ensure safe management and reuse of bottom ash and slags from biomass firing. BAT for this sector concern introduction of a waste management plan, handling and storage of raw materials and waste and reuse internally collected wood residues. Both the PP and WBP sectors have many waste generation related BATs providing techniques, but none of them sets BAT-AEPLs.

- 66% of all industrial **paper waste** is generated by PP sector and 6% and 5% are linked to the FDM and STS sectors respectively. The PP sector is, at the same time, a major user of pulp from recycled paper as a material input for paper production. The nature of BATs for PP and FDM are described above with regard to wood waste. The STS-sector has several BATs addressing waste generation, but most of them focus on chemicals and hazardous waste. Only a general applicable BAT with the aim to prevent and reduce waste generation via monitoring waste quantities and to reduce the generation of waste from wood preservation with chemicals is relevant for paper waste.
- The **plastic waste** is dispersed across mainly IED-sectors, but most relevant are the sectors FDM, STS, STM, POL and NFM. The BREFs for STM and POL have not been reviewed under the IED. The BATC for FDM, STS and NFM do not specifically focus on plastic waste. All of them are general qualitative guidelines or focus on chemical or hazardous waste streams.
- 46% of the industrial generation of **glass waste** is linked to the sectors FDM and IRPP. BATs for these sectors include only general waste management BAT. The amounts of glass waste from agriculture, mining and manufacturing together account for only 13% of the total glass waste production of all economic sectors, with inclusion of households, which produce nearly half of the total volume, making the IRPP contribution (a small fraction of 46% of 13% of the total) is rather irrelevant in absolute term.
- Almost all **ashes waste** is generated by the WI and LCP sectors. The WI and LCP sectors are covered by a mix of BATs covering waste minimisation, waste management, recycling and recovered materials, with the goal to develop waste streams and residue management plans, with an aim to minimise the generation of residues, optimise the reuse, regeneration, recycling and recovery of residues and ensure the proper disposal of residues. Other BATs concern optimisation of the incineration process, increasing the resource efficiency and improvements in the recovery of useful materials from the incineration residues.
- The industrial **metal waste** is mostly generated by the IS sector (76%), the STM and STS-sectors (7% each). The BATs on waste generation for the IS-sector include integrated and operational techniques for waste minimisation and controlled management of residues which can't be avoided or recycled but all waste generation related BAT for the sector are qualitative. Metal waste is often valuable and commonly used as a source of secondary materials. For instance, Blast Furnace Slags can be used in different applications, depending on the slag origin and quality, e.g. (slow) air cooled lump slag (ABS) is used in road construction layers under the final paving, while rapid cooled granulated slag (GBS) is for about 90% is used in cement production. The BREFs for the STS and STM sectors have not yet been reviewed under the IED.
- More than a third of the total industrial **sewage waste** is generated by the sectors FDM and LFIC-AAF. The LFIC-AAF BREF have not yet been reviewed under the IED.

The construction, mining and quarrying sectors are out of scope of the IED Annex I activities. However, the wastes from these sectors are input streams for the production processes of the CER and WT sectors which are in the IED scope. The CER BREF has not yet been reviewed under the IED. The BATs for the WT sector concern minimisation of waste sent for disposal. However, none of the example techniques specifically addressed on construction materials waste or mining waste.

[40] van Bruggen, R., van der Zwaag, N. (2017). Knelpuntenanalyse houtrecycling, Ministerie van Infrastructuur en Milieu, The Netherlands.

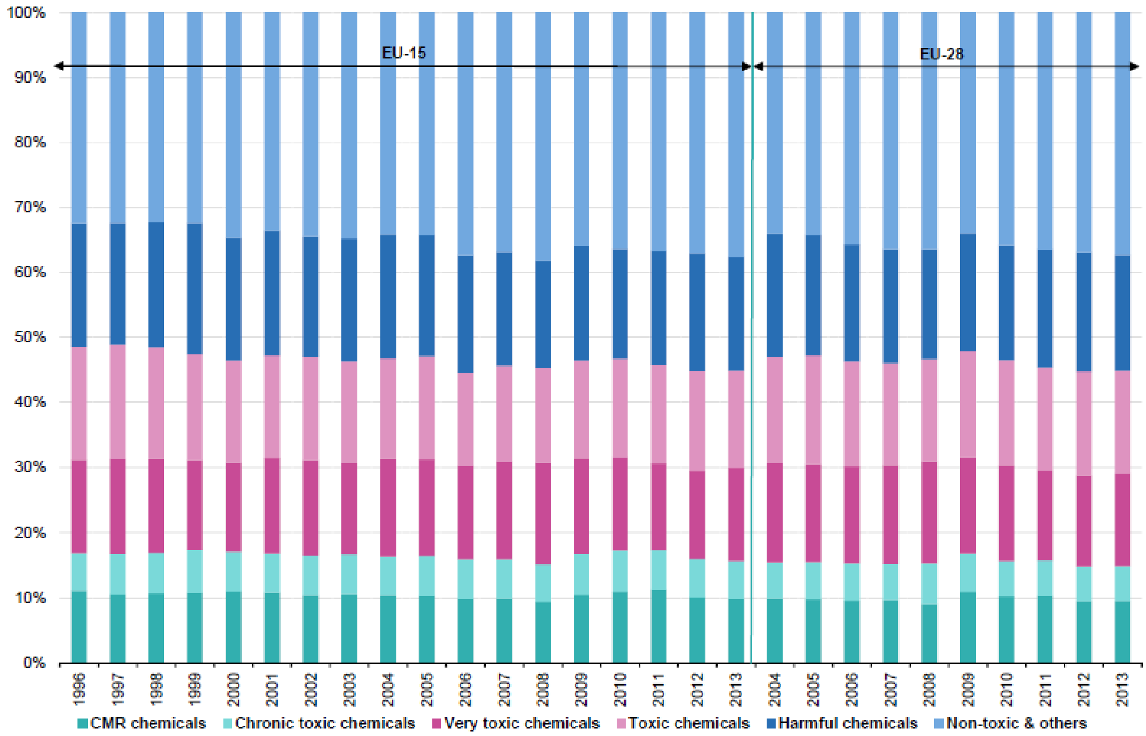
3.1.4 Hazardous chemicals use

3.1.4.1 Use of hazardous chemicals by IED sectors

There is no comprehensive data source that collates information on the use of hazardous chemicals in EU 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.

There are data on total production of hazardous chemicals, which are published in the Eurostat's Manufactured Goods database (PRODCOM). It is also known that 71% of total chemicals (hazardous and non-hazardous) produced by the EU chemical industry is sold to companies within the EU (CEFIC, 2018), however the proportion of hazardous and non-hazardous chemicals in internal sales vs exports is not known, much less on a chemical level. Therefore, production data can't be easily converted to sales of hazardous chemicals. When combined with hazardousness information from the Classification, Labelling & Packaging (CLP) Regulation 1272/2008, the Eurostat production statistics provide a share of hazardous chemicals in the EU's total chemical production and sales. Figure 35 shows the share of total mass of chemicals produced in the EU (from PRODCOM) by hazard class, from 1996 to 2013.

Figure 35 The 1996-2013 trend in relative share of different chemical hazardousness classes across total EU production of chemicals (NACE codes 20.11 to 20.15: Manufacture of industrial gases; dyes and pigments; inorganic base chemicals; other organic base chemicals; fertilisers and nitrogen compounds) Source: Eurostat (2016) compilation of chemical indicators – Development, revision and additional analyses



Eurostat have completed mapping of over 300 entries representing chemicals in PRODCOM, to their hazardousness statements from CLP (H-statements) [41]. 130 out of 300 entries representing chemicals in PRODCOM are considered hazardous. These entries have been classed as:

A. Carcinogenic, mutagenic or toxic for reproduction (CMR) chemicals
B. Chronic toxic chemicals

[41] The Eurostat methodology contains information on this mapping of chemical production to information on toxicity, which has been done to create the Eurostat hazardous chemical indicator [env_chmhaz]. Compilation of chemical indicators: Development, revision and additional analyses, 2016 edition: https://ec.europa.eu/eurostat/web/products-statistical-working-papers/-/KS-TC-15-006?inheritRedirect=true

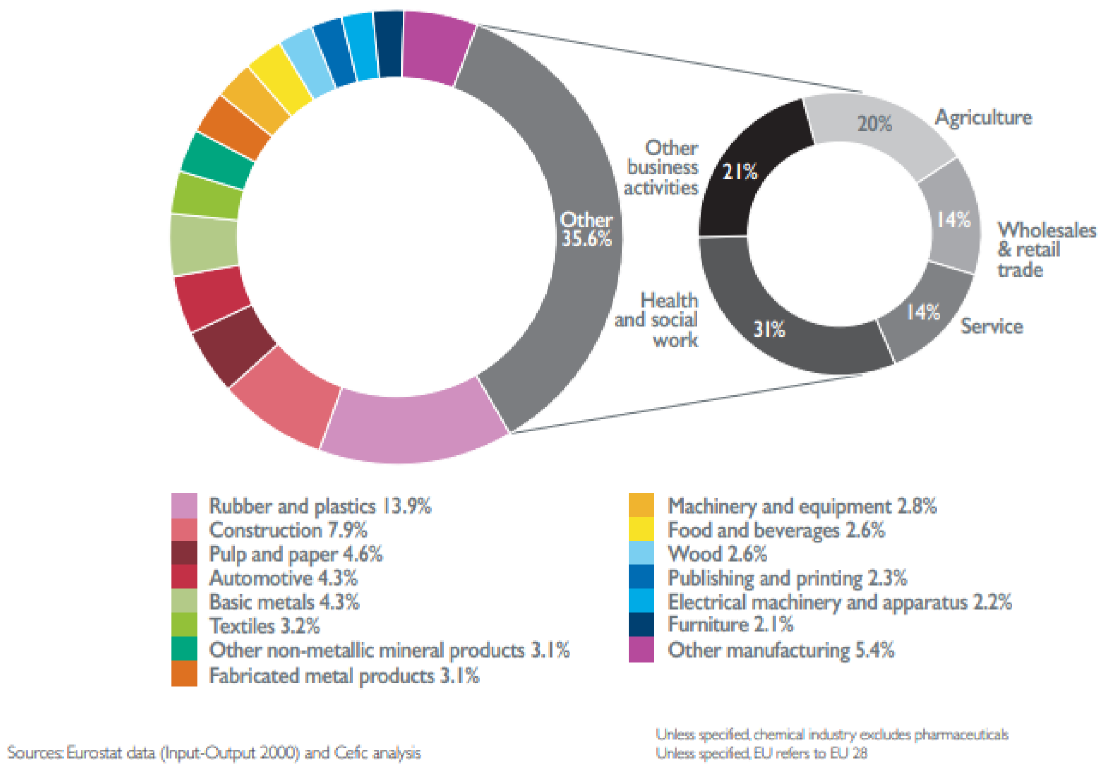
C. Very toxic chemicals
D. Toxic chemicals
E. Harmful chemicals
F. Non-toxic & other chemicals

The categories A – F are shown in reverse (ascending) order in Figure 35 (Eurostat, 2016), with non-toxic chemicals at the top and CMR chemicals at the bottom.

The chemical classification is based on hazard statements, which is a series of classifications that describe the chemical's effects. For example, CMR chemicals (A) are those who have proven carcinogenic or mutagenic effects or cause reproductive malfunction (endocrine effects). CMR chemicals made up 9% of EU production in 2013. Chemicals that have other chronic effects such as damage to unborn children (B), these comprise 6% of chemicals produced in the EU. The remaining classes cover acute toxic effects, with very toxic chemicals (C) covering those with direct fatal effects, for example when in contact with human skin or if swallowed. Approximately 15% of EU production of chemicals is of very toxic chemicals. Toxic chemicals (D) cover those which can cause acute damage to organs, though whose effects are not as severe to be fatal, and also cover ~15% of EU chemical production. Lastly, harmful chemicals (E) includes those who have shown to be damaging to organs in certain cases, but whose effects are not toxic in all cases of exposure. This covers another 18% of production. The remaining 37% is classified as non-toxic.

Next to information on total hazardous chemical production, there is information on the use of total chemicals, published by CEFIC. As stated in the first paragraph of this section, this does not distinguish hazardous from non-hazardous chemicals. The data is shown in Figure 36.

Figure 36 Customer sectors of the EU chemical industry (CEFIC, 2018)[42]



It shows that the largest single industrial consumers by sector are (with approximate mapping to the most appropriate IED sectors that contribute to this sector); 13.9% rubber and plastics (LVOC), 7.9% Construction (CLM, IS, STS), 4.6% Pulp and Paper (PP), 4.3% Automotive (NFM, IS, STS), 4.3% basic metals (IS, NFM, CER, FMP), 3.2% Textiles (TXT), 3.1% Other non-metallic mineral products (CER, CLM, LVIC) and 3.1% fabricated metals (NFM, FMP) . These sectors' combined chemical consumption

[42] CEFIC (2018), Facts & Figures of the European chemical industry, p14. Found at: http://www.cefic.org/Documents/RESOURCES/Reports-and-Brochure/Cefic_FactsAnd_Figures_2018_Industrial_BROCHURE_TRADE.pdf.,

amounts to 44% of total chemical consumption (including non-industrial use) and nearly 69% of industrial chemical consumption.

This data is compared to the data in Figure 18 on chemical and plastics use. Figure 18 shows that key sectors in the EU consuming chemical and plastic products are LVIC, STM/STS, and FDM. Note that the difference in highlighted sectors between the two data sources is due to classification differences, where the Exiobase input-output model used to produce the data in Figure 18 shows the end-use sectors, and the data shown in Figure 36 shows supply of base chemicals as produced by the chemical industry. It should also be noted that the LVIC (large volume inorganic chemicals) main output is agricultural fertiliser (20% of other, which is ~7% of total chemical consumption), which is not classified under industrial production by CEFIC but grouped under 'Other', and another large share (3.1%) of LVIC is classified as 'Other non-metallic mineral products'. Further, the use of plastics by FDM for packaging explains its large share in Figure 18 and its relatively small share in Figure 36. The raw materials used to produce these plastics are included in the 14% sector consumption for rubber and plastics in Figure 36 (14%). This can be assumed as of this 14%, 96% of production is plastics and only 4% is rubber (Statista, 2018) (Statista, 2018a).

Taking the classification differences between different sources into account, there is relative agreement on the most important end-use sectors that consume chemicals within the EU. Within the IED, these sectors are FDM (largely through plastics use), STS/STM (for any sector that requires treatment, coating and printing of surfaces, such as construction, automotive, basic metals, wood products), Pulp and Paper (PP) and Textiles (TXT). The emphasis is on end-use, as this is the approach taken in this work and is ultimately where the chemicals are used for their intended purpose.

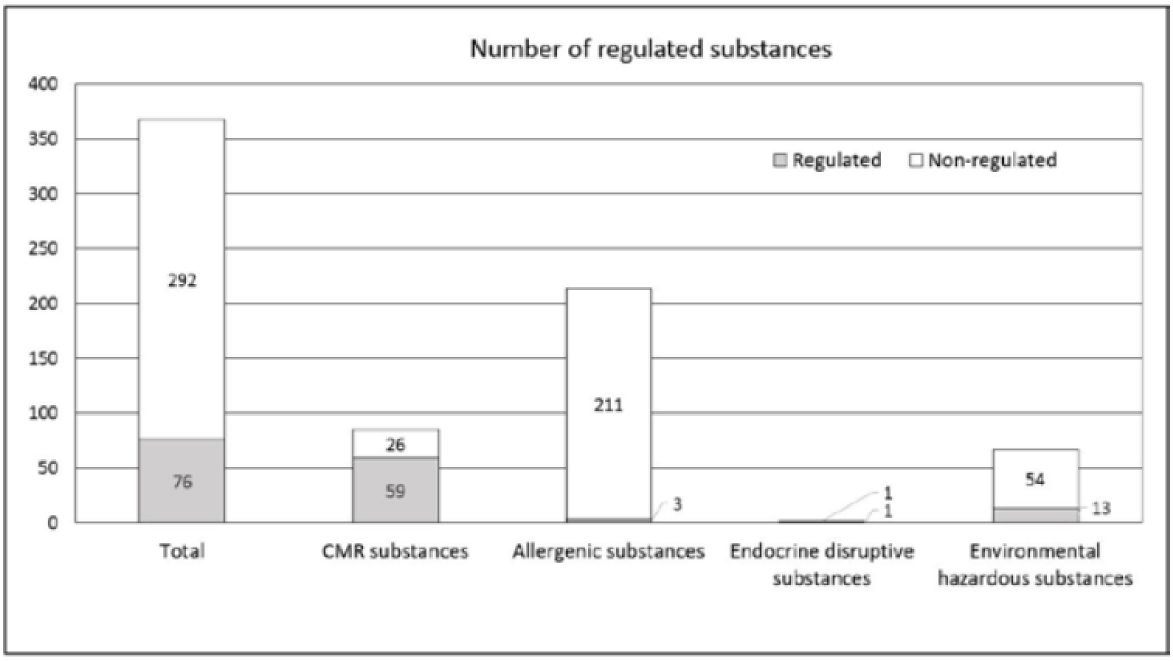
Sector specific examples of hazardous chemical use

While there are no data on the relative use of hazardous to non-hazardous chemicals in an individual sector, as stated in the beginning of this section, sector specific sources have been consulted to characterise the hazardousness of the chemicals used in these most important sectors at a qualitative level. Chemicals used by industry can just be part of the process, or can be an intended part of the product to ensure a certain trait (such as softeners in plastics). These chemicals can cause human/environmental exposure through different pathways, such as direct industrial effluent to the environment in the case of process-only chemicals, and through exposure from the use of products that contain these chemicals. From our data, we are not able to estimate the different scale of exposure from these different pathways.

As an example for a sector where chemicals may end up in the product is the FDM sector. Here, it can be assumed that a large share of the chemicals and plastic use is taken up by plastic for packaging. There can be hazardous substances in these plastics that migrate into food products. For example, the compound bisphenol A DEHP, which is an endocrine disruptor classified under category A; CMR chemicals in Figure 37. This is listed as a substance of very high concern under REACH and restricted for use, yet is still allowed in plastic containers for non-fatty foods, as regulated but not banned by Commission Regulation (EU) 2018/213 on the use of bisphenol A in varnishes and coatings that come into contact with food. A second use of hazardous chemicals in the sector is through cleaning agents in factories, which can also contain suspected CMR chemicals that can end up in the food produced. Third, agricultural production uses a lot of pesticides that remain on the food, and again some of these pesticides are potential endocrine disruptors, categorising them as a hazardous CMR chemical.

As an example of a sector whose chemical use is predominantly in the process (though the products are not chemical free) is the TXT sector, where large quantities of chemicals are used in many steps of the production process. Textiles are chemically pre-treated to clean, soften and shrink-proof the material. Dying and printing is performed using dyes and pigments which are generally synthetic organic compounds, and the dying process may rely on chemical reactions between the fibres and chemicals in the dye. Lastly, coatings are applied for waterproofing, stain-proofing or improving the appearance and texture of a textile product. The Swedish Chemicals Agency (KEMI) has produced an overview of which chemicals used for all these processes are classified as hazardous, shown in Figure 37. Out of 2400 identifiable substances, over 350 have hazardous properties. It should be noted that as most textile production for products sold in the EU happens outside of the EU, this number of chemicals is likely an underestimation, as many countries may allow the use of chemicals that are restricted for use under REACH in the EU.

Figure 37 Number of regulated substances found in EU textile industry and the proportion regulated by REACH to some extent (KEMI, 2016)



As a third example, the Pulp and Paper (PP) industry uses a large amount of potentially hazardous chemicals in order to produce white paper from raw wood material. The two main steps of paper production are pulping raw wood materials, and bleaching the pulp to create white paper. During the pulping process, acidic and alkaline substances such as sodium hydroxide, sodium sulphide and sulphurous acids are used to remove coloured fibres from the paper (Ince et al., 2010). Sodium hydroxide is classified under REACH as a very dangerous substance causing skin burns and eye damage and is classified as a very toxic chemical (class C) under the CLP regulation.

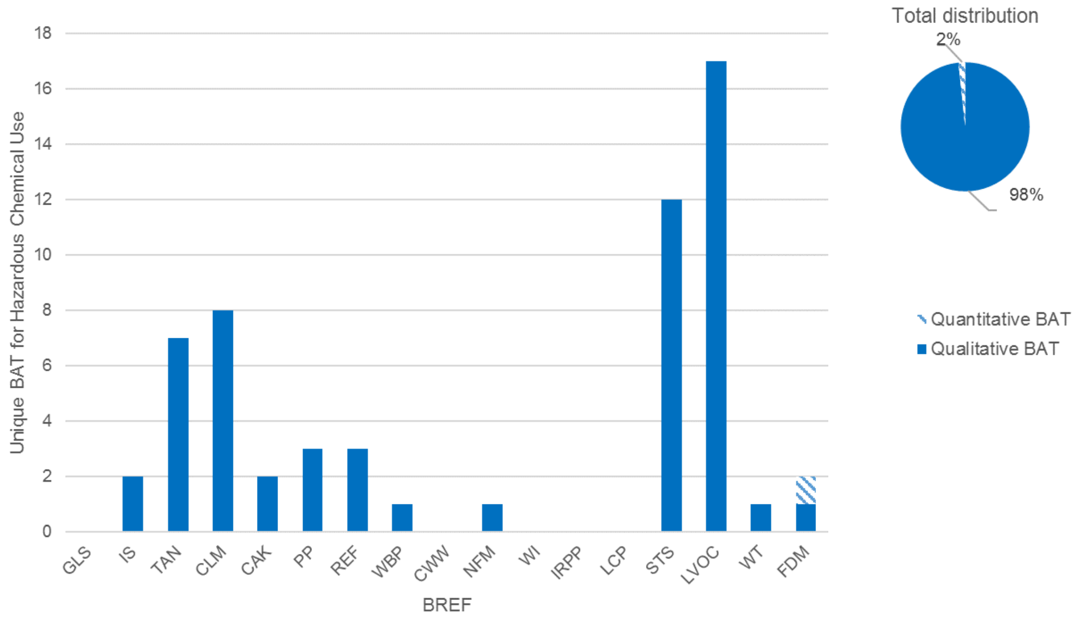
3.1.4.2 BATs related to hazardous chemicals use in BATC

Overview

BATs related to hazardous chemical use are less frequent (16% of all BATs in the IED BATC, the same proportion as BATs related to materials use) compared to other circular economy topics covered in this study, as shown in Figure 7. The similar proportion of hazardous chemicals use and materials use related BATs is linked to the fact that many BATs have been counted as relevant for both topics.

The review has identified 59 hazardous chemical use related BATs across the BATCs. Distribution of these BATs across sectors is presented in Figure 38. The sectors with the highest number of hazardous chemicals use-related BATs are the LVOC sector (17), followed by the STS-sector (12), the CLM-sector (8) and the TAN-sector (7). PP and REF sectors have three BATs each related to hazardous chemicals use. GLS (Glass manufacturing), CWW (Common Waste Water and Gas Treatment), IRPP (Industrial Rearing of Poultry and Pigs) and LCP (Large Combustion Plants) have no BATs related to hazardous chemicals use. While LCP, CWW and IRPP are not large users of hazardous chemicals, the GLS sector uses hazardous chemicals; for example hydrofluoric and sulphuric acids are used in glass manufacturing, though there is no mention of these in the BATC for GLS (European Commission , 2012).

Figure 38 Number of hazardous chemical related BATs in IED BATC



Qualitative and quantitative BATs

Across all BATs related to hazardous chemical use, only one BAT (in the FDM sector, related to hexane use) has a strict quantitative limit for the use of a hazardous chemical in order to reduce VOC; the remaining BATs are all narrative, i.e. no associated quantitative performance levels are set.

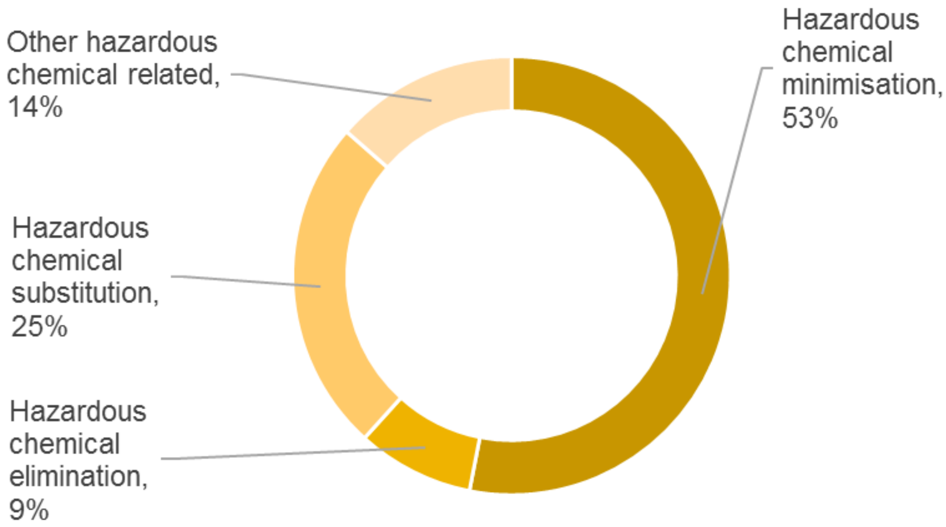
Types of BATs on hazardous chemical use

The BATs related to reduction in use of hazardous chemicals identified in the BATC were grouped into the following four categories:

- Hazardous chemical minimisation: reducing the quantity of a chemical used without a change in the process (optimisation of chemical use).
- Hazardous chemical elimination: removing the use of a chemical, by encouraging industrial processes and/or feedstocks that can enable this.
- Hazardous chemical substitution: replacing hazardous chemicals with a non-hazardous alternative.
- Other hazardous chemical related: mostly used for BATs that promote good management and monitoring.

Figure 39 shows the categorisation of hazardous chemicals use related BATs across all the BATC. It indicates that across all sectors, minimisation of hazardous chemicals use is the most common type of BAT on hazardous chemicals use, followed by substitution and finally elimination.

Figure 39 Proportion of hazardous chemical BATs across IED BATC



Examples of typical BATs of each type include:

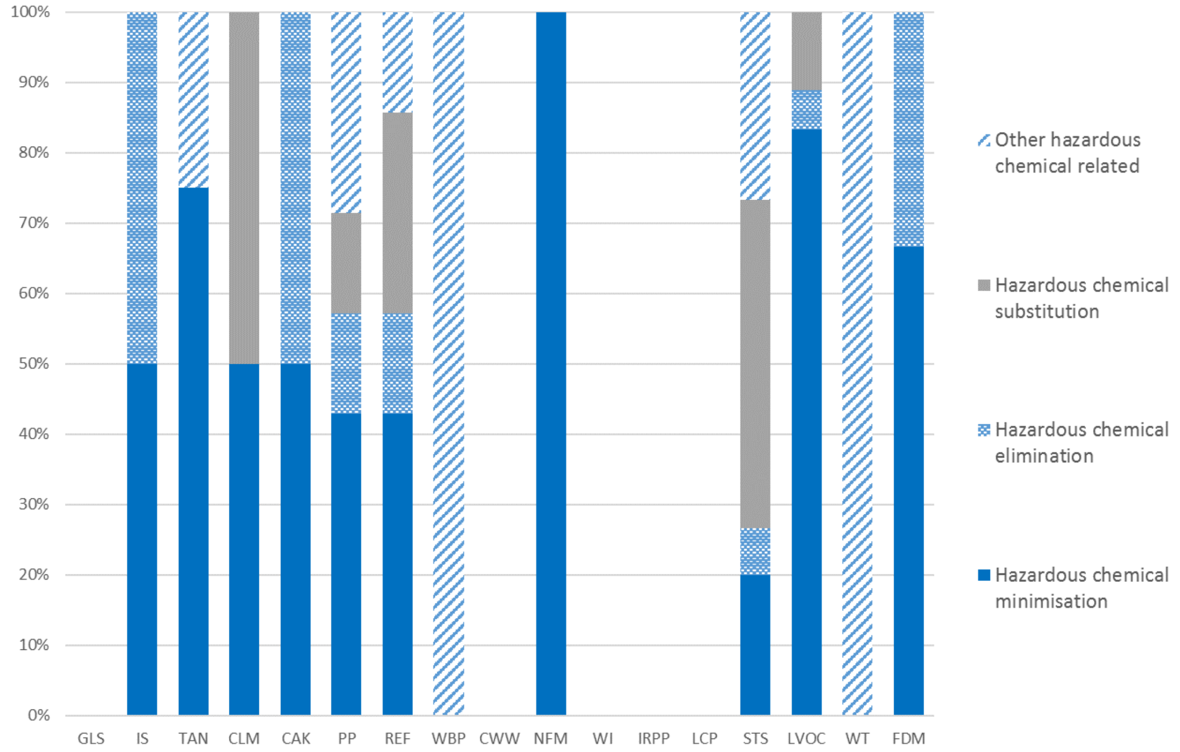
- **Minimisation**:
  - *TAN BAT 2, "To minimise the environmental impact of the production process, BAT is to apply the principles of good housekeeping by applying the following techniques … (iii) minimisation of the use of chemicals to the minimum level required by the quality specifications of the product"*
  - *STS BAT 38, "In order to reduce the environmental impact and risk associated with the use of biocides and solvent-containing preservatives, BAT is to reduce the consumption of preservatives/treatment chemicals by applying all of the techniques given below."*
- **Elimination:**
  - *CAK BAT 1: BAT for the production of chlor-alkali is to use one or a combination of the techniques given below. The mercury cell technique cannot be considered BAT under any circumstances. The use of asbestos diaphragms is not BAT.*
  - *CAK BAT 9: The use of carbon tetrachloride for the elimination of nitrogen trichloride or the recovery of chlorine from tail gas is not BAT*
- **Substitution:**
  - *PP BAT 3: In order to reduce the release of not readily biodegradable organic chelating agents such as EDTA or DTPA from peroxide bleaching … BAT is preferential use of biodegradable or eliminable chelating agents, gradually phasing out non- degradable products*
  - *CLM BAT 53: In order to minimise the emissions of metals from the flue-gases of kiln firing processes, BAT is to … Selecting fuels with a low content of metals*

As the BATC main purpose is to reduce the environmental impact of industrial sectors with a focus on established, available techniques, the majority of BAT involve the optimisation and optimal use of existing industrial processes. In this context, the minimisation of hazardous chemicals is often captured by BATs for which the primary objective is to reduce emissions of these substances to the environment. On the other hand, elimination and substitution of hazardous chemicals may often require substantial overhaul of techniques, using different reactants, feedstocks and/or processes, which may not yet be established enough to be considered BAT. Another possible reason is that in the development of BATC, it is more difficult to include more difficult process overhauls that are costlier to industry than abatement techniques for existing processes using hazardous chemicals. Some BATC have a heavy focus on elimination/substitution of hazardous chemicals use, such as the focus of the CAK BREF on the elimination of the mercury cell process, and the focus on biodegradable and less toxic chemicals for dyes in the TXT BREF.

Figure 40 illustrates the different types of hazardous chemical use-related BATs in each BATC and shows that:

- For 10 sector BATC, hazardous chemical minimisation is the dominant category. All BATs in the NFM BATC concern minimisation. A large number of these type of BAT is due to its link to the reduction of emissions of chemicals to the environment
- Elimination and substitution BATs are more complex than minimisation, and occur less frequently across BATC: 7 BATC included BAT(s) on elimination, and 5 BATs on substitution of hazardous chemicals.
- The category 'Other hazardous chemical related' is mostly used for BATs that promote management and/or monitoring processes. For example, the Waste Treatment (WT) BATC contains BATs that improve the tracking of which hazardous chemicals are present in the effluent.

Figure 40 Types of hazardous chemical BAT categorisations in IED BATC



3.1.4.3 Contribution of the IED to minimisation of hazardous chemicals use

As quantitative data on the use of hazardous chemicals in industry is mostly unavailable, it is not possible to identify the largest consumers of *hazardous* chemicals across the IED sectors. However as explored earlier in this section on hazardous chemicals, production processes in several sectors rely heavily on chemicals to produce their goods. The BATC have had an impact on the reduction of this use in some instances. This section explores two such examples of how the IED BREF has been successfully aiding the minimisation, elimination and substitution of hazardous chemicals use, through the elimination of mercury from the CAK sector and the minimisation of hexane losses in the FDM sector.

Example 1 of the contribution of an IED BATC to the minimisation of hazardous chemicals use: Chlor-Alkali (CAK) and the elimination/substitution of mercury

In the CAK sector, a significant number of chlorine producing plants use mercury cell technology. According to the European trade association Eurochlor, at the beginning of 2017 mercury cell technology accounted for 17.4% of EU chlorine production capacity (Eurochlor, 2017). According to REACH, mercury is one of the most toxic heavy metals, and the EU has a longstanding policy to become mercury-free, summarised in the EU Mercury Strategy (EU, 2016). This strategy is the implementation of the Minamata convention signed in 2013, which globally restricts the use of mercury.

The CAK BATC explicitly state that the mercury cell process is not BAT in BAT 1 and has BAT 2 and 3 specifically for the decommissioning of mercury cell plants; which in practical terms imposes a ban on the use of this technique across the EU. Only other chlorine production routes such as monopolar/bipolar membrane and asbestos-free diaphragm are considered BAT.

The deadline for compliance with BATC passed in December 2017.

With the implementation of the BATC into environmental permits by 2017 (and in some delayed cases, in 2018/19), the CAK sector has had to dispose of up to 6,000 tonnes of mercury that was stored inside the plants (EU, 2018). Furthermore, the CAK sector used an additional 160 – 190 tonnes annually, which was estimated to be around 40% of the total in 2014-2015 use in the EU (ICF, 2015). EEA estimates of industrial mercury consumption expect total industrial use of mercury to reach near zero in 2021. And the single largest contributor to this decline will have been the elimination of the mercury cell technology from use in the CAK sector (EEA, 2018).

The CAK BATC have had a large impact on the overall flows of mercury in the EU, through imposing a ban on mercury-based technology, as well as disposing of the remaining mercury in existing plants.

Example 2 of the contribution of an IED BATC to the minimisation of hazardous chemicals use: Food, Drink and Milk industries (FDM) and the minimisation of hexane losses during vegetable oil processing.

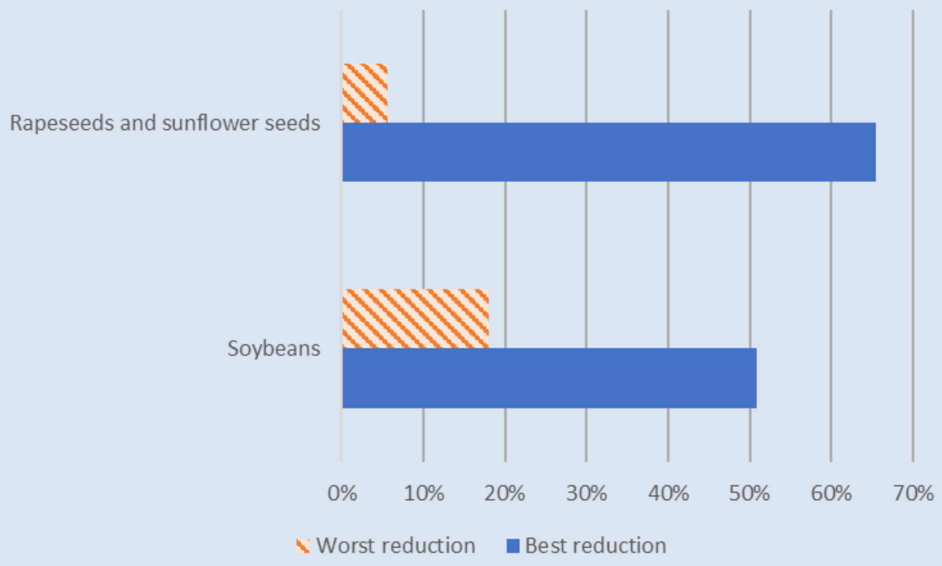
B**AT 31 in the FDM (Food, Drink and Milk products)** proposes measures to reduce the losses of hexane from oilseed processing and refining, which is an example of how the IED minimises the use of hazardous chemicals, as there is a specific BAT-AEPL on how much of the chemical hexane can be used per tonne of product. Table 3 shows the BAT description and its accompanying BAT-AEPL and reference levels.

Table 3 BAT 31 of the FDM sector, for vegetable oil processing, detailing hexane loss limits and associated BAT-AEPL and current emission and consumption levels.

BAT description	Product	BAT-AEPL summary	Current Consumption levels
FDM 31: In order to reduce the hexane losses from oilseed processing and refining, BAT is to use all of the techniques given below.	Rapeseeds and sunflower seeds for vegetable oil	0.2 – 0.7 kg hexane loss/tonne of seeds processed	0.22 – 1.0 kg hexane loss/tonne of seeds processed
	Soybeans for vegetable oil	0.3 – 0.55 kg hexane loss/tonne of beans processed	0.22 – 1.0 kg hexane loss/tonne of beans processed

To understand the impact of this BAT-AEPL requires knowledge of the total amount of soybeans and/or rapeseeds that are processed by the FDM sector for vegetable oil. To estimate the potential reductions in total hexane use from this BAT-AEPL, the methodology used is similar to the quantitative analysis for energy use in section 3.1.1.[43] This method first assumes a normal distribution of operators with two standard deviations between the mean and the 95th percentile. It then estimates the percentage of the population which is above the Lower AEPL and the percentage that is above the upper AEPL. The midpoint of these two populations is then used to calculate best and worst loss reduction estimates. The following reductions are obtained as shown in **Figure** 41.

Figure 41 Estimated hexane loss reduction from FDM BAT 31



The figure shows that in the most optimistic scenario, with a strict implementation of the low BAT-AEPL value across the EU (0.2 kg hexane loss/tonne of rapeseeds/sunflower seeds processed, and similarly 0.3 kg hexane loss/tonne seeds processed for soybeans), the best reduction in hexane loss would be 65% for rapeseeds/sunflower seeds and a little over 50% for soybeans. Conversely, if only the upper AEPL values are implemented in permits, the worst reductions are ~ 5% and ~18% respectively. These reduction figures can then be used with information on total use of hexane for this process, to estimate the reduction in use of this hazardous chemical by the FDM sector as a result of FDM BAT 31.

Publications by FEDOIL (the EU vegetable oil and protein meal industry association) provide information on the total quantity of soybeans, rapeseeds and sunflower seeds crushed for vegetable oil. The total reduction in hexane loss is calculated from the reference of 0.22 to 1.0 kg hexane loss/tonne of seed or bean processed (current consumption level from BREF), using the average figure of 0.61 kg hexane loss per tonne of raw material. This results in a total of 28.7 kilotonnes of hexane loss as shown in **Table** 4[44]. In the best-case scenario, hexane loss is reduced to 11.2 kilotonne, and ~ 26 kilotonne in the worst-case scenario.

Table 4 Estimated absolute impact of full implementation of BAT 31 on use of hexane by FDM sector for vegetable oil processing

Product	2017 Product Crushed (kt)	Hexane loss baseline data (t)	hexane loss best case (t)	hexane loss worst case (t)
Soybeans	14,952	9,121	4,484	7,477
Rapeseeds	24,199	14,761	5,095	13,922
Sunflower seeds	7,929	4,837	1,669	4,562
Total of the above	**47,080**	**28,719**	**11,249**	**25,960**

[43] This quantitative method for comparing limit values with current consumption levels was developed and implemented in discussions with the EIPPCB during the study on the 'Industrial Emissions Directive's contribution to water policy' (Ricardo, 2017). The same method is used here too.
[44] (FEDOIL , 2017)

3.1.5 Industrial symbiosis

3.1.5.1 Definition of industrial symbiosis

Industrial symbiosis is an exchange among economic players (producers and users of streams such as businesses, territorial public administrations, research and knowledge organisations) whereby secondary industrial outputs and by-products produced by some of them are used/reused as an input by some others. According to Marian Chertow, industrial symbiosis is an "inter-firm resource sharing" (Chertow, 2007) and can be defined as follows: "*The part of industrial ecology known as industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity*" (Chertow, 2000).

Based on the differences between production residues, by-products and waste described in the Interpretative Communication on waste and by-products (EU, 2007), the following distinction between industrial symbiosis and recycling can be made: the exchange of production residues is considered as recycling, and not as industrial symbiosis, when a production residue that is categorised as waste, is reprocessed into products, materials or substances, whether for the original or other purposes, in a facility that exclusively or mainly uses wastes as an input for its production.

Industrial Symbiosis is an activity that occurs as a result of decisions by economic operators on the basis of the available cost evidence. Framework conditions such as the cost of primary raw materials, the levies for landfilling and/or incineration as well as the applicable waste legislation shape to large extent the decisions of economic operators on whether or not to seek industrial symbiotic exchanges as destination for their secondary outputs. By maximising reutilisation and valorisation of secondary output streams, environmental impact of the industry and the demand for virgin resources are reduced.

This definition, as well as the heterogeneity of sectors which might benefit from its applicability, can be illustrated by the following example of the Scottish industrial symbiosis relationship between an alcoholic drinks manufacturer and a firewood producer.

Industrial symbiosis example

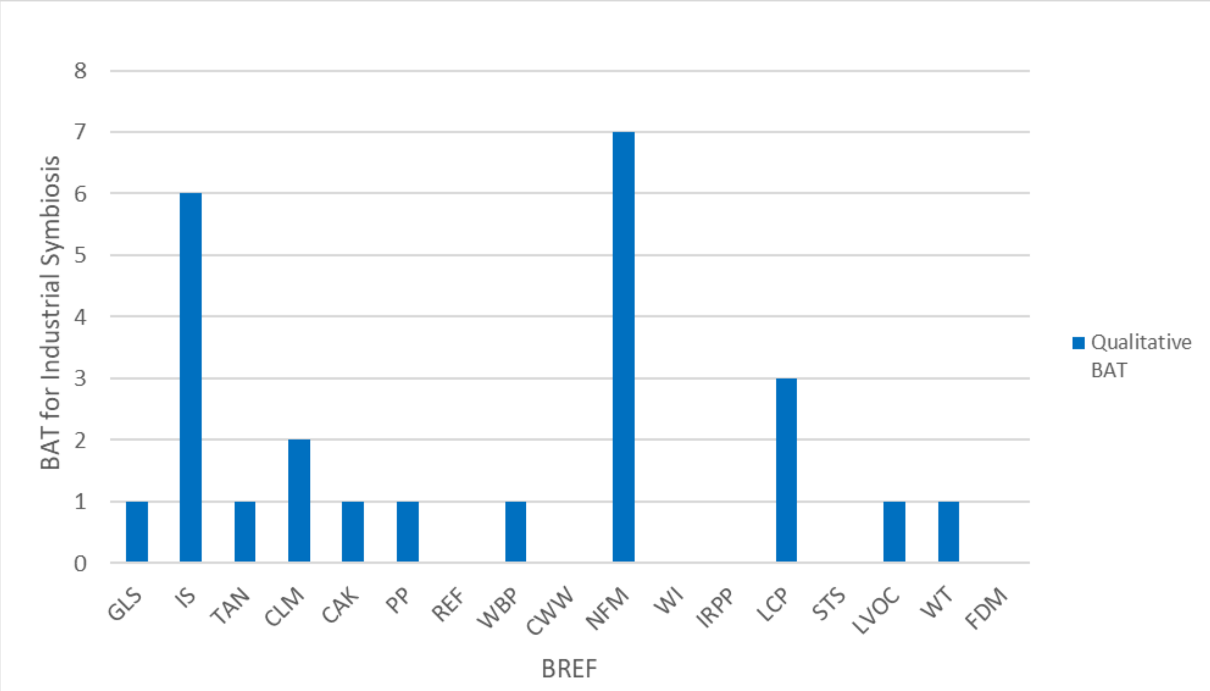
Diageo, a global manufacturer of alcoholic drinks, was receiving aromatics to use in its production process packaged in hessian sacks, which were landfilled after use. Diageo wanted to reduce its landfill costs and was looking for a more sustainable way to reuse its textile waste packaging. NISP (National Industrial Security Programme) identified Maltwood, a start-up using the staves from old whisky barrels to produce firewood, as a potential receiver. Maltwood was buying hessian sacks as packaging for their own product. Once NSIP proved the high quality of used sacks, Maltwood was willing to accept used sacks from the Diageo as a cheaper option. Before being allowed to send those used sacks to Maltwood, Diageo re-categorised the hessian sacks waste as a by-product thanks to the help of the Scottish Environmental Protection Agency. This synergy has saved Maltwood over £20,000 in packaging costs, which has helped them considerably as a start-up. Diageo was also seeing cost reductions, as they no longer had to pay to dispose of the sacks in landfill (NISP, 2009).

3.1.5.2 BATs related to industrial symbiosis in BATC

Overview

BATs related to industrial symbiosis are the least frequent (7% of all BATs) across the circular economy topics covered in this study. The review has identified 26 BATs related to industrial symbiosis across the BATCs. Distribution of these BATs across sectors is presented in Figure 42. The sectors with the highest number of industrial symbiosis-related BATs are the NFM-sector (7), followed by the IS sector (6), and the LCP sector (3). For six BREF sectors, there are no BATs relating to industrial symbiosis: REF, CWW, WI, IRPP, STS and FDM. All other sectors have BATCs that contain at least one BAT relating to industrial symbiosis.

Figure 42 Number of industrial symbiosis related BATs in IED BREFs



Qualitative and quantitative BATs

All BATs related to industrial symbiosis are narrative, i.e. no associated quantitative performance levels are set. The description of two identified BATs related to industrial symbiosis (from Figure 42) is for instance shown below:

- *LVOC BAT 28: In order to use resources efficiently, BAT is to maximise the use of coproduced hydrogen, e.g. from dealkylation reactions, as a chemical reagent or fuel by using BAT 8a. or, where that is not practicable, to recover energy from these process vents (see BAT 9).*
- *NFM BAT 161: In order to reduce the quantities of slag sent for disposal, BAT is to organise operations on site so as to facilitate slag reuse or, failing that, slag recycling, including by using one or a combination of the techniques given below:*
  - *Use of slag in construction applications*
  - *Use of slag as sandblasting grit*
  - *Use of slag for refractory castables*
  - *Use of slag in the smelting process*
  - *Use of slag as raw material for the production of silico- manganese or other metallurgical applications.*

Types of BATs on industrial symbiosis

BAT concerning industrial symbiosis were grouped into the following three categories:

- **Use or recycling of waste in a different process**: When the previously under-utilised outputs of one process are made available for use in a different process through active management and cooperation between actors.
- **Utility/infrastructure sharing:** When efficiencies in the management of inputs and output flows can be gained by sharing infrastructure.
- **Joint provision of goods/services:** When different goods/services are produced in a synergistic process, using the same inputs. This can help in gaining efficiency, reduce waste and material use.

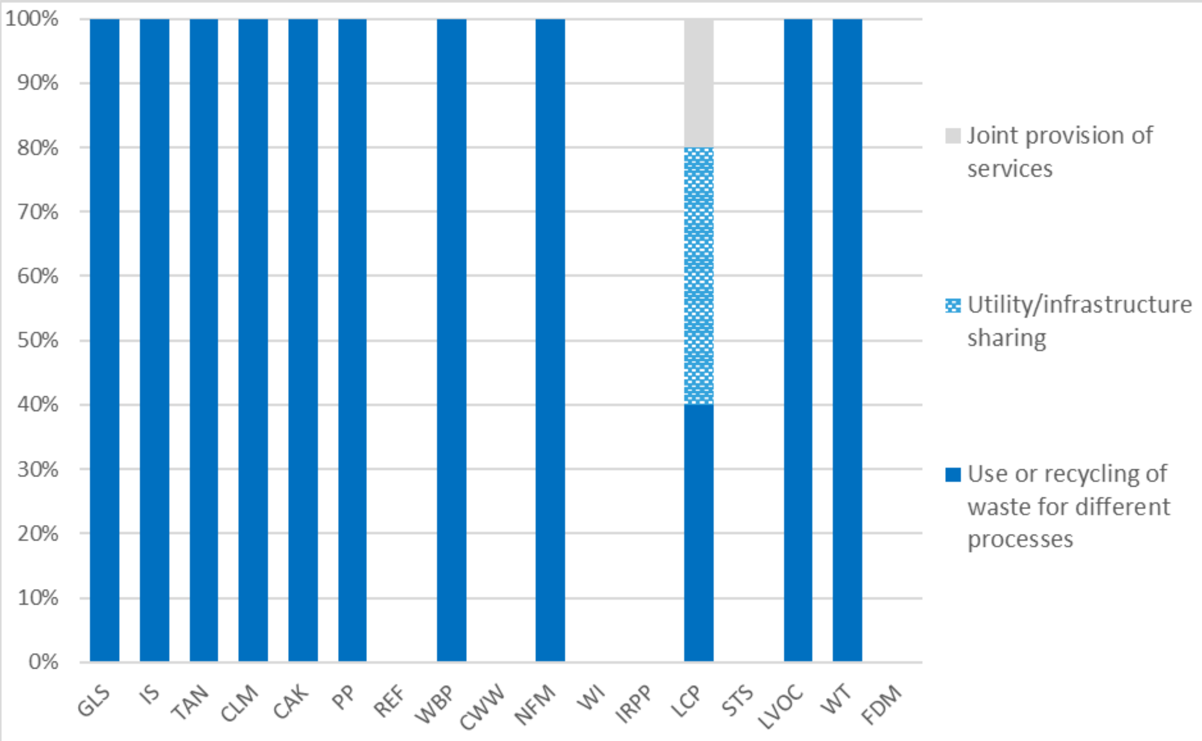
Figure 43 shows the categorisation of BATs related to industrial symbiosis across all BATC. Only the LCP sector included all three categories of BAT. The joint provision of goods/services is for instance illustrated with LCP BAT 12:

In order to increase the energy efficiency of combustion, gasification and/or IGCC units operated ≥ 1 500 h/yr, BAT is to use an appropriate combination of the techniques given below: (…) Heat recovery by cogeneration (CHP): Recovery of heat (mainly from the steam system) for producing hot water/steam to be used in industrial processes/activities or in a public network for district heating. Additional heat recovery is possible from:

- *flue-gas*
- *grate cooling*
- *circulating fluidised bed (…).*

In the remaining sectors all industrial symbiosis BATs concerned the use or recycling of waste in a different process.

Figure 43: Types of industrial symbiosis BAT in IED BREFs



Appendix 8 includes a list of IED installations identified as applying industrial symbiosis related BATs. Five examples are described in more detail in the next section.

3.1.5.3 Contribution of IED to circular economy through facilitation of industrial symbiosis

The impacts of selected BATs related to industrial symbiosis are illustrated by a series of case studies. These case studies cover:

- NFM BAT 54 involving the Copper and the Cement industries
- LCP BAT 16 involving a Power plant and the Construction industry (gypsum plasterboard)
- IS BAT 93 involving the Steel and Construction industries
- GLS BAT 14 involving the Glass and Refractory industries
- CAK BAT 4 involving the chemical sector and chlor-alkali production.

The description of those five case studies as well as conducted interviews for detailing two of them have allowed to identify key and common parameters driving and enabling industrial symbiosis. Synergetic relationships of mutual interest, resulting in cost reduction for the actors are the main drivers. Most of the time it corresponds to a reduction of cost for the disposal of waste for the donor and a reduction of processing costs for the receiver. While the compliance with waste legislation as well as associated environmental benefits (e.g. reduction of consumption of primary raw materials, avoided emissions) drive industrial symbiosis, the positive corporate image is also taken into consideration by the actors.

Expertise provided by a third party with regards to the compliance with the waste legislation and the marketing of secondary raw materials has been shown to be beneficial for some donors. Factors such as the logistics and local regulations are key parameters determining a potential successful symbiosis relationship.

Industrial Symbiosis Case Study 1: Example of IED plants illustrating BAT 54 in NFM BREF

Symbiosis relationship in use of slag from copper production in the construction industry, Austria

Description of applicable BAT	
BAT 54 in NFM BREF: *"In order to reduce the quantities of waste sent for disposal from primary and secondary copper production, BAT is to organize operations so as to facilitate process residues reuse or, failing that, process residues recycling, including by using one or a combination of the techniques given below: (…) Use the final slag from furnaces as an abrasive or (road) construction material or for another viable application (…)"*	
Installations involved in industrial symbiosis	
Donor	Montanwerke Brixlegg AG
Receiver	Cement industry
Description	
Montanwerke Brixlegg AG receives 160 000 tonnes of copper scrap each year and produces an output of 118 000 tonnes of ultra-pure form of copper cathodes with a content of 99,99%. This process generates about 20 000 tonnes per year of a by-product made of accumulated iron-silicate slag from the blast furnace. The slag is granulated, classified and put on the market as a fine-grained, sharp-edged product under the name of Granos©. Those Granos© are used in sandblasting, for removing the coatings on metal or for de-rusting steel parts but also used in the form of fayalite hard stone for concrete constructions. While Montanwerke Brixlegg AG reduces its disposal costs, the cement industry benefits from a "ready-to-use" source of iron with superior mechanical properties (e.g. abrasion resistance, compressive strength). When used as a partial replacement of cement, substantial amounts of energy required for production of cement, and consequently processing costs, are saved.	
References	
https://www.wko.at/branchen/t/industrie/Praesentation-MWB-deutsch_kurz.pdf http://files.montanwerke-brixlegg.com/NHB_2012_Internet_E.pdf http://www.montanwerke-brixlegg.com/en/products/fields-of-applications/	

Industrial Symbiosis Case Study 2: Example of IED plants illustrating BAT 16 in LCP BREF

Symbiosis relationship in use of power plant gypsum for plasterboard manufacture in Kalundborg, Denmark

Description of applicable BAT	
BAT16 in LCP BREF: *"In order to reduce the quantity of waste sent for disposal from the combustion and/or gasification process and abatement techniques, by implementing an appropriate combination of techniques such as: (…) Recover gypsum as by product (…)"*	
Installations involved in industrial symbiosis	
Donor	Asnæs Power Station (Ørsted)
Receiver	Gyproc, gypsum boards manufacturing plant
Description	
Ørsted produces steam which is used to drive turbines and produce electricity for the power grid. Within the flue gas desulphurisation of the exhaust smoke, gypsum is produced as a by-product. This industrial grade gypsum is sold to Gyproc, a plasterboard manufacturer, for the substitution of primary raw materials. While a transition from coal to biomass is being implemented at Ørsted (gypsum production will be stopped in 2023), this long-standing practice has provided a stable supply to Gyproc. In 2017, 20 000 tonnes of power plant gypsum were still sold to Gyproc. While allowing Ørsted to recycle 100% of this by-product, it gives Gyproc's access to local raw materials of a high quality at a competitive price compared to natural gypsum. Indeed processing costs for the manufacture of plasterboards are reduced because the gypsum has already been crushed, less energy is required for drying. Less than 5 km separate Ørsted from Gyproc, this geographical proximity also provides considerable savings in transportation costs and associated emissions.	
References	
Interview conducted with (on 17/01/2019): Mr. Folmer Fogh Lead Process Chemistry Specialist - Ørsted http://www.symbiosis.dk/en/ https://www.researchgate.net/publication/268440220 https://www.researchgate.net/publication/301518066	

Industrial Symbiosis Case Study 3: Example of IED plants illustrating BAT 93 in IS BREF

Symbiosis relationship in use of EAF slag in construction industry, Luxemburg

Description of applicable BAT	
BAT 93 in IS BREF: *"BAT is to manage in a controlled manner EAF process residues which can neither be avoided nor recycled: (…)V. external use of refractory materials and slag from the electric arc furnace (EAF) process as a secondary raw material where market conditions allow for it. (…)"*	
Installations involved in industrial symbiosis	
Donor	ArcelorMittal Luxemburg
Receiver	Road construction companies
Description	
In 2018, the Belval and Differdange sites generated over 250,000 tonnes of EAF slags during the manufacture of steel. This by-product is then delivered to CLOOS which acts as a service provider for the processing and marketing of EAF slags. During the processing, the material passes several crushers, i.e. drum- and gyratory crusher in order to be broken into aggregates of the dimensions requested by the customers. Then, due to iron separation through electromagnets and screening in several stages the aggregates reach their final characteristics such as granulation, form and cleanliness index. The slag are subject to a series of technical regulations - standards, technical regulations, guidelines and information sheets. CLOOS markets the slag products under the trade name Acrstone©. They are then used as aggregates for the construction of roads by local companies. Those companies benefit from a local access, thus reducing transportations costs, of aggregates with similar mechanical properties. While decreasing raw materials consumption, processing costs compared to natural aggregates are also reduced. By subcontracting the processing of slags ArcelorMittal benefits from the expertise of CLOOS, with regards to the Waste Framework Directive and customer requirements on the market, and is able to recycle 100% of its EAF slags.	
References	
Interview conducted with (on 30/01/2019): Mr. Guillem Dollé, Head of Environment & Energy & Sustainability - ArcelorMittal Europe Long Products - Luxembourg Mr. Pablo Delgado Environmental & Climate change affaires - ArcelorMittal Europe http://www.cloos.lu/index.php?lang=eng&c=products_services&product=1 https://corporate.arcelormittal.com/~/media/Files/A/ArcelorMittal/sdr-2015/2014-Sustainable-Development-EN.pdf	

Industrial Symbiosis Case Study 4: Example of IED plants illustrating BAT 14 in GLS BREF

Symbiosis relationship in end-of-life management of refractory materials from glass furnaces, France

Description of applicable BAT	
BAT14 in GLS BREF: *BAT is to reduce the production of solid waste to be disposed of by using one or a combination of the following techniques: (…) Valorisation of end-of-life refractory materials for possible use in other industries (…)*	
Installations involved in industrial symbiosis	
Donor	Glass manufacturer
Receiver	Refractory manufacturers
Description	
Valoref, subsidiary of Saint-Gobain, offers a complete service of refractory waste management for glass manufacturers. Customers of Valoref might also be part of the Saint-Gobain Group. The service includes the demolition of the furnace, sorting and transportation of refractory materials. Valoref collects about 35 000 tonnes per year of refractory materials of which 95% comes from glass furnaces. Those refractory materials are processed in Valoref facility in Bollène (France) to achieve a recycling rate of about 85% for their customers. Secondary raw materials meeting specific customers specifications are also produced, e.g. Valorzac© obtained from used fused-cast AZS refractory linings from glass furnaces. Its typical applications range from the manufacture of concrete and shaped refractories, wear-resistant linings, cleaning and surface treatment, or special abrasive and ceramic applications. The glass manufacturers benefits from a reduction of landfill costs as well as comprehensive document management, from waste identification and waste monitoring forms to recycling certificates. While mineral resources consumption is reduced, the production costs are reduced for the refractory manufacturers, which thus benefit from an economical and tailor-made solution.	
References	
http://imformed.com/wp-content/uploads/2017/07/IMFORMED-Refractory-Recycling-Glass-Int-Mar-2016.pdf https://www.valoref.com/history	

Industrial Symbiosis Case Study 5: Example of IED plants illustrating BAT 4 in CAK BREF

Industrial symbiosis in production of Chlor-Alkali sector: Port of Antwerp, Belgium

Description of applicable BAT	
BAT4 in the BATC for installations producing chlor-alkali states: *In order to reduce the generation of waste water, BAT is to use a combination of the techniques given below (…) b. Recycling of salt- containing waste water from other production processes (…)"*	
Installations involved in industrial symbiosis	
Donor	Chemical industry cluster, Port of Antwerp
Receiver	Solvic, Chlor-alkali plant
Description	
Input	Salty waste water
Treatment	Based on the inventory of all potentially recyclable water flows, water streams most suitable for recycling were selected. Additional treatment modules were installed where needed. Salty effluents of a neighbouring industry partner are used in the Solvic's manufacturing loop, following brine pre-treatment.
Final use	Production of chlorine from brine via electrolysis.
Benefits	Solvic achieved 20 m³/h water savings (170 000 m³/year) and a strong reduction of virgin salt consumption by 10 t/h, while the chemical industry cluster avoided effluent discharge and any costs associated with its potential treatment. The project serves as an "Industrial experimental garden" with the intention to inspire other water reuse in the chemical sector via similar symbiotic cooperation.
References	
LVOC BREF, E4 Water http://www.e4water.eu/_media/E4Water_Newsletter_05_2015_(3).pdf	

3.2 Measuring IED contribution

Industrial activities require the input of materials and products. Most of these materials and products are (further) processed and converted into semi-finished and finished products, generating added value in complex value chains that include exchanges of material resources between facilities located in the EU geographical region or abroad. In these industrial processes, some material resources are consumed in the process, particularly energy carriers. Part of the material input will leave the facility as emissions, whereas the difference between the inputs and the output products and the emissions is discarded as waste.

Some industrial processes allow for internal recycling of production waste. Such internal recycling is also targeted in efforts for production process optimisation. However, no sector-wide insights are available on this, and it is not likely that facilities would be keen to share such information. On the other hand, internal recycling concerns waste prevention, not waste management, and will improve material productivity and decrease material use and consumption per unit of output.

The prevention of waste is the core objective of circular economy policies. Industrial waste prevention achieved by the reduction of industrial output is not desirable however, so the IED contribution to circular economy resides in the relative reduction of the mass of waste per unit of material input to a particular IED sector. This means the sector should aim for improving the material resource productivity of their most relevant material and product inputs, for instance by increasing internal recycling.

In some sectors, part of the material input is provided by industries and services related to waste management, that collect, store and process waste from both industries and households, in order to recover secondary materials from it. This way, steel scrap that is recovered from End-of-Life Vehicles can be re-melted into products that can be used by steel product purchasing industries, e.g. for the production of construction materials. In such case, the secondary steel is considered as a material input to the construction sector, indistinguishable from the steel produced directly from iron ore.

In a circular economy, material consumption should be reduced, even if the source of the material is (partially) secondary. However, at the same time, the supply of primary materials should be substituted to the extent possible with secondary materials, this is materials that result from the treatment of waste. This strategy is expected to allow a major growth of those industrial activities related to waste treatment, that currently constitutes a relatively small economic sector.

To obtain a general idea on the different treatments applied to industrial waste streams, the figures on waste generation per waste category by industrial sectors, included in section 3.1.3.1, were complemented with graphs on the shares of different uses of the same waste categories. However, the latter percentages reflect the uses or treatments of the different waste categories without distinguishing the source/generator. For instance, 6% of waste ashes go to re-processing of ash into clinker, but no figures are readily available of the proportions of respectively WI, LCP and other IED sector ashes within this 6%. Estimating such source-based distribution can only be done by using expert insights on the qualities and types of ashes from each of the industrial sectors (IED and other, and in some cases households, services, etc.) and their corresponding applicability for clinker production. The same holds for the other industrial sectors' waste categories and the corresponding category's treatments. This kind of work is however beyond the scope of this study.

The IED contribution to the circular economy is assessed in this section using selected indicators from the EU Circular Economy monitoring framework.

3.2.1 EU self-sufficiency for raw materials

The indicator 'EU self-sufficiency for raw materials' measures to what degree the EU is dependent on the rest of the world for the supply of raw materials. The transition to a circular economy should help to address the supply risks for raw materials, in particular critical raw materials.

To contribute to a reduced dependence on raw materials from non-EU countries, industries could:

- (i) decrease the consumption and use of non-EU sourced raw materials;
- (ii) increase the production of raw materials within the EU, e.g. by developing more and/or more efficient mining and refining activities, or;
- (iii) intensify and develop new recycling activities that lead to an increase of the supply of secondary raw materials.

All such measures are of special relevance when targeting raw materials that have been categorised as critical for the EU (critical raw materials, CRMs) [45].

In practice, it is not feasible to distinguish between EU and non-EU-sourced raw materials, as aimed for under (i). However, a decreased raw material consumption in general will contribute to improved security of supply, particularly for CRMs. This can be achieved through applying BAT that aim for minimising and eliminating material use, and applying BAT that envisage substituting critical raw materials with more abundant ones.

Across all IED BATC, 61 BATs related to materials use were identified. Of these 61 BATs – and acknowledging that some BATs are in more than 1 category – 32 are on materials use minimisation, 15 on material substitution and four on elimination. In addition, 21 BATs concerned other matters such as management systems and inventories of materials. Based on the analysis in section 3.1, BATs targeting the production chains of food products, textiles, paper and wood products, energy (related) products, plastics, chemicals and metal products can contribute to addressing the supply risks for raw materials. Less impact is expected from mineral products and electronics which are not consumed by the IED sectors to a large extent.

A small number of BATs were identified that are intended to increase raw material production capacities or efficiencies, or to increase the supply of secondary raw materials, as meant under (ii) and (iii) above. Examples include:

- BAT20 and 74 in NFM: Specific techniques for increasing aluminium and copper yields enable the separation of non-metallic constituents and other metals from the targeted aluminium. This BAT thus contributes to a reduced dependence by increasing raw material production efficiency (point (ii) in the list above).
- BAT93 in IS: This BAT aims to facilitate the external recovery of iron in the ferrous metals industry and recovery of non-ferrous metals such as zinc in the non-ferrous metals industry. This measure thus contributes to an increase in the supply of secondary raw materials, as meant under (iii) in the list above.

Most of the identified BATs are however only narrative, refer to very generic and/or preventive techniques, or target very specific chemicals and materials, especially hazardous substances. Despite the adverse impacts on human health and environment, these substances are used in relatively low quantities and thus are not very relevant to the indicator for self-sufficiency in raw materials. These characteristics of BAT weaken the probability of achieving substantive reductions in those raw materials consumed by the IED sectors in the largest quantities, and that could be sourced from outside of the EU.

Across the BATC, no BATs were identified that specifically refer to the minimisation of the use of raw materials that are listed as critical for the EU economy. However, BREFs for some IED sectors that are known to consume CRMs – chemical industry, specifically fertilisers and pharmaceutical production (LVIC, OFC) – have not yet been reviewed under the IED. Thus, there is an opportunity to explore the role of these sectors in CRM consumption once the relevant BREF review processes are initiated for LVIC; it is understood that the OFC BREF is not going to be reviewed. This is discussed further in Section 4.

3.2.2 Waste generation

In a more circular economy, the value of products, materials and resources is maintained in the economy for as long as possible and the generation of waste is reduced (European Commission, 2015). The Circular Economy monitoring framework measures 'waste generation' using three indicators:

- Generation of municipal waste per capita;
- Generation of waste excluding major mineral waste per GDP unit; and
- Generation of waste excluding major mineral wastes per domestic material consumption.

The generation of municipal waste is out of the scope of the IED. Only the latter two indicators can be influenced by the BATC. EU policies observe that '*waste prevention is closely linked with improving*

[45] A 2017 study commissioned by the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (EC) identified 27 raw materials and groups of raw materials as critical raw materials for the EU https://publications.europa.eu/en/publication-detail/-/publication/08fdab5f-9766-11e7-b92d-01aa75ed71a1/language-en

manufacturing methods and influencing consumers to demand greener products and less packaging' (European Commission, 2016).

As explained in section 3.1.3, around 70% of the total EU industrial waste (in units of mass) originates from sectors covered by the IED, with the remaining 30% generated by sectors not covered by the IED. For example, 33% of glass waste and 56% of manure is generated from non-IED sectors. However, even where non-IED facilities are more dominant compared to IED industries classified in the same sector, it can be concluded in general that the IED sectors are responsible for a large share of EU industrial wastes.

The shares of the different categories of waste generated by IED-related sectors was presented in section 3.1.3. In order to have a positive effect on the EU's Circular Economy waste generation indicator, **BAT should target absolute decreases of tonnages of waste, particularly of hazardous wastes, in every sector, and the corresponding measures should focus on waste minimisation and recycling.**

BATs related to waste generation are second most frequent (29% of all BATs) across the topics covered in this study. The highest number of BATC on waste can be found in the LVOC, NFM and IS sectors. Since BAT should focus on the reduction of tonnages of waste in order to support waste minimisation across the IED sectors, it is relevant to note that NFM and IS account together for almost 80% of the EU metal waste generation, making the identified BAT on waste for these sectors especially relevant. More than 40% of the NFM waste-related BAT focus on waste minimisation, whereas almost half of the IS BAT refer to recycling thus positively contributing to this indicator.

3.2.3 Food waste

This indicator measures the waste generated in the production, distribution and consumption of food (in mass unit). Food waste, assessed to be around 20% of all food produced, is a significant concern in Europe. It has been estimated that **the largest share of food waste in the EU (53%) originates from households, and 19% from processing** (i.e. the FDM sector) (FUSIONS, 2016). The remaining 28% of food waste comes from:

- primary production: 11% of all food waste originates from agriculture, horticulture, aquaculture, fisheries or other primary production activities; some of these are captured by the IRPP BREF,
- food service: 12%, and
- wholesale and retail: 5%.

In order to have a positive effect on the EU's Circular Economy food waste indicator value**, BAT should target food waste minimisation.** Analysis in section 3.1.3 showed that the *industrial* generation (i.e. processing) of food waste in the EU-28 is almost fully attributable to the IED-sectors FDM and IRPP. Figure 44 includes the mass-based shares of different applications of food waste.[46]

Food waste is referred to in the key environmental issues section of the FDM BREF and thus has been identified as an important issue to tackle in that sector.

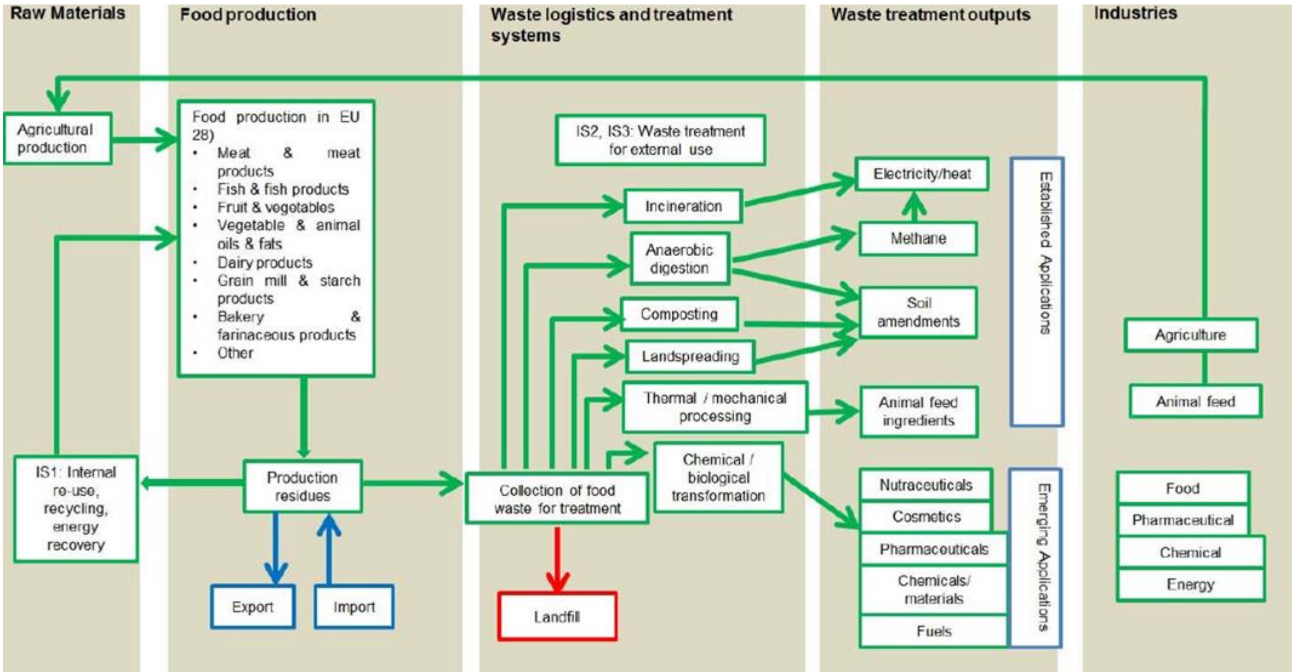
According to the information presented in Appendix 1, there are 8 BATs relating to waste generation in the FDM BREF. Two BATs relate specifically to food waste:

- BAT21 on reducing waste sent for disposal in the dairy sector
- BAT23 on reducing waste by recovery and reuse of yeast

The other BATs refer more generally to waste management though it is recognised that the FDM waste stream is dominated by food waste. The only quantitative BAT in the FDM BREF relates to hexane loss. The only BAT in the IRRP sector concerning waste is BAT29 on monitoring of manure waste generation thus it does not consider food waste.

[46] The 2014 Final Report 'Analysis of certain waste streams and the potential of Industrial Symbiosis to promote waste as a resource for EU Industry' includes the following statement on the application of food production residues (PR): '*As quantitative data on the importance of the various application areas for food PRs on the EU level is absent, one needs to rely on information from national sources. However, even these sources need to be interpreted with care, as they are often based on data for a limited number of companies and/or based on extrapolations and best estimates. […] The Food and Drink Federation (FDF) in the UK conducts on a biannual basis a survey among its members about the generation and valorisation of PRs in the industry. As can be seen in Table 8 for pure food waste (first column) the land-spreading method was most used, followed by anaerobic digestion, thermal treatment with energy recovery and composting. Landfill for this category was practically non-existent*.'

Figure 44 Food production residues flow diagram (source: IDEA Consult)



3.2.4 Recycling rates

In the Circular Economy monitoring framework, 'recycling rates' are measured via two indicators:

- Recycling rate of municipal waste;
- Recycling rate of all waste excluding major mineral waste

Municipal waste is out of the scope of the IED, however BATC can contribute towards the second of the above indicators. The indicator is calculated as recycled waste divided by total waste treated, expressed as a percentage. Thus, **in order to contribute to this indicator, industries could increase the amount of waste being recycled.**

There are many studies available on the potential for recycling at Member State, sectoral and EU level, and diverse policies in place that target increasing the recycling of waste. However, the focus of this study is the potential for increasing recycling of industrial waste by IED BATs.

The IED contribution to waste minimisation has already been discussed in section 3.2.2.

Recycling is a topic widely covered across the BATC, with 54 BATs relating to recycling. 16 BATC contain at least one recycling BAT. The scope of these BATs vary:

- Some BATC include recycling as part of broad waste management related BATs, for example BAT16 for LCP includes recycling among a prioritised list of generic techniques for waste management (i.e. waste prevention, waste preparation for reuse, waste recycling, other waste recovery);
- Some BATC include dedicated BAT on recycling only, for example BAT29 for IS refers to selective on-site recycling of residues back to the sinter process and external recycling whenever on-site recycling is hampered;
- Some BATC include BAT on recycling of specific waste streams, for example BATs 8, 16 and 17 in the LVOC BATC refer specifically to recycling of hydrogen, organic solvents and catalysts.

There are no BATs which have quantitative targets related specifically to recycling. It is likely not feasible to consider such targets, for instance because recycling efficiencies will not only depend on the technique, but also, to a large extent, on the waste input qualities, which will be hard to regulate. It may be possible to establish BAT on hazardous or unwanted substance removal efficiencies.

BATs which reduce the usage of hazardous materials may enable recycling of some waste streams. A number of sectors contain BATs relating to the reduction of hazardous chemical use, in particular the

LVOC, STS, CLM and TAN sectors, making up 16% of BATs across the BATC. For example, BAT3 in PP relates to the usage of eliminable chelating agents and phasing out of non-degradable products, which may enable greater rate of waste recycling in the sector.

Finally, the IED regulates the waste treatment sector itself, and within that, facilities recycling hazardous waste streams, i.e. inorganic materials other than metals or metal compounds. The WT BATC describes BAT for treating different types of hazardous and non-hazardous wastes; however it does not include performance or efficiency targets for the recycling processes.

3.2.5 Recycling rates for specific waste streams

This indicator consists of separate recycling rate indicators for the following waste streams: overall packaging, plastic packaging, wooden packaging, e-waste, biowaste (composted / methanised municipal waste) and construction and demolition wastes. **Across these specific waste streams, IED sectors can contribute to the three indicators on packaging wastes, by increasing the rate of packaging being recycled and/or minimising packaging waste**. Industrial packaging waste is however less relevant to the indicator, which mainly focuses on household packaging waste. In Belgium, where an EPR for industrial packaging is in place, in 2017 698 kt of household packaging was recycled, compared to 675 kt of industrial packaging. Data analysed in section 3.1.3 did not include packaging waste as a specific category. Packaging wastes are recorded as part of other waste categories, including plastic, paper and wood waste.

Only two BATC have been identified as including specific BATs on packaging waste:

- BAT 24 in WT states that BAT is to maximise the reuse of packaging.
- BAT 41 in STS supports delivery of treatment chemicals or solvents in bulk to eliminate packaging.

3.2.6 Contribution of recycled materials to raw materials demand

In the Circular Economy monitoring framework, the contribution of recycled materials to the raw materials demand is measured by two indicators.

- End-of-life recycling input rate: this measures for a given raw material how much of its input into the production system comes from recycling of "old scrap".
- The circular material use rate, which is the ratio of the circular use of materials to the overall material use.

In order to contribute to these indicators, **industries should increase the use of secondary raw materials / recycled material products**. As stated in section 3.1.2.3, at current, the circular use of raw materials in the EU economy is still below 10%. Based on the analysis in section 3.1.3, the IED sectors were found to be the major users (more than 50% by value) of food, textile, paper and wood, energy, plastics and chemicals and metal products compared to other industries, but no comparable sector-specific data on the share of secondary materials within these purchased material resources are available. As explained in the introductory paragraphs of this section, it is often not possible in practice to generate such data and, for example, to make a distinction between metals from primary and secondary sources. Pharmaceuticals and chemical production are considered priority sectors due to significant consumption levels of CRMs. While there is no quantitative data on the use of secondary raw materials or recycled products by industry, several relevant BATs supporting recycling and closing the materials loop have been identified as discussed above in sections 3.2.1 and 3.2.4. In addition, this indicator is supported through BATs on industrial symbiosis, though these are the least frequent (7% of all BATs) across all topics covered in this study.

3.2.7 Innovation

Innovation is an important aspect of the EU transition towards a circular economy. In the Circular Economy monitoring framework, innovation is measured by the number of patents related to recycling and secondary raw materials. **Industry can contribute to this indicator by testing and developing new recycling / secondary raw materials techniques.**

The IED makes specific provisions related to “emerging techniques”. An emerging technique is defined in Article 3(14) of the IED as “*a novel technique for an industrial activity that, if commercially developed, could provide either a higher general level of protection of the environment or at least the same level of protection of the environment and higher cost savings than existing best available techniques*”.

The IED aims to enable development of testing emerging techniques in order to achieve better environmental impacts. As such, Article 15(5) of the IED allows competent authorities to temporarily exempt installations that are testing and using emerging techniques from meeting BAT-based emission limit values. The emerging techniques identified per sector during the BREF review process are included in the BREFs but are not part of BATC. There has been a programme of work by the European Commission (including 2015 study *'Supporting information exchange on new facilities and the development and identification of emerging techniques in the context of the IED'*) to try to further improve the capture of information on emerging techniques within the BREF process. The latest component of this programme is a testing that is ongoing of an innovation observatory that tracks and collates information on emerging techniques to feed in to the frontloading of the BREF process by the EIPPCB.

Across the BREFs reviewed under the IED, the majority of the emerging techniques focus on emission abatement and reduced energy consumption. However, in some sectors, the emerging techniques described in BREFs focus on materials recovery, recycling of waste or substitution of hazardous chemicals. Some such examples include:

- NFM BREF which provides descriptions of emerging techniques for recovery of zinc and lead.
- GLS BREF which describes two emerging techniques relevant to the circular economy: new binder formulation for mineral wool products which substitute phenol-formaldehyde binders; and waste injection in the stone wool production process which enables recycling of between 80-100% of waste from the fiberising process.
- IS BREF which describes emerging techniques for recycling dry waste dust; injection of waste into the blast furnace; improvement of slag stability which enables its use as a construction material; and recycling of slags and tyres in electric steelmaking.
- PP BREF which describes the technique of gasification of black liquor for production of energy and biofuels.

While the emerging techniques are in no way binding on operators, the IED allows a temporary derogation from the emission limit values in order for the operators to test such techniques at industrial scale. Based on the information provided by Member States in Module 3 of Member States reports on implementation of the IED (EIONET, 2019), in 2016 three installations in Europe were granted derogations according to Article 15(5). One of these installations was the iron and steel works which trialled the use of old tyres for its injection inside the furnace (as described in the bullet points above).

While it is not possible to link this evidence directly with the number of patents granted in relation to recycling and secondary raw materials, emerging techniques can positively contribute to the development and implementation of new techniques for reducing energy consumption, use of waste as a resource and recovery of materials.

3.2.8 Conclusions

Based on the above assessment, a summary of the contribution of the IED to the selected indicators in the circular economy monitoring framework is presented in Table 5. The indicators are set to monitor the EU's progress towards achieving circular economy objectives.

It should be noted that the circular economy monitoring framework and supporting indicators have been designed to track progress at Member State level, and cover aspects not relevant to the IED, for example municipal waste generation. **The framework therefore does not provide a perfect measure for contribution to circular economy from IED industry specifically.**

The IED subject matter defined in Article 1 is to lay *"down rules on integrated prevention and control of pollution arising from industrial activities (...)"* and "*to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole".* Considering the subject matter of the IED, the following indicators were excluded from the assessment of IED contribution to circular economy:

- **Indicator 2 Green public procurement** – it is not within the subject matter of the IED to promote sustainable public procurement practices
- **Indicator 8 Trade in recyclable raw materials** - the movements of raw materials originating from waste, i.e. secondary raw materials, crossing European boundaries both as imports and exports, as well as of intra-EU trade is outside the subject matter of the IED

- **Indicator 9 Private investment, jobs and gross value added related to circular economy** – this indicator refers to the recycling sector and repair and reuse sector. While some recycling activities are covered by the WT BREF (e.g. recycling/reclamation of inorganic materials other than metals or metal compounds) most of the recycling, repair and reuse sector in the EU is not covered by the scope of the IED.

Table 5 Contribution of BATs to the selected indicators in the circular economy monitoring framework

Indicator	Contribution	Potential	Justification
EU self- sufficiency for raw materials	Very Low	Low	Industry is a high consumer of materials. It can contribute to self-sufficiency in raw materials by decreasing the consumption and use of non-EU sourced raw materials, increasing the production of raw materials and developing new recycling activities. BATs targeting these actions are already present in BATC but constitute a small share of all BATs (16% of BATs concern materials use), are narrative (qualitative) and focus mainly on mitigation of environmental impacts from use of certain materials, not raw materials use directly. It will not be possible to impede industries to import (embedded) raw materials from non-EU sources through the implementation of BATs.
Waste generation	Low	Medium	Industry generates significant quantities of waste. It can contribute to this indicator by decreasing the tonnages of waste, particularly of hazardous wastes and focusing on waste minimisation and recycling. BATs targeting waste generation comprise 29% of all BATs, with one waste related measure included in every sector. However, there are only three examples of quantitative BATs on this topic. More could be achieved if further quantitative BATs (relative to the (value of) production) were included, particularly for sectors responsible for majority of the industrial waste generation of certain waste streams.
Food waste	Low	Low	19% of all EU food wastes is generated from food processing. These activities are covered by the FDM BATC, which includes 8 BATs addressing waste generation. This is one sector with the highest number of BATs related to waste but only one BAT is quantitative. Given importance of this sector to the overall EU food waste generation, there is potential to further industrial contribution to this indicator by inclusions of further quantitative BATs and promoting greater process efficiencies and minimisation of waste.
Recycling rates	Low	Medium	Industry generates significant quantities of key waste streams. In order to contribute to this indicator, industries could increase the amount of waste being recycled. Recycling is well covered within the BATC. All except one (CWW) include at least one recycling BAT. However, no performance targets are set. Recycling is also facilitated by the IED through BATs addressing use of hazardous chemicals which help limit the presence of these substances in waste.
Recycling rates for specific waste streams	Very Low	Very Low	Industry is not a key contributor of waste streams specified in this indicator. The most relevant waste stream is packaging waste which has been covered in BATC for two sectors. There is a potential to mainstream the topic of packaging waste across BREFs and BATC, however potential improvements made will have an overall small contribution to this indicator.
Contribution of recycled materials to raw materials demand	Very Low	Medium	Industry is a high consumer of materials and some sectors the IED regulates are high consumers of CRMs. In order to contribute to this indicator, industries should increase the use of secondary raw materials / recycled material products. BATs targeting these actions mainly concern recycling and industrial symbiosis. There is potential to address the consumption of CRMs in the upcoming review of LVIC BREF.
Innovation	Very Low	Medium	Industry can contribute to this indicator by providing a field for testing and developing new recycling / secondary raw materials techniques. Provisions in the IED on emerging techniques allow for this to happen and several BREFs include descriptions of emerging techniques relevant for circular economy. However, the uptake of these opportunities to date appear to be low with only three installations testing circular economy related technique in 2016.

4 Relevance of circular economy topics in sectors pending BREF reviews

Chapter 3 assessed the contribution to the circular economy of the BATCs approved under the IED. There are however several additional sectors for which the BREF review process under the IED is either at the early stages of the review or has not yet started (Table 6). This chapter assesses the relevance of the circular economy topics (energy and materials use, waste generation and hazardous chemicals use) for these additional sectors. Industrial symbiosis is not included in this analysis, as it is a solution rather than a topic that can be found in Key Environmental Issues sections of the BREFs. This assessment is based on the quantitative data on energy and materials use, waste generation and hazardous chemicals presented in section 3.1.

In addition, the following horizontal BREFs have been issued under the IPPCD: emissions from storage (EFS), industrial cooling systems (ICS) and energy efficiency (ENE), Economics and Cross-Media effects (ECM). At the Article 13 Forum meeting in November 2018 the Commission sought views of the Forum on whether the EFS and ISC should form part of a future Resource Efficiency BREF (EIPPCB, 2018).

Table 6 Sectors pending the BREF review

BREF industrial sector	Stage of the BREF review
Ferrous metals processing (FMP) industry	Review started: pre-draft 1 (scheduled for 1st quarter of 2019)
Ceramic manufacturing industry (CER)	Review due to start in 2019 with the re-activation of TWG
Surface Treatment of metals and plastics (STS)	Review start outstanding
Textiles industry (TXT)	Review started: pre-draft 1 (scheduled for 4th quarter 2019)
Smitheries and Foundries (SF)	Review started: TWG kick-off meeting (scheduled for 3rd quarter 2019)
Slaughterhouses and animal by-products industries (SA)	Review started: TWG kick-off meeting (scheduled for 3rd quarter 2019)
Manufacture of polymers (POL)	No review planned
Organic fine chemicals (OFC)	No review planned
Speciality inorganic chemicals (SIC)	No review planned
Large volume inorganic chemicals (LVIC)	Review start outstanding

4.1 Ferrous metals processing industry

Based on the data presented in Section 3.1, the ferrous metals processing industry (FMP) is a significant consumer of metal products. The shares in other materials use categories are insignificant. Within the generation of wastes, the sector is responsible for 5% of the total weight-based generation of metal wastes. The shares in other waste categories are insignificant.

Table 7 presents the relevance of the circular economy topics to the FMP sector based on the scope and introductory sections of the IPPCD BREF. The main points are:

- **Energy consumption** is a key environmental issue for hot rolling (furnaces) and continuous hot dip coating (furnaces). In the IPPCD BREF there are 6 BATs focussing on energy consumption for hot rolling mills. For continuous hot dip coating there are 7 BATs. No BAT-AEPLs are defined for these processes.
- **Waste generation** is a key environmental issue for hot rolling (oil containing waste), cold rolling (acidic and oil-containing wastes), wire drawing (acidic wastes; spent lubricant, lead-containing wastes from lead baths), continuous hot dip coating (zinc-containing residues) and batch galvanizing (spent process solutions, or degreasing solutions, pickling baths and flux baths, oily wastes, e.g. from cleaning of degreasing baths and zinc containing residues, e.g. filter dust, zinc ash, hard zinc). There are multiple BATs on waste generation in the IPPCD BREF, covering the different processes. No BAT-AEPLs are defined.
- During the kick off meeting for the revision of the FMP BREF in November 2016, KEI were (re)defined: Energy consumption/use/efficiency for all FMP processes, material consumption / use / reuse (especially on oil and acid consumption) for all FMP processes, residues for hot rolling, cold rolling, wire drawing, hot dip coating and batch galvanizing processes, and CMR substances. The aim was noted to define BAT-AEPL, if possible.

Table 7 Relevance of the circular economy topics to the FMP sector based on the IPPCD BREFs

Energy use	Waste generation	Materials use	Use of hazardous substances
Relevant to 2 out of 5 processes	Relevant to 5 out of 5 processes	Not relevant	Relevant (Unknown number of processes)

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.2 Ceramic manufacturing

Based on the data presented in Section 3.1, the ceramic manufacturing (CER) sector is not a significant consumer of any of the material categories. Within the generation of waste, the sector is responsible for approximately 50% of the total weight-based generation of construction materials waste. The shares in other waste categories are insignificant.

Table 8 presents the relevance of the circular economy topics to the CER sector based on the scope and introductory sections of the IPPCD BREF. The main points are:

- Due to the high thermal requirements, **energy consumption** is KEI for drying of ceramic products and firing, as well as possible KEI for the preparation of raw materials, the shaping and forming of ware and surface treatment and decoration. The IPPCD BREF only covers 2 BAT on energy consumption related to kilns and dryers: improved design, recovery of excess heat, fuel switch, modification of ceramic bodies and to cogeneration/combined heat and power plants. No BAT-AEPLs are defined.
- The **generation of wastes**, hazardous and/or non-hazardous, is considered to be KEI for preparation of raw materials, component mixing, shaping and forming of ware, surface treatment and decoration, firing, subsequent treatment (product finishing), sorting, packaging and storage, supply and disposal facilities (off-gas treatment and process waste water). The IPPCD BREF covers 5 BAT on solid process losses / solid waste; one generic, one for the production of refractory products, one for the production of wall and floor tiles, one for the production of table- and ornamental ware (household ceramics), one for technical ceramics. No BAT-AEPLs are defined.
- Material use is suggested not to be KEI.
- **Use of hazardous substances** is considered KEI for surface treatment and decoration, and possible KEI for component mixing. The use of hazardous substances is not covered by BAT, nor BAT-AEPLs in the IPPCD BREF.

Table 8 Relevance of the circular economy topics to the CER sector based on the IPPCD BREFs

Energy use	Waste generation	Materials use	Use of hazardous substances
Relevant to 5 processes due to high thermal requirements	Relevant to: 6 processes (hazardous waste); 7 processes (non-hazardous waste)	Not relevant	Relevant to 2 processes

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.3 Surface Treatment of metals and plastics

Based on the data presented in Section 3.1, is the Surface Treatment of metals and plastics (STM) a significant user of energy (related) products, plastics and chemicals, metal products and electronics. The shares in other materials use categories are insignificant. Within the generation of wastes, the sector is responsible for 13% of the total weight-based generation of plastic wastes and 7% of the metal wastes. The shares in other waste categories are insignificant.

The STM sector BREF is not structured at process level and thus the assessment of relevance at process level is not possible in the same way as the other BREF sectors. Nevertheless, the main points of the circular economy topics to the STM sector based on the scope and introductory sections of the IPPCD BREFs are:

- The main environmental impacts relate, amongst others, to **energy consumption** (electrochemical reactions and operation of plant equipment), the **consumption of raw materials** and solid and liquid **waste**s.
- The BAT in the IPPCD BREF are generic and process specific and cover effective management systems (including the prevention of environmental accidents), efficient energy and raw material usage, the substitution by less harmful substances, as well as minimisation, recovery and recycling of wastes.
- The IPPCD BREF also includes materials use efficiency levels for several processes.

4.4 Textiles industry

Based on the data presented in Section 3.1, the textiles industry (TXT) is a significant consumer of textile products. The shares in other materials use categories are insignificant. Within the generation of wastes, the sector is responsible for 76% of the total weight-based generation of textile wastes. The shares in other waste categories are insignificant. Table 9 presents the relevance of the circular economy topics to the TXT sector based on the results of the KEI study (Ricardo, 2018). The main points are:

- **Waste generation** (hazardous and non-hazardous waste) is considered to be a key environmental issue (KEI) for the textiles processes in general (e.g. waste water sludge containing auxiliaries such as detergents), as are **energy consumption**, the **use of hazardous substances** including carcinogenic, mutagenic or toxic for reproduction (CMR) substances, other substances of very high concern (SVHC), priority hazardous substances and persistent organic pollutants (POPs). The IPPCD BREF has solely end-of-pipe waste techniques (e.g. "collect separately unavoidable solid waste, use bulk or returnable containers"). Waste prevention techniques have been identified in other documents.
- **Waste generation** is considered to be KEI for fellmongering and production of man-made filaments & fibres and a possible KEI for spinning preparation for wool fibres, spinning, weaving, tufting and non-woven, dyeing and finishing machines. The IPPCD BREF did not identify BAT for fellmongering, for which waste generation is considered to be KEI. Other reference documents include techniques to minimise environmental impact of fellmongering, that go beyond the adopted BREF's BATs.
- **Energy consumption** is considered to be KEI for retting, spinning, winding, reeling and covering, texturing, bulking and crimping, doubling and twisting, weaving preparation, weaving,

pre-treatment, dying, water extraction and drying, and finishing and a possible KEI for spinning preparation for wool fibres and kitting.

- **Material (resource) use** is considered to be a possible KEI for finishing machines.
- The **use of hazardous substances** is considered to be KEI for spinning preparation for cotton fibres, spinning preparation for wool fibres, spinning, dyeing, finishing machines and printing a possible KEI for doubling and twisting, pre-treatment, finishing machines and printing. The IPPCD BREF contains various conclusions on the avoidance and minimisation of hazardous substances.
- During the kick off meeting for the revision of the TXT BREF in June 2018 it was agreed that the selection and use of chemicals are important issues in the textiles sector, as are the generation of waste by-products, and consumption of energy. For most of these topics the setting of BAT and/or BAT-AEPLs will be considered at a later stage.

Table 9 Relevance of the circular economy topics to the TXT sector based on Ricardo (2018)

Energy use	Waste generation	Materials use	Use of hazardous substances
Relevant to 13/20 specific processes	Relevant to sector in general and 8/20 specific processes	Relevant to 1/20 specific processes	Relevant to sector in general 8/20 specific processes

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.5 Smitheries and Foundries

Based on the data presented in Section 3.1, the smitheries and foundries (SF) is not a significant consumer for any of the material categories. Within the generation of wastes, the sector is not responsible for a significant share in the total weight-based generation of metal wastes.

Table 10 presents the relevance of the circular economy topics to the SF sector based on the results of the KEI study (Ricardo, 2018). The main points are:

- Due to the high thermal requirements, **energy consumption** is a KEI for ferrous metal melting & metal treatment. It is a possible KEI for moulding and core-making with chemically bonded sand. There are no BAT concerning energy consumption in the IPPCD BREF for ferrous metal melting & metal treatment, nor for moulding and core-production.
- Waste generated from foundry processes are slags, dross, refractory, dust, sludge from wet dedusting and scrubbers, waste sand and general industrial waste. **Waste generation** (hazardous and non-hazardous waste) is a KEI for casting, cooling and shake-out. It is a possible KEI for foundries in general, ferrous metal melting & metal treatment, green sand moulding, moulding with unbonded sand, moulding and core-making with chemically bonded sand, sand regeneration, casting, cooling and shake-out, casting in permanent moulds and finishing operations. The IPPCD BREF identifies various process integrated measures and end-of-pipe techniques for the minimisation and the pre-treatment of solid waste for external re-use. No evidence on additional measures than described in BREF was identified.
- (Raw) **material use**, more specific, material selection is a possible KEI for green sand moulding and moulding and core-making with chemically bonded sand.
- No evidence identifies that the use of hazardous substances is relevant for the SF sector.

Table 10 Relevance of the circular economy topics to the SF sector based on Ricardo (2018)

Energy use	Waste generation	Materials use	Use of hazardous substances
Relevant to 2/10 foundry installation processes	Relevant to sector in general and 8/10 foundry installation processes	Relevant to 2/10 foundry installation processes	Not relevant

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.6 Slaughterhouses and animal by-products industries

The slaughterhouses and animal by-products industries (SA) is not covered in Section 3.1 because of the difference in granularity with this industry and the macro-economic data sources used in this report.

Table 11 presents the relevance of the circular economy topics to the SA sector based on the results of the KEI project (Ricardo, 2018). The main points are:

- The **generation of wastes**, both hazardous and non-hazardous, is considered to be KEI for slaughterhouses, and possible KEI in general. The coverage of BAT in the IPPCD BREF is:
    - There is a BAT on sectoral benchmarking for choice of input materials and generation of waste. Most of the generic BAT on waste are strongly linked to the prevention of waste water contamination. Same accounts for the slaughterhouse specific BAT on waste.
    - There are no indications for new or additional techniques to reduce the generation of waste in general.
    - There are indications for new or additional techniques to reduce foreign matter in slaughtering residues to facilitate their further processing.
    - The BREF does not contain BAT-AEPLs for waste generation. The industry is already well set up to minimise waste (and maximise valorisation of animal by-products), driven by economics and current legislation on hygienic and quality.
- **Energy consumption** is considered to be KEI in general: KEI for slaughterhouses, and possible KEI for most animal by-product installation processes. The coverage of BAT in the IPPCD BREF is:
    - The IPPCD BREF contains a BAT on sectoral benchmarking for energy efficiency and energy conservation activities.
    - Strong indications are given for new or additional techniques to reduce the energy consumption in general and in slaughterhouses
    - The IPPCD BREF does not contain BAT-AEPLs for energy consumption. For the meat processing industry, BAT-AEPLs for energy efficiency are included in the latest draft of the FDM BREF. These may also be appropriate for the SA industry.
    - Evidence for lower specific energy consumption for pig and cattle slaughterhouses than was identified in the IPPCD BREF.
- Consumption of materials is suggested not to be KEI.
- There is no evidence that the use of hazardous substances is relevant.

Table 11 Relevance of the circular economy topics to the SA sector based on Ricardo (2018)

Energy use	Waste generation	Materials use	Use of hazardous substances
Relevant to: sector in general, slaughterhouses and 8 animal by-product installation processes	Relevant to: sector in general (hazardous and non-hazardous), 3 animal by-product installation processes (for each of hazardous and non-hazardous waste)	Not relevant	Not relevant

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.7 Manufacture of polymers, organic fine chemicals, speciality inorganic chemicals

These three IPPCD BREFs are no longer going to be updated, as a result of the horizontal BREFs CWW and WGC covering the emissions that these sectors would emit through their effluents, smokestacks and production processes. As such, the review of IPPCD documents was not done to the process level, instead is limited to the issues that were identified as a whole. This is consistent with the three BREF documents, as key environmental issues are only mentioned for the sector as a whole, not by process/product. Subsequently, the CWW and WGC BREF BAT conclusions are compared to this, to understand how the new horizontal BREFs cover the topics identified in these sectors, relevant to the circular economy. The key points of relevance are summarised in Table 12 and are as follows:

- **CWW BREF coverage of identified KEI:** The focus of this BREF is wholly on emissions management, monitoring and abatement, covering topics such as emissions to water, waste and emissions to air.
  - From a **waste generation** perspective, the CWW BREF covers the POL KEI on waste waters with organic compounds, as well as solid wastes containing heavy metals, as there are limit values identified for what can be emitted into the environment. A *potential gap* is the coverage of specific non-recyclable wastes and what to do with them.
  - From an **energy generation** perspective, the CWW BREF does not cover this topic, and thus the KEI insight and associated BAT conclusions would not be up to date.
- **WGC BREF proposed coverage of identified KEI:** The WGC BREF is in initial drafting stage, but KEI have been identified that this BREF is going to focus on. The approach of identifying KEI for the WGC BREF centres wholly around identifying those substances that are of concern as a waste gas. It does not mention energy consumption.
  - Therefore, it is expected that the WGC BREF will cover the emissions of toxic and carcinogenic compounds as identified in the SIC BREF on **hazardous substances**
  - However, it is not expected that this BREF will contain BATs on energy efficiency and other energy-related topics, and this remains a potential gap.

Table 12 Relevance of the circular economy topics for the POL, OFC and SIC sectors, based on the KEI in the BREFs. These three sectors have not been reviewed to the process level and there is no KEI per process identified as a proportion of all processes. Instead, the KEI have been reviewed to understand if the topic mentioned in the KEI chapter is generic across most/all processes, or only specific to some.

BREF	Energy use	Waste generation	Materials use	Use of hazardous substances
POL	Mentioned as high energy demand that is applied to many of the sector's processes	Waste waters with high loads of organic compounds, applcable to many of the sector's processes	Not relevant	Not relevant
OFC	Not relevant	Waste waters + non-recyclable waste in high quantities for many of the sector's processes	Not relevant	Not relevant
SIC	Identified as consumption of energy for many of the sector's processes	Risk identified from solid wastes containing heavy metals for some specific processes	Not relevant	Identified as a risk of emissions of toxic and carcinogenic compounds from some specific processes

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

4.8 Large volume inorganic chemicals

The IPPCD BREFs for Large volume inorganic chemicals is split between two documents: LVIC-AAF (Ammonia, Acids and Fertilisers) and LVIC-S (Solids and Others). Based on the data presented in section 3.1, the LVIC-AAF sector is responsible for a significant share of weight-based use of materials, comprising nearly 40% of the total 2011 use. Within the generation of wastes, the sector is responsible for a significant share of sewage, at around 13% of total sewage generated by industrial activities in the EU. The LVIC-S is not seen as a significant contributor to material use or generation of wastes. Lastly, fertiliser production within the LVIC-AAF sector is expected to use 2-3% of total EU energy consumption.

Table 13 presents the relevance of the circular economy topics to the LVIC sector based on the review of the IPPCD BREF KEIs. The main points are:

- **LVIC - AAF**
  - Due to the high energy requirements, **energy consumption** is a KEI for the production of ammonia for nitrogen, the conversion of ammonia to urea, and the mining/refining of phosphate ore. Further, energy losses are a concern in the production of sulphuric acid and nitric acid. The processes to produce these acids release some of the energy used to produce the feedstocks, which currently is not sufficiently utilised. The BREF contains BATs on optimising the use of heat from one process to enable others, as well as optimising inputs to prevent the process from running inefficiently. There are specific BATs for the exothermic responses to promote the use of the energy released during for example the production of sulphuric acid.
  - Concerning **waste generation**, several large volume by-products are produced in the manufacture of phosphates, such as phosphogypsum (4-5 tonnes per tonne of superphosphates), the majority of which does not find a market and is disposed of. A second waste product of concern is fluosilicic acid and anhydrite from the production of hydrofluoric acid. There is a BAT on superphosphates to promote the recycling of waste water.
  - Raw **material use** is a KEI for the phosphate-based fertiliser (3/9 processes) and production of sulphuric acid, due to impurities in raw materials affecting the quality of products and by-products. Impurities in raw materials are dealt with in the BATs for all 9 product processes by prescribing the most optimal technologies that ensure proper conversion. The overall approach is still focusing on emissions abatement technologies.
  - The use of **hazardous substances** is relevant for the LVIC-AAF sector in 2 processes, namely the production of ammonia and nitric acid creating a storage and loading risk. Further, explosive gases can be created through reactions with catalytic materials on fertilisers (3 processes are affected). No specific BATs (excluding those that concern emissions) are identified that deal with this topic.
- **LVIC – S**
  - Several processes to produce salts have very high **energy consumption** which is a KEI for several salt products such as sodium chlorate and calcium carbide, or soda ash. 1 BAT is identified on energy efficiency including energy consumption levels for each of the 6 main processes described.
  - Concerning **waste generation**, the BREF only mentions several guidelines on what waste problems could occur, and provides an example of calcium chloride as a by-product of soda ash production is cited as a potential problem. There are no specific BAT conclusions on the treatment of waste, aside from those that prescribe the recycling of some key process ingredients, such as recycling of water.
  - Raw **material use** is mentioned as a key environmental issue for each of the 6 main processes in the LVIC- S sector. Concerning mostly impurities in raw materials which play an important role in any harmful emissions that occur during production. No BAT conclusions were identified to address the impurity issue. Solutions seem to be all end-of-pipe focused on emissions.

- Hazardous substances are not specifically mentioned as relevant to this sector. However, there is 1 BAT conclusion specifically for 1 of the 6 sector processes (soda ash) that mentions minimising the disposal of hazardous waste and requiring treatment.

Table 13 Relevance of the circular economy topics to the LVIC sector based on IPPCD BREF KEI review

BREF	Energy use	Waste generation	Materials use	Use of hazardous substances
LVIC -AAF	Relevant to sector in general and 5/9 acid and fertiliser production processes	Relevant to 2/9 hydrofluoric acid and phosphor fertiliser production processes	Relevant to 4/9 fluoric, sulphuric and phosphor fertiliser production processes	Relevant to 5/9 ammonia and nitric acid production processes
LVIC -S	Relevant to 3/6 salts and soda ash production processes	Relevant to sector as whole and 1/6 production process	Relevant to sector in general and 6/6 production processes	Not relevant

Key: Red – topic not relevant for the sector overall or any processes; Orange – topic not relevant for the sector overall but relevant for some processes; Green – topic relevant for the sector overall and all or most processes.

5 Untapped potential for IED to contribute further to circular economy

This section builds on the assessment presented in section 3 to define untapped potential for the IED to contribute further to circular economy and discusses options on how this can be realised and monitored in practice.

5.1 Untapped potential: key areas of focus

The analysis presented in sections 3 and 4 shows that there is yet untapped potential for the IED to contribute further to circular economy in the following ways:

- Circular economy references in the BATC and BREFs are often not explicit. In some cases BATs with a positive impact on circular economy topics have the primary aim of reducing emissions without mentioning the contribution the BAT makes to e.g. reduction in materials or hazardous chemical use. Revising the wording of these BATs to reflect the co-benefits to circular economy would contribute to mainstreaming circular economy topics across the IED community. **There is potential to make the text of the BREFs and BATC more explicitly targeting circular economy objectives and strategies.** This would raise awareness of circular economy issues as well as allow better identification of the circular economy related BATs in the future.
- Analysis of IED BATs demonstrated that while energy use and waste management BATs are featured commonly across all BATC, BATs on use of materials, hazardous chemicals and industrial symbiosis are less frequent. **There is potential to include BATs on materials use, hazardous chemicals use and industrial symbiosis more systematically across the BATC**, through as a minimum deriving BAT for each circular economy topic identified as KEI. The review of KEIs and BATs for individual sectors presented in Appendix 7 demonstrated that BATs have been put in place for all topics identified as the KEI (and often on topics that were not described as KEI). However hazardous chemicals use was rarely referred to in the description of KEIs in the BREFs.
- One of the limitations of current BATs on topics relevant to circular economy is lack of quantitative targets. The cause for it could be:
  a. BAT-AEPLs on these topics could be difficult to set as material consumption, local recycling capacities, opportunities for industrial symbiosis may differ a lot across individual installations depending on the specific processes they use, their location and supply chain. But this ought to be possible to accommodate with BAT-AEPLs expressed as ranges.
  b. Data collected during the information exchange is insufficient to derive robust BAT-AEPLs
  c. Not all Member States may consider BAT-AEPLs binding in the same way as BAT-AELs are.
  d. Issues of confidentiality and hesitation by the operators to share the data.

  There is potential to address these limitations through data collection during the BREF process. Data collection from individual operators and of a magnitude that is conducted during BREF development are rare and thus there is potential for the process to significantly increase the knowledge base on these topics.
- The Circular Economy Monitoring Framework only includes a few indicators relevant to the IED. Indicators within the CE Monitoring Framework **where the IED has the highest potential to contribute to the circular economy objectives are waste generation, recycling rates, contribution of recycled materials to raw materials demand and innovation.** There may be more that can be done on the opportunities to link the IED and the Environmental Technology Verification (ETV) programme which is mentioned in the CE Action Plan.

- Circular economy is important for IED sectors currently at an early stage of BREF development process or for which the review has not yet started. These BREF reviews provide an opportunity to address the following topics of relevance (highest priority are in bold):
    a. Ferrous metals processing: **waste generation**, energy use;
    b. Ceramic manufacturing: energy use, waste generation, use of hazardous chemicals;
    c. Surface treatment of metals and plastics: energy use, materials use
    d. Textiles industry: energy use, **waste generation**, materials use, **use of hazardous chemicals**
    e. Smitheries and foundries: energy use, **waste generation**, materials use;
    f. Slaughterhouses and animal by-products: **energy use**, **waste generation;**
    g. Waste gas in chemicals (to cover POL/OFC/SIC sectors): **energy use**, **waste generation**;
    h. Large volume inorganic chemicals: **energy use**, waste generation, **materials use**, use of hazardous chemicals.
- Chemical production is particularly important to the achievement of circular economy objectives, as it uses significant quantities of CRMs (European Commission , 2018). The LVIC sector, particularly the LVIC-AAF BREF review is pending, is important for this objective as it captures manufacturing of fertilisers. While the CWW and WGC BREFs will capture the impact of the sector on air and water quality, neither cover within their scope the consumption of raw materials nor waste management. As there are no intentions to update the POL, OFC and SIC BREFs **there is a risk that potential for the IED to promote use of alternative and secondary raw materials in the chemical production sector will be missed, unless an alternative solution is sought** (potential options are discussed below).
- With the exception of a limited set of horizontal BREFs/REFs, the focus of individual documents remains on a single sector. Yet the concepts of circular economy including energy, materials and waste flows do not always fit well within these sectors' boundaries. **There is potential to provide better links across the sectors to maximise thinking across the value chain.**
- BREFs include descriptions of emerging techniques, some of which provide innovative ways to recycle waste streams, recover materials, enabling symbiotic relationships between different industries. Provisions in the IED (Article 15(5)) give flexibility to the industry to test these techniques, yet these opportunities do not seem to be realised in practice. **There is potential for the IED to contribute further to innovation in the field of circular economy by promoting better uptake of emerging techniques in industry.** Actions are underway to improve the uptake of emerging techniques (e.g. ongoing project testing an innovation observatory on emerging techniques), but they have not specifically focused on topics relevant to the circular economy.

As the IED was adopted several years before the CEAP, there is no clear framework to measure contribution of the industry regulated under the IED to circular economy. While some of the indicators from the EU Circular Economy Monitoring Framework could be used for this purpose, there is lack of quantitative data to underpin them. The focus of other indicators is on aspects not within the scope of the IED. **Without a clear way to monitor progress achieved by the IED against the circular economy objectives, it will be difficult to assess whether its potential is fulfilled moving forward.** Given the upcoming evaluation of the IED, there is an opportunity to consider the way in which circular economy objectives can be integrated in the IED to a greater degree and how the contribution made could be measured. Specifically, one option could be to reconsider Annex I of the IED (including its thresholds) as it may have been inspired mostly by impacts on emissions to air and water, and could be reconsidered in light of circular economy topics. Sections below discuss options which could be considered to allow IED contributing further to circular economy.

5.2 Mainstreaming circular economy topics in BREFs and BATC

The circular economy topics could become **more mainstreamed across the BREFs** through **direct references and use of key words on circular economy related policies, topics, indicators and opportunities**. For example:

1. **General information on the sector:** in addition to information commonly present, this could overview whether the sector is relevant to circular economy objectives, including consumption of primary and secondary materials, waste generation and opportunities for industrial symbiosis, and usage of hazardous chemicals.
2. **Key environmental issues**: the section could systematically include sub-headings relevant to circular economy issues e.g. energy use, materials use, hazardous chemicals use.
3. **Indicate potential side effects elsewhere in the chain,** when describing the process-related environmental effects. This should capture the environmental impacts not only of the process itself but impacts happening before the process takes place and during the use of the products (i.e. consider the lifecycle impacts). For example, if a process uses a specific raw material, the BREF should consider the impacts of mining and obtaining this raw material, as well as opportunities to recover this material from waste and products at the end of their life cycle.
4. **Provide more real-life examples of industrial symbiosis,** when describing the techniques used for determination of BAT. These examples, similar to those presented in section 3.1.5 of this report, may serve as an inspiration for the operators to explore opportunities across their value chain.

These improvements could be introduced into future BREFs without interfering with the existing structure of the BREF as specified in the *Commission Implementing Decision of 10 February 2012*[47]. Yet in the context of the upcoming evaluation of the IED, it may be beneficial to explore whether the guidance could be updated in order to reinforce the circular economy aspects.

5.3 Changes to the BREF development process and formulation of BAT to strengthen the links to a circular economy

The Commission Decision (2012/119/EU) provides guidance concerning collection of data, drawing up BREFs and quality assurance. The following changes to the BREF development process could be considered to facilitate greater contribution from the IED sectors to circular economy objectives:

1. **Broadening the pool of experts invited to participate in Technical Working Groups to include circular economy experts and experts from other sectors providing materials or receiving by-products/wastes.** Current TWGs comprise mainly of experts on the sector concerned. In order to strengthen focus in the BREFs and BATC on circular economy aspects there may be merit in inviting circular economy experts in the process. The TWG could also expand to incorporate views from sectors further down and up the supply chain and discuss, among other topics opportunities for industrial symbiosis. The benefit of such wider participation will be the opportunity to explore the barriers for more efficient materials use and waste re-use and recycling.
2. During identification of **key environmental issues,** greater focus could be on **energy and materials (waste) flows within the production chain in which the particular sector takes part,** going beyond the sectoral boundaries. This information can be used to **guide the data collection** on materials use, hazardous chemical use, waste generation and opportunities for industrial symbiosis. When circular economy measures or strategies are explicitly integrated into the KEI, more attention can be given to issues such as contamination of waste products with hazardous chemicals and what can be considered BAT in order to enable use of this waste in associated or subsequent processes and industries.

[47] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012D0119&from=EN

3. **Formulation of the BAT-AEPLs can be difficult for topics such as materials use or hazardous chemical** use as these relate to the manufacturing process (i.e. these are primary measures rather than secondary measures concerning abatement techniques). Operators may be reluctant to support more prescriptive and quantitative BAT as they prefer to control their feedstocks. Particularly for the topic of hazardous chemicals, it may be difficult to set any quantitative targets due to challenges in data collection:
   - operators have information on the brand / trademark of the chemical, but may face difficulties in identifying the actual substances despite REACH.
   - the chemicals used by operators can frequently change which could make the data collection redundant by the time BATC are adopted.

   However BATs do not have to be quantitative to support the implementation of circular economy strategies in industrial activities. BATs related to inventories of materials and chemicals use would facilitate better understanding of what industry uses and in what quantities. Rather than referring to specific chemical substances or materials, BAT could be formulated in broader terms for example:

   'BAT is not to use chemicals of toxicity class X or Y for a particular process'

   'BAT is not to use / minimise the use of critical raw materials as identified by the Commission in...'

   'BAT is to review use of hazardous chemicals and potential for their substitution with safer alternatives at least once per year...'

   Proposals for embedding circular economy thinking in this process of formulating BATs is presented in the box below.

Re-thinking current BAT evaluation to realise circular economy potential

The circular economy is about retaining value across the full chain, not in separate activities. BATs are currently determined for each industrial activity separately. The identified BATs are "techniques" that can be implemented in the installations under consideration, with the aim to limit the (direct) environmental impact of these installations.

Value chain aspects could be systematically included in the BAT process through (Huybrechts et al. , 2018):

1. **Considerations of cross-sectoral effects:** In addition to the current BAT approach, a systematic check of possible positive or negative effects of the technique in other parts of the value chain or on the value chain as a whole is performed for each technique considered in the BAT evaluation.
2. **Determining value chain BAT:** This involves collaboration with upstream and downstream partners in the value chain. BATs are still determined for each industrial activity separately, and the identified BAT are techniques and practices that can be implemented in the installations concerned. However, the focus should be not only on techniques that aim to limit the (direct) environmental impact of the installations themselves, but also on techniques that will reduce the environmental impact elsewhere in the value chain.
3. **Including 'collaboration with upstream and downstream partners in the value chain'** as a general value chain BAT for each sector.

5.4 Use of horizontal BREFs in the context of circular economy

Proposals for a horizontal BREF on resource efficiency have been made by the EIPPCB during the Article 13 Forum meeting in November 2018. Horizontal BREFs, applying to all IED sectors, have to date been issued for the topics of energy efficiency and emissions from storage. Rather than through separate vertical (i.e. sector specific) BREFs, the chemical sector under the IED is also covered by the horizontal BREF on CWW and WGC (currently in preparation). **Given the cross-sectoral nature of the circular economy, there may be value in producing a horizontal BREF on circular economy topics, particularly covering materials and raw materials use, waste generation and use of hazardous chemicals.** Such a horizontal BREF could highlight the importance of self-sufficiency in raw materials, and production of secondary raw materials. Topics related to energy use are already covered by the horizontal BREF though it is not yet clear whether this BREF will be updated under the IED. As energy use and energy efficiency appear to be well covered across existing BATCs, it is suggested that energy is excluded from the scope of such a horizontal BREF.

Specifically for chemical-producing sectors which are important due to their use of CRMs, there would be a benefit in developing a horizontal BREF covering energy use, materials, waste and hazardous chemicals flows. Together with the CWW and WGC BREFs this would cover all aspects of environmental management of chemicals production in the EU. For such a BREF it is suggested that energy is included in the scope as neither CWW nor WGC cover energy management aspects. Such a BREF is even more important given that the OFC BREF which captured production of pharmaceutical products will not be updated under the IED and because the pharmaceutical industry is a priority sector with regard to CRMs.

The main difficulties with the use of horizontal BREFs to date for permitting process have been:

- **Lack of quantitative BATs** – horizontal BREFs generally do not include BAT-AELs or AEPLs due to coverage of all sectors. An exception is the CWW BREF where BATC include BAT-AELs for the chemical sector. With regard to a circular economy this may not necessarily be a drawback as quantitative BATs may be very difficult to establish. Instead BREFs could establish minimum rules.
- **Difficulty in implementing horizontal BREF requirements into permits alongside requirements of vertical BATC –** permitting authorities have faced difficulties in determining how the horizontal BREFs interact with the vertical BREFs. In some Member States only changes to vertical BREFs and publication of BATC triggered permit reviews, while publication of horizontal BREF alone did not. To ensure that best practices in the circular economy BREF are considered by the authorities during permit reviews, clear guidance on the interaction between the BREF and other BREFs and BATC will need to be provided to the Member States. Such guidance has been requested by the Member States as noted in the ongoing study led by Ricardo for DG ENV "Implementation support for the Industrial Emissions Directive".

5.5 Industrial cluster studies

IED contribution to circular economy could be supported by industrial cluster studies to facilitate the identification of 'cross-sector' effects and opportunities across the value chain. This could link specific waste materials in one sector to the raw materials of another sector to encourage synergy between sectors, waste recycling, waste reuse, raw material minimisation, and industrial symbiosis. Bringing these topics into a dedicated report explaining the energy and material (waste) flows in the chain and **opportunities for improved resource efficiency** would provide the operators (and permitting authorities) with a **clear guidance on best waste management and resource efficiency practices in industrial sectors** and **understanding what can be done to further facilitate transition to circular economy.** Circular economy should be presented to the industry as an opportunity to minimise future risks related to the supply chain and decreasing operational costs as demonstrated by the industrial symbiosis case studies in section 3.1.5.

5.6 Tracking progress towards circular economy objectives

There are already EU monitoring tools such as the raw materials[48] and/or resource efficiency scoreboards[49]. The extent to which the concepts in these existing monitoring tools could be applicable at industrial sector level should be investigated. The Circular Economy Monitoring Framework could be refined to make sure that indicators are relevant to industry (and the IED), and focus on the right topics, such as waste streams and materials use. The recent study for DG ENV on '*Indicators for Industrial Emissions Policy*' provided recommendations on the set of indicators for industrial emissions policy for air and water emissions but did not cover any of the circular economy topics. The main challenge for measuring and quantifying the contribution of industry and the IED to circular economy strategies is the provision of quantitative data on the type and mass of consumed materials and chemicals, and of the waste generated. In the absence of such data the indicators would need to build on available information

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[48] https://ec.europa.eu/growth/content/raw-materials-scoreboard-2018_en
[49] http://ec.europa.eu/environment/resource_efficiency/targets_indicators/scoreboard/pdf/EU%20Resource%20Efficiency%20Scoreboard%202015.pdf

such as the coverage of BATs across the BATC and mainstreaming of circular economy topics in the BREFs.

To measure progress towards circularity at an individual operator or sector level, BREFs could suggest a metric to monitor circularity of products produced by IED installations. In 2015, the Ellen MacArthur Foundation published a report and supporting toolkit on **Circularity Indicators** (Ellen MacArthur Foundation, 2015), which aimed to provide a framework for determining how effective a company is in making the transition from 'linear' to 'circular' models. The **Material Circularity Indicator** proposed in this work focuses on the following product characteristics:

- the mass of virgin raw material used in manufacture,
- the mass of unrecoverable waste that is attributed to the product, and
- a utility factor that accounts for the length and intensity of the product's use.

Such an indicator could be used as a starting point for a more bespoke circular economy indicator for the IED sectors to monitor their progress.

5.7 Facilitating uptake of emerging techniques related to the circular economy

There has been a programme of work by the European Commission to try to further improve the capture of information on emerging techniques within the BREF process. This was initiated by a first study in 2014-5 that identified options for improving the information exchange on emerging techniques.[50] The latest component of this programme is an ongoing test (for two BREFs: TXT and SA) of an **innovation observatory** that tracks and collates information on emerging techniques to feed in to the frontloading of the BREF process by the EIPPCB. The objectives of the Innovation Observatory are threefold:

1. Delivering a more complete and comprehensive set of information on novel techniques by (a) capturing information on novel techniques more systematically and consistently; (b) engaging with a wider and more comprehensive set of stakeholders than might otherwise be engaged for the BREF review process; and (c) staying abreast of the latest technique developments and innovation cycles. In part, but not exclusively, this aims to improve the degree of capture in coverage of process-integrated techniques.

   → This latter point on process-integrated techniques has particular relevance to circular economy topics (see point #3 in section 5.3).
2. Assisting the core EIPPCB staff who are responsible for delivering the BREF review and revised BREF documents by making available the latest information on novel techniques for the two sectors to be tested and using this information to draft text that can be used in the "Emerging techniques" chapter of the BREF under revision.
3. Encouraging and stimulating innovation and the market for emerging techniques (specifically in the final stages of technique development) by providing a platform for technique developers to obtain substantiated recognition for their techniques.

   → The possibility of a platform is also a way to share information about waste streams that could be materials streams in the concept of the circular economy.

Based on the experience of the current project on innovation observatory for novel techniques, there may be benefit in adopting such a platform to encourage greater take up of circulate economy emerging techniques. Options for such a platform include:

- Adjusting the current trial of the innovation observatory on novel techniques;
- Establishing a new, additional innovation observatory for encouraging circular economy measures
- Linking and building on the work undertaken by the eco-innovation observatory[51].

The scope of any option(s) would need to be cross-sectoral (to enable identification of solutions downward and upward value chain) and cross-disciplinary (covering materials and waste).

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[50] "*Supporting information exchange on new facilities and the developments and identification of emerging techniques in the context of the IED*".
[51] http://www.eco-innovation.eu/

6 Conclusions and recommendations

6.1 Conclusions on IED contribution to circular economy

6.1.1 By circular economy topic

Energy use	• Many IED sectors are energy intensive industries, several of which have shown reductions in energy consumption over the last decade. Some of this decline is likely to be attributable to improvements in energy efficiency. There appears to have been a decoupling of energy consumption from economic growth. • The largest proportion of BATs on circular economy topics from across all the BATC published is on energy use. The energy-related BATs are primarily focussed on process optimisation measures, energy/heat recovery and the use of process streams as fuel. The category of energy-related BATs least applied is in the topic of renewable energy, but this may reflect the high intensity of energy requirements of many IED sectors. • Of the BATs on energy in the IED BREFs, nearly four fifths of these BATs are qualitative rather than quantitative. The more recent FDM and LCP BREFs have many more process/subsector-specific quantitative BAT (i.e. setting BAT-AEPLs) which may reflect a move in the direction of setting more quantitative BATs). • Several of the most energy intensive sectors do not have any quantitative BAT set. This is most apparent in the case of the IS (iron and steel production), REF (refineries), GLS (glass), and PP (pulp and paper) BATC. The REF BATC in particular only sets one BAT related to energy. This therefore is a particular untapped potential. • The (more recent) FDM BREF uses the term “indicative” performance level rather than BAT-AEEL/AEPL. 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 circular economy.
Materials use	• Due to growing concern over access to certain raw materials, the European Commission has created a list of 27 critical raw materials. The chemicals sector (specifically the production of catalysts, fertilisers, polymers, pharmaceuticals and dyes) is a key sector for the consumption of critical raw materials. • The data available on material consumption is taken from the Exiobase database. It is more limited than for other topics and provides information on material flows across sectors up to the year 2011 when the IED came into force. At this date, it is estimated that IED sectors were the major consumers (more than 50% by value and mass) of food, textiles, paper and wood, energy, plastics and chemicals and metal products compared to other industries. They consumed relatively small amounts of electronics and mineral products (less than 30% by value). Pharmaceuticals and chemical production are considered priority sectors due to significant consumption levels of critical raw materials. • After energy and waste, the next largest proportion of BATs on circular economy topics from across all the BATC published is on material consumption. Across all sectors, material minimisation is the most common type of BAT, followed by materials substitution. Material elimination is less common. Just under one third of all BATs were categorised as “other” and concerned measures related to overall management and preparation of materials. • Across all BATs related to materials use, 92% are narrative, i.e. with no associated quantitative performance levels.

Waste generation	• Based on the analysis of waste generation by the IED sectors using the EXIOBASE data, the IED sectors are the major contributor to EU waste generation from industrial activities. Certain types of wastes are mainly generated by one or two IED sectors, for example: o The industrial generation of food waste is almost fully linked to the FDM-sector. Except for the production of vegetable oil, no BAT-AEPLs are set for this sector however. o 87% of industrial textile waste is generated by the sectors TXT and TAN. The BREF for the TXT-sector is in the early stages of review. None of the BATs in the TAN BREF set quantitative targets nor do they specifically address textile waste. o 76% of industrial metal waste is generated by the IS sector. The BATs on waste generation for the IS-sector include integrated and operational techniques for waste minimisation and controlled management of residues which can't be avoided or recycled but all waste generation related BAT for the sector are qualitative. o 66% of all industrial paper waste and half of the industrial wood waste generation is generated by the PP sector. The PP sector has many waste generation related BATs providing techniques, but none with BAT-AEPLs. o 43% of the industrial manure waste is linked to the IRPP sector. BAT on waste generation for the IRPP-sector concerns monitoring the process parameters of manure generation but do not set specific quantitative targets. • BATs related to waste generation are second most frequent (29% of all BATs) across the topics covered in this study. • Across all BATs related to waste generation 97% are narrative, i.e. no associated quantitative performance levels are set. This appears to be an untapped potential for the contribution to the circular economy. • Across all sectors, waste minimisation and recycling are the most common type of waste-related BAT, followed by recovered material quality and waste management
Hazardous chemicals use	• There is no comprehensive data source that collates information on the use of hazardous chemicals in EU 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. • Taking the classification differences between different sources into account, there is relative agreement on the most important end-use sectors that consume chemicals within the EU. Within the IED, these sectors are FDM (largely through plastics use), STS/STM (for any sector that requires treatment of surfaces, such as construction, automotive, basic metals), Pulp and Paper (PP) and Textiles (TXT). • BATs related to hazardous chemical use are less frequent (16% of all BATs in the IED BATC, the same proportion as BATs related to materials use) compared to other circular economy topics covered in this study. • Hazardous chemical use is only prominent in a small selection of BREFs (LVOC, STS, TAN & CLM), the remaining BREFs either have less than 3 relevant BATs, or have no mentions at all. • Across all BATs related to hazardous chemical 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, i.e. no associated quantitative performance levels are set. • Due to the focus on abatement techniques, the majority of mentions of hazardous chemicals concerns their minimisation. From a circular economy perspective, the approach is to eliminate and substitute these chemicals, but the IED BAT conclusions very rarely take this approach. • There are some example of successful use of the IED as a way to reduce the use of hazardous chemicals, either through BATs that state a particular process using a dangerous chemical is not BAT (CAK mercury) or using a BAT-AEPL that minimises the use of a chemical by mandating strict loss reduction measures.

Industrial symbiosis	• BATs related to industrial symbiosis are the least frequent (7% of all BATs) across the circular economy topics covered in this study. The review has identified 26 BATs related to industrial symbiosis across the BATCs. The majority of these relate to the use or recycling of waste in a different process. • The sectors with the highest number of industrial symbiosis-related BATs are the NFM-sector (7), followed by the IS sector (6), and the LCP sector (3). For six BREF sectors, there are no BATs relating to industrial symbiosis: REF, CWW, WI, IRPP, STS and FDM. All other sectors have BATCs that contain at least one BAT relating to industrial symbiosis. • All BATs related to industrial symbiosis are narrative, i.e. no associated quantitative performance levels are set. • The impacts of selected BATs related to industrial symbiosis are illustrated by a series of 5 case studies. Synergetic relationships of mutual interest, resulting in cost reduction for the actors are the main drivers for industrial symbiosis. Most of the time it corresponds to a reduction of cost for the disposal of waste for the donor and a reduction of processing costs for the receiver. While the compliance with waste legislation as well as associated environmental benefits (e.g. reduction of consumption of primary raw materials, avoided emissions) drive industrial symbiosis, the positive corporate image is also taken into consideration by the actors. Expertise provided by a third party with regards to the compliance with the waste legislation and the marketing of secondary raw materials has been shown to be beneficial for some donors. Factors such as the logistics and local regulations are key parameters determining a potential successful symbiosis relationship.

6.1.2 By indicator

A summary of the estimated contribution of the IED to the selected indicators that have been set to monitor the EU's progress towards achieving circular economy objectives is below. The IED is judged in this study to have the highest potential to contribute to the circular economy objectives in waste generation, recycling rates, contribution of recycled materials to raw materials demand and innovation.

Relevant indicators in the circular economy monitoring framework	Current contribution	Potential contribution
EU self- sufficiency for raw materials	Very low	Low
Waste generation	Low	Medium
Food waste	Low	Low
Recycling rates	Low	Medium
Recycling rates for specific waste streams	Very low	Very low
Contribution of recycled materials to raw materials demand	Very low	Medium
Innovation	Very low	Medium

6.2 Recommendations on how to realise untapped potential for the IED to contribute further to the circular economy

The IED has been found to have in general a low contribution to achieving a circular economy. Indeed, the IED as an instrument, according to the DG ENV webpages "aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques (BAT)".

The European Trade Union, in its plea for 'An industrialised circular economy - policy brief 2016-03', states that 'by feeding the industrial production system with re-used, repaired or upgraded products, or with recycled materials, industrial systems keep the value, materials and energy embedded in industrial products longer in use'. The link between the use of re-used, repaired or upgraded products or recycled materials, will only indirectly affect industrial emissions, and probably not even in a positive way (since such products or materials are likely to be less reliable or pure then new products and primary materials. The main focus of circular economy strategies is on longevity, which produces environmental benefits by avoiding mining and production activities.

As a policy which was implemented prior to the formalising of the EU's latest policies to move the bloc towards a circular economy, and which has an expressed aim differing from the circular economy, it is perhaps not unsurprising that the IED is not the ideal instrument to deliver circular economy objectives.

More can be done however to make better use of the IED's existing mechanisms. In defining KEI and subsequently the BAT conclusions for industrial sectors, Technical Working Groups often identify energy use as a KEI in intensive industries; however material use and waste generation are less often identified, and normally dealt with in generic management BATC. The following recommendations have been made to increase the IED's contribution to circular economy objectives.

Nevertheless, it is noted that in the current Sevilla process the TWG decides the KEIs. It would therefore be for the TWG to consider whether the aspects suggested below are appropriate for the sector under consideration. The TWGs have limited resources and must make decisions to prioritise their work.

Consider possible changes to the IED:

- There is potential for the IED to contribute further to innovation in the field of circular economy by promoting better uptake of emerging techniques in industry that have a focus on the circular economy. This could be through the existing testing underway on an innovation observatory.
- The upcoming IED evaluation should be used as an opportunity to consider the way in which circular economy objectives can be integrated in the IED to a greater degree and how the contribution made could be measured. For example:
    - Reconsider which activities are included in Annex I of the IED in light of circular economy topics
    - Making *explicit* reference to circulate economy objectives. The IED was formulated before the CEAP. The 'integrated approach' mandated in the permitting under the IED is *implicitly* able to cover the whole range of circular economy topics.
    - Providing greater flexibility for industrial symbiosis.

Consider changes <u>in general</u> to the content/structure of BREFs:

- Include BATs on materials use, hazardous chemicals use and industrial symbiosis more systematically across the BATC where appropriate, through as a minimum deriving BAT for each circular economy topic identified as KEI.
- Increase the number of BATs on circular economy topics set with quantitative targets. Address any limitations on lack of quantitative data through the BREF data collection process. However, BATs do not have to be quantitative to support the implementation of circular economy strategies in industrial activities
- Mainstream circular economy topics through direct references and use of key words on circular economy related policies, topics, indicators and opportunities:
    - Section providing general information on the sector could overview whether the sector is relevant to circular economy objectives
    - The key environmental issues section could systematically include sub-headings relevant to circular economy issues for sectors where this is appropriate. There could be greater focus on energy and materials (waste) flows within the production chain in which the particular sector takes part, going beyond the sectoral boundaries.
    - Indicate potential side effects elsewhere in the chain when describing the process-related environmental effects
    - Provide more real-life examples of industrial symbiosis.
- Align with REACH, by for example adopting general BATC that promote the elimination and substitution of chemicals that are required to be reported under REACH. (e.g. it is BAT to use chemicals that are not listed as carcinogenic, mutagenic or as having reproductive effects as per their REACH registration). This may be more effective than describing specific chemicals, for which the BREF documents with their 10 year lifespan may not be suitable.

Consider changes to the BREF process exchange of information:

- **The BREF process** could be enhanced by broadening the pool of experts nominated by Forum members to participate in Technical Working Groups to include circular economy experts and experts from other sectors providing materials or receiving by-products/wastes.

- **Switch the way of thinking in BREFs:** Avoid over-focussing on determining BATs for each industrial activity separately. Instead, consider cross-sectoral effects, and determine the value chain BAT through collaboration with upstream and downstream partners to also identify techniques that will reduce environmental impacts elsewhere in the value chain.

Consider changes for reviews of specific BREFs:

- TWGs may decide that hazardous chemicals are a Key Environmental Issue for those sectors where the quantity of chemical use is relatively high (LVOC, PP, TXT, STS/STM, CLM and CAK) and/or where the potential risk from exposure is high (FDM, TXT), to enable BAT conclusions to reference the use of a chemical, rather than only its presence in emissions.
- Circular economy is important for IED sectors currently at an early stage of BREF development process or for which the review has not yet started. These BREF reviews provide an opportunity to address the following high priority circular economy topics with BATs *and ideally quantitative performance levels*:
    - Ferrous metals processing: waste generation;
    - Textiles: waste generation, use of hazardous chemicals;
    - Smitheries and foundries: waste generation;
    - Slaughterhouses and animal by-products: energy use, waste generation;
    - Waste gas chemicals (to cover POL/OFC/SIC sectors): energy use, waste generation. There is a risk that the potential for the IED to promote use of alternative and secondary raw materials in the chemical production sector will be missed because the WGC BREF do not cover waste management or raw materials.
    - Large volume inorganic chemicals: energy use, materials use. For this sector (LVIC-AAF), which is a significant consumer of critical raw materials in the manufacture of fertilisers, it will be of particular importance to focus on materials use.
- Consider an additional horizontal BREF on circular economy.
- When considering the economic viability of available techniques for the reduction of use of hazardous chemicals (or releases of such chemicals), further consideration should be given to alternative business models that may make such techniques viable. An example is the business model of chemical leasing.
    - While in a traditional chemical industry business, profit depends on turnover, and the more chemicals are sold, the more revenue is attained. In **chemical leasing**, instead the ‘use of the chemical’ as a service is monetised. The supplier sells the function of the chemical. The supplier of chemicals no longer measures success according to the volume of chemicals supplied, and has a cost-driven incentive to reduce, re-use or recycle the volume while maintaining the same function. This aligns interests of supplier and user in reducing chemical use at all elements of the supply chain (circle).
    - From a policy perspective, the EU Council delegations has mentioned chemical leasing when discussing key issues in chemicals policy (Council of the European Union, 2014), as a way to optimise the cost-benefit balance towards benefitting the environment more. The objectives of the IED can directly and indirectly be supported by this business model, as it is able to effectively reduce resource use in practical applications that are governed by the IED, such as the surface treatment of metals in automotive production, whereby an example implementation for a car manufacturer in Poland also indirectly reduced chlorine emissions to water by 70% (OECD, 2017).

Improve how the contribution of the IED to the circular economy can be tracked and monitored:

- Refine the Circular Economy Monitoring Framework to make sure that indicators are relevant to IED industry
- Consider whether existing EU monitoring tools such as the raw materials and/or resource efficiency scoreboards can be expanded on.
- At the level of the individual installation or sector, build on existing indicators such as the Material Circularity Indicator.

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Appendices

Appendix 1 Status of BREF reviews and BATC published[52]

Sectors covered by the IED

BREF reviewed and BATC published (1)

- Manufacture of Glass (March 2016)
- Iron and Steel Production (March 2016)
- Tanning of Hides and Skins (February 2017)
- Production of Cement, Lime and Magnesium Oxide (April 2017)
- Production of Chlor-alkali (December 2017)
- Production of Pulp, Paper and Board (September 2018)
- Refining of Mineral Oil and Gas (October 2018)
- Wood-based Panels Production (November 2019)
- Common Waste Water and Waste Gas Treatment / Management Systems in the Chemical Sector (June 2020)
- Non-ferrous Metals Industries (June 2020)
- Intensive rearing of poultry and pigs (July 2021)
- Large combustion plants (July 2021)
- Large volume organic chemicals (December 2021)
- Waste treatment (August 2022)

BREFs at different stages of the review

Pre-kick off meeting of Technical Working Group

- Slaughterhouses and Animal By-products
- Smitheries and Foundries

Preparation of Draft 1

- Common Waste Gas Treatment in the Chemical Sector
- Textiles

Draft 1 published

- Surface Treatment using organic Solvents, including Wood and wood-products Preservation with Chemicals
- Ferrous Metals Processing

Final draft published

- Waste Incineration
- Food, Drink and Milk (pending adoption)

BREFs for which review has not yet started (2)

- Ceramics industry
- Surface Treatment of Metals and Plastics
- Large Volume Inorganic Chemicals

Notes: (1) Dates in brackets are deadlines for compliance with BATC requirements; (2) BREFs for Manufacture of polymers, Organic fine chemicals and Speciality inorganic chemicals will not be reviewed under the IED.

[52] Based on the presentation by the EIPPCB given at the IED Article 13 Forum meeting in November 2018 https://circabc.europa.eu/sd/a/6ee47201-ff9c-44a0-8869-6ef1aeb9adb2/6.%20Work%20programme.pdf

Appendix 2 Literature register

Appendix 2 SR13
Data register.xlsx

Appendix 3 BREF data extraction process

Appendix 3 BREF
data extraction proc

Appendix 4 BATC database

[Provided separately]

Appendix 5 Mapping of Eurostat Energy Balance Indicators to IED sectors

Annual data on quantities for crude oil, petroleum products, natural gas and manufacture gases, electricity and derived heat, solid fossil fuels, renewables and wastes covering the full spectrum of the energy sector from supply through transformation to final consumption by sector and fuel type is available in the Eurostat database Energy statistics- -supply, transformation and consumption [nrg_10). Eurostat 'Simplified energy balances - annual data [nrg_100a]' has been extracted to show energy use trends for activities relevant to the IED. This dataset has been chosen because it was previously identified as the most appropriate record of energy consumption from industrial sectors in the IED Country Profiles study[53]. The latest update of Eurostat data (Updated May 2018) has been conducted and the available time series extends to 2016. Simplified energy balances use energy balance indicators which have their own classification codes but which are built on NACE Rev2 classification. As part of the IED Country Profiles study, these codes were mapped as closely as possible to IED sectors. The same classification has been used here, with some alterations due to this study's focus on the BAT Conclusions:

- Coke ovens, included under energy refining in the SR3 study due to the IED activity coding, is included in the iron and steel sector.
- Activities which were grouped under 'other activities' according to IED activity coding are presented separately in this study.

Industrial sectors for energy consumption	Energy balance indicators	IED BREF/ BATC
Energy – power	B_101301 - Own Use in Electricity, CHP and Heat Plants	LCP
Energy: refining, gasification and liquefaction	B_101307 - Consumption in Petroleum Refineries B_101314 - Consumption in Gas Works B_101316 - Consumption in Coal Liquefaction Plants B_101317 - Consumption in Liquefaction (LNG) / regasification plants B_101319 - Consumption in Gas-to-liquids (GTL) plants (energy) B_101320 - Consumption in Non-specified (Energy)	REF
Metals: iron and steel	B_101315 - Consumption in Blast Furnaces B_101805 - Iron and Steel B_101312 - Consumption in Coke Ovens	I&S
Metals: non-ferrous	B_101810 - Non-Ferrous Metals	NFM
Minerals	B_101820 - Non-Metallic Minerals	CER GLS
Chemical	B_101815 - Chemical and Petrochemical	LVOC CAK
Waste: hazardous	*No indicator available*	
Waste: non-hazardous	B_101318 - Consumption in Gasification plants for biogas	WT WI
'Other activities' (Assessed separately in this study)	B_101830 - Food and Tobacco B_101840 - Paper, Pulp and Print B_101851 - Wood and Wood Products B_101835 - Textile and Leather	FDM PP WBP TAN TXT

[53] https://circabc.europa.eu/webdav/CircaBC/env/ied/Library/studies/Country%20Profiles/

The following limitations arise from this mapping:

- Several of the sectors represented are expected to overestimate the IED activity due to broader scope:
    - The ‘B_101301 - Own Use in Electricity, CHP and Heat Plants’ is broader in scope than the LCP BREF due to inclusion of plants smaller than 50MWth which are below the IED threshold. This is expected to lead to an overestimate of activity in relation the LCP BREF.
    - The energy balance indicator for the chemical activity grouping includes petrochemicals and is expected therefore be an overestimation of activity in relation to the chemical BREFs.
    - B_101840 - Paper, Pulp and Print is broader in scope than the PP BREF as IED activity 6.1 includes a threshold on installation size- there is therefore expected to be an overestimate of energy use in relation to the PP BREF.
    - Energy consumption is reported at an aggregated level for B_101830 Food and Tobacco. This is broader in scope than IED activity 6.4 (which includes specific food products, slaughterhouses and milk production) as it also includes tobacco and the full food and drinks sectors. This is expected to overestimate energy use in relation to the FDM BREF.
    - Energy consumption is reported at an aggregated level for B_101835 Textile and Leather.
- No detail is available for the energy balance indicators to show the industrial sector split for mineral subsectors. The mineral industry is therefore presented in aggregate.
- There are no data to represent some IED activities.
    - Limited data is available for waste management – this results in an underestimation of the data reported for the waste management industrial sectors. The energy consumption data that has been used has only limited coverage of the waste management sector. Data for this sector is therefore expected to be underreported as only one energy balance indicator was identified as relevant to this industrial sector: the energy consumed by gasification plants for biogas. The energy consumption dataset has poor representation of the waste management sector. The only indicator identified in the Energy statistics as representing waste management (non-hazardous) is B_101318 - Consumption in Gasification plants for biogas. It is not clear in which energy balance indicators the remaining waste management industry is categorised (it could be potentially under power production or as other non-specified industry. This is a significant gap in the overall energy consumed by IED activities considering the number of installations within this grouping.
    - No energy consumption data was identified for surface treatment (STS BREF), or intensive rearing of poultry or pigs (IRRP BREF). Energy consumption data for these activities may or may not be included in the ‘non-specified industry’ reporting category in Eurostat.
    - In some cases, data for BREFs which are missing from Eurostat may be filled by using Exiobase, notably IRRP and WT/WI.

Appendix 6 Mapping of Exiobase sectors to IED sectors

Industrial activity (NACE)	IED BREF	Abbreviation
Pigs farming	Intensive Rearing of Poultry and Pigs	IRPP
Poultry farming		
Processing of meat cattle	Food Drink and Milk Industries	FDM
Processing of meat pigs		
Processing of meat poultry		
Production of meat products nec		
Processing vegetable oils and fats		
Processing of dairy products		
Processed rice		
Sugar refining		
Processing of Food products nec		
Manufacture of beverages		
Manufacture of fish products		
Manufacture of textiles	Textiles Industry	TXT
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	Tanning of Hides and Skins	TAN
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Wood-based Panels Production Surface treatments using organic solvents (for wood preservation using chemicals)	WBP STS
Re-processing of secondary wood material into new wood material	Wood-based Panels Production	WBP
Pulp	Production of pulp, paper and board	PP
Re-processing of secondary paper into new pulp		
Paper		
Publishing, printing and reproduction of recorded media	Surface treatments using organic solvents *(for wood preservation using chemicals)*	STS
Manufacture of coke oven products	Iron and steel production	IS
Petroleum Refinery	Refining of Mineral Oil and Gas	REF
Plastics, basic	Production of polymers	POL
N-fertiliser	Large volume inorganic chemicals - Ammonia, acids & fertilisers	LVIC-AAF
P- and other fertiliser		
Chemicals nec	*Potentially all chemical BREFs*	

Industrial activity (NACE)	IED BREF	Abbreviation
Manufacture of rubber and plastic products	Production of polymers	POL
Manufacture of glass and glass products Re-processing of secondary glass into new glass	Manufacture of glass	GLS
Manufacture of ceramic goods Manufacture of bricks, tiles and construction products, in baked clay	Ceramic Manufacturing Industry	CER
Manufacture of cement, lime and plaster Re-processing of ash into clinker	Production of Cement, Lime and Magnesium Oxide	CLM
Manufacture of other non-metallic mineral products n.e.c.	Large Volume Inorganic Chemicals - Solids and Others Industry	LVIC-S
Manufacture of basic iron and steel and of ferro-alloys and first products thereof	Iron and Steel Production Smitheries and Foundries Industry Non-ferrous metals industries *(for ferro-alloys)*	IS SF NFM
Manufacture of gas; distribution of gaseous fuels through mains	Refining of Mineral Oil and Gas	REF
Re-processing of secondary steel into new steel	Iron and Steel Production	IS
Precious metals production Re-processing of secondary precious metals into new precious metals Aluminium production Re-processing of secondary aluminium into new aluminium Lead, zinc and tin production Re-processing of secondary lead into new lead Copper production Re-processing of secondary copper into new copper Other non-ferrous metal production Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	Non-ferrous metals industries	NFM
Casting of metals	Smitheries and foundries	SF
Manufacture of fabricated metal products, except machinery and equipment	Ferrous metals processing industry Non-ferrous metals industries Surface treatment of metals and plastics Surface treatments using organic solvents	FMP NFM STM STS
Manufacture of motor vehicles, trailers and semi-trailers	*(for surface treatment)* Surface treatment of metals and plastics Surface treatments using organic solvents	STM STS

Industrial activity (NACE)	IED BREF	Abbreviation
Manufacture of other transport equipment	*(for surface treatment)* Surface treatment of metals and plastics Surface treatments using organic solvents	STM STS
Recycling of waste and scrap	Waste treatment industries Non-ferrous metals industries Iron and Steel Production	WT NFM IS
Production of electricity by coal	Large Combustion Plants	LCP
Production of electricity by gas		
Production of electricity by petroleum and other oil derivatives		
Production of electricity by biomass and waste	Large Combustion Plants Waste Incineration	LCP WI
Re-processing of secondary construction material into aggregates	Waste treatment industries Ceramic Manufacturing Industry	WT CER
Incineration of waste: Food	Waste incineration	WI
Incineration of waste: Paper		
Incineration of waste: Plastic		
Incineration of waste: Metals and Inert materials		
Incineration of waste: Textiles		
Incineration of waste: Wood		
Incineration of waste: Oil/Hazardous waste		
Biogasification of food waste, incl. land application	Waste treatment industries	WT
Biogasification of paper, incl. land application		
Biogasification of sewage slugde, incl. land application		
Composting of food waste, incl. land application		
Composting of paper and wood, incl. land application		
Waste water treatment, food		
Waste water treatment, other		

Appendix 7 Sector factsheets

Appendix 7 Sector
Factsheets.docx

Appendix 8 List of IED installations identified as applying industrial symbiosis related BATs

Sector	Product / Sub-Sector	BAT Number	Text of relevant BAT	Examples of IED plants		
				Donor	Receiver	Country
Glass Manufacturing	All	BAT 14	BAT is to reduce the production of solid waste to be disposed of by using one or a combination of the following techniques: (...) Valorisation of solid waste and/or sludge through appropriate use on-site (e.g. sludge from water treatment) or in other industries (…)	Glass manufacturer	Bet-Ker Oy (refractory materials manufacturer)	Finland
				Panimoyhtiö Hiisi (glass manufacturer)	Glass blower/glass artist	Finland
				Glass manufacturer	Valoref (refractory materials manufacturer)	France
Iron and Steel	Generic	BAT 9	BAT is to maximise external use or recycling for solid residues which cannot be used or recycled according to BAT 8, wherever this is possible and in line with waste regulations. BAT is to manage in a controlled manner residues which can neither be avoided nor recycled.	Tata Steel	ENCI (cement production company)	Netherlands
				ArcelorMittal	Cement making industry	Belgium
	Basic Oxygen Furnace	BAT 82	BAT is to prevent waste generation by using one or a combination of the following techniques (see BAT 8): BAT is to manage in a controlled manner basic oxygen furnace process residues which can neither be avoided nor recycled.	Voestalpine Stahl GmbH	Zinc Industry	Austria
	Electric Arc Furnace	BAT 93	BAT is to prevent waste generation by using one or a combination of the following techniques: BAT is to manage in a controlled manner EAF process residues which can neither be avoided nor recycled.	ArcelorMittal	Construction Industry	Luxemburg
				BSW	Construction Industry	Germany

Sector	Product / Sub-Sector	BAT Number	Text of relevant BAT	Examples of IED plants		
				Donor	Receiver	Country
				Georgsmarienhütte GmbH	Construction Industry	Germany
				Salzgitter Stahl AG	Construction industry	Germany
Non-ferrous metals	Copper	BAT 54	In order to reduce the quantities of waste sent for disposal from primary and secondary copper production, BAT is to organise operations so as to facilitate process residues reuse or, failing that, process residues recycling, including by using one or a combination of the techniques given below:	Aurubis	Construction industry	Bulgaria
			(…) Use the slag from the slag flotation as an abrasive or construction material or for another viable application (…)			
			(…) Use the final slag from furnaces as an abrasive or (road) construction material or for another viable application (…)	Montanwerke Brixlegg AG	Construction industry	Austria
Chlor-Alkali	Generic	BAT 4	In order to reduce the generation of waste water, BAT is to use a combination of the techniques given below: (…) Recycling of salt-containing waste water from other production processes (…)	Port of Antwerp; Chemical Industry cluster	Solvic	Belgium
	Generic	BAT 14	In order to reduce emissions of chlorate to water from the chlor-alkali plant, BAT is to use one or a combination of the techniques given below: Waste water streams of the chlor-alkali plant are recycled to other production units		AkzoNobel	Germany
					Dow	Germany
					Sabic	Netherlands
					Zachem	Poland
					Solvay	Portugal
					Electroquímica	Spain
					Kemira	Finland

Sector	Product / Sub-Sector	BAT Number	Text of relevant BAT	Examples of IED plants		
				Donor	Receiver	Country
Large Combustion Plant	All	BAT 16	In order to reduce the quantity of waste sent for disposal from the combustion and/or gasification process and abatement techniques, BAT is to organise operations so as to maximise, in order of priority and taking into account life-cycle thinking: a. waste prevention, e.g. maximise the proportion of residues which arise as byproducts; b. waste preparation for reuse, e.g. according to the specific requested quality criteria; c. waste recycling; d. other waste recovery (e.g. energy recovery), by implementing an appropriate combination of techniques such as: Recover gypsum as by product; increase quality of gypsum	Ørsted	Gyproc	Denmark
				Power plant company	Cement manufacturer	Austria (Hartberg Eco-park)

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