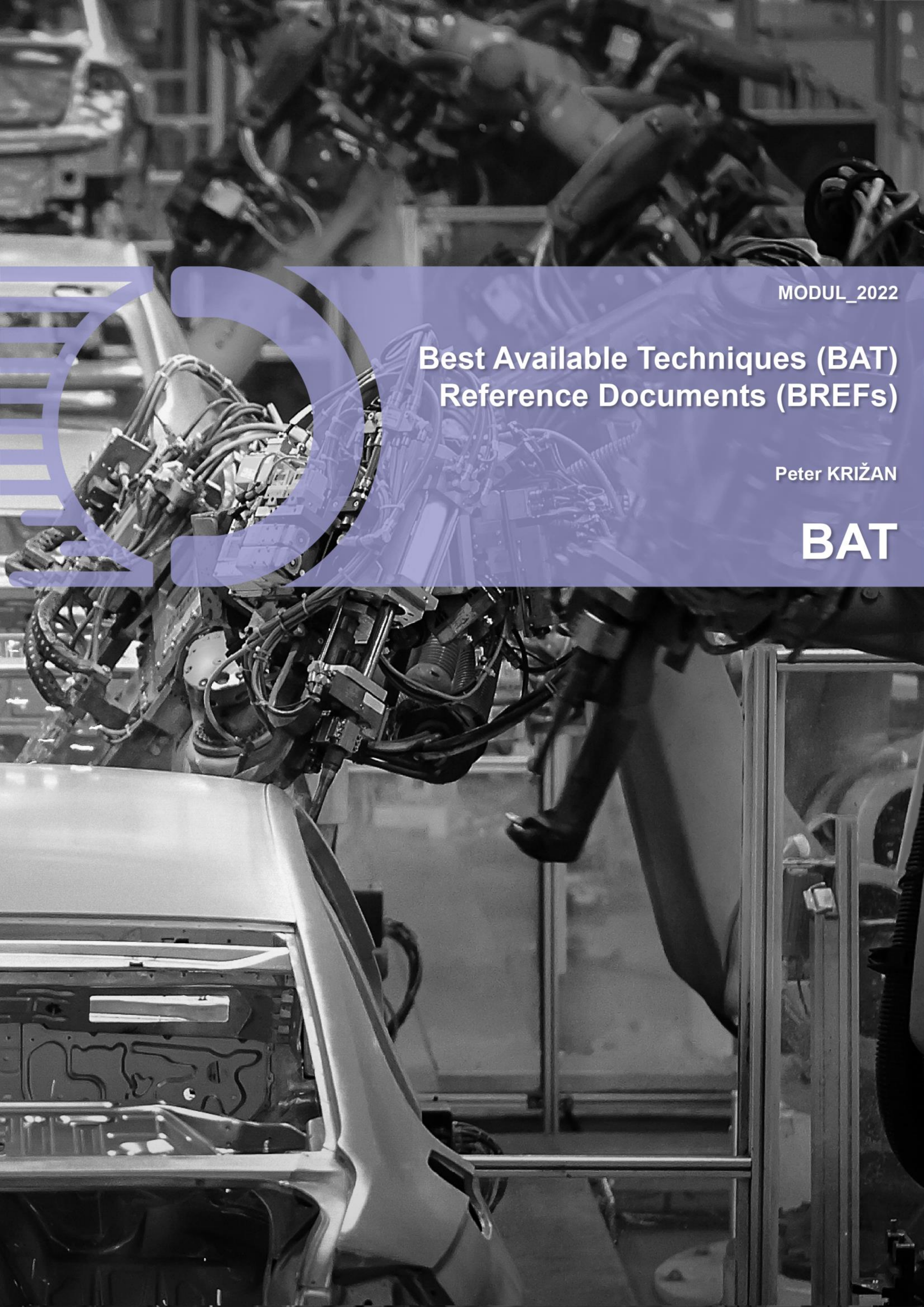

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Best Available Techniques (BAT) Reference Documents (BREFs)

Peter KRIŽAN

BAT

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1. INTRODUCTION TO BEST AVAILABLE TECHNIQUES (BAT)

To ensure a high level of protection for human and environmental health, different policies and practices are being implemented around the world. BATs (best available techniques) are incorporated into many of these policies. For the purpose of preventing and controlling industrial emissions, the BAT concept has the potential to play a crucial role in setting emission limit values. As a concept, BAT has gained international acceptance and been incorporated into national environmental regulations as well as those of the European Union and other international organizations.

EU approved the Integrated Pollution Prevention and Control (IPPC) Directive in 1996 [1].The IPPC Directive gives the definition of BAT which is used throughout Europe today.

BAT MEANS [1]:

"*the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole*:
• *"techniques" shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned,*
• *"available" techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,*
• *"best" shall mean most effective in achieving a high general level of protection of the environment as a whole."*

To achieve '**a high level of environmental protection overall**,' specific industrial activities will need to be authorized. It includes measures aimed at preventing or reducing emissions to air, water, and land, as well as those aimed at improving energy efficiency and waste reduction. A major objective of the Directive [1] is to utilize the best available techniques while taking local conditions into consideration. A distinction is made between the Directive and previous legislation that dealt exclusively with air emissions and water emissions. It is therefore necessary for manufacturers and authorities to consider emissions to all environmental media and other effects when designing plants ('**clean technology**') as opposed to relying on '**end-of-pipe**' techniques.

In determining the best available techniques, according to [1], special consideration should be given to the **listed items**:

1. the use of low-waste technology;
2. the use of less hazardous substances;
3. the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;
4. comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;
5. technological advances and changes in scientific knowledge and understanding;
6. the nature, effects and volume of the emissions concerned;

7. the commissioning dates for new or existing installations;
8. the length of time needed to introduce the best available technique;
9. the consumption and nature of raw materials (including water) used in the process and their energy efficiency;
10. the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;
11. the need to prevent accidents and to minimize the consequences for the environment;
12. information published by public international organizations;

The Directive may also be thought of as a '**framework'** measure. This is because it provides for common EC emission limits to be adopted at a later date. In addition, it creates a new structure within which certain existing quantitative EC standards are to be applied. **Key elements** include:
• Requirement for installations to implement BAT;
• Requirements for installations to have integrated permits;
• A key decision is whether to set site specific emission limit values (ELVs) that encourage appropriate BATs, although, in practice, governments might issue guidance on ELVs that, while not obligatory, are generally incorporated into permit conditions.

As part of the implementation of the Directive it was decided that the EU should develop so called BREF documents (BAT reference documents), which describe the best available techniques in each industrial sector as well as techniques that can be applied in several sectors. A total of 33 BREF documents are to be produced.

Among the **six categories of industries** covered by the Directive are energy, metals and minerals production and processing, chemicals, waste management, and 'other' [2]. 'Other' facilities are engaged in pulp and paper production, textile treatment, tanning, food production, and intensive pig and poultry rearing. The scope of the Directive differs according to each category, either by the nature of the product or process, or its size.

According to the European Commission Directive 2010/75/EU [3] is an excellent example of how BATs are understood in most countries. '**Best available techniques**' means the most effective and advanced stage in the development of activities and their methods of operation, which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole. The Directive [3] also presents the listed items above as a criteria for determining best available techniques.

From the conclusions of the Stockholm Convention on Persistent Organic Pollutants, the use of the best available technology shall be encouraged in some cases and required in others. In addition, we shall promote the application of best environmental practices.

On the base of Guidelines on BAT and provisional guidance on best environmental practices [4], for the purposes of Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants [5] the definitions are as follows:
"**Best available techniques**" means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for release limitations designed to prevent and, where that is not practicable, generally to reduce releases of chemicals listed in Part I of Annex C and their impact on the environment as a whole. In this regard:

"**Techniques**" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
"**Available**" techniques means those techniques that are accessible to the operator and that are developed on a scale that allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages; and
"**Best**" means most effective in achieving a high general level of protection of the environment as a whole;
"**Best environmental practices**" means the application of the most appropriate combination of environmental control measures and strategies;

When applying best available techniques and best environmental practices, participants should take into consideration the general guidance on prevention and release reduction measures in Annex C [6] and guidelines on best available techniques and best environmental practices to be adopted by decision of the Conference.

2. BAT RELATED POLICIES IN THE EUROPEAN UNION (EU)

For some time, industrial emissions have been subject to EU-wide legislation. All these policies represent a technology-based approach to prevention and control of industrial emission, whether or not combined with an environmental quality-based approach. IED (industrial emissions directive) 2010/75/EU replaces seven earlier pieces of legislation regulating industrial emissions [7], including IPPC 1996/61/EC and LCP 2001/80/EC. Using an integrated approach, the IED outlines the main principles for permitting and controlling installations. In order to ensure compliance with permit conditions, including emission limit values (ELVs), the best available techniques must be used. It is also important to note that the IED creates an important relationship between the permit conditions and the BAT.

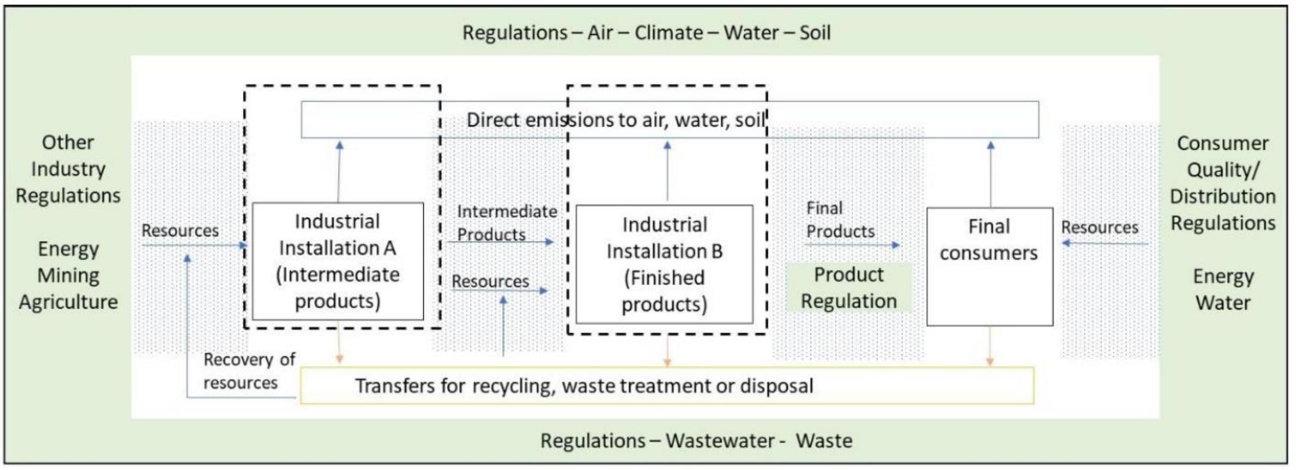
There are also three **policy frameworks** that must be mentioned: the EU Eco-Management and Audit Scheme (EMAS) regulation, the Directive on Stage I Petrol Vapour Recovery (PVR), and the Medium Combustion Plant Directive (MCP). In accordance with the EMAS Regulation, organizations may participate in the Eco-Management and Audit Scheme on a voluntary basis. EMAS promotes best environmental management practice (BEMP) through Sectorial Reference Documents (SRDs), which should be considered by registered organisations when assessing their environmental performance.

By reducing emissions from volatile organic compounds caused by evaporation of petrol, the Directive 1994/63/EC on petrol storage and distribution aims to significantly reduce greenhouse gas emissions. Technical requirements included in this directive's annexes are synonymous with when BAT is used; although the requirements are now somewhat outdated 23 years after they were written.

As part of the Directive 2015/2193/EU on medium combustion plants (MCP), the Directive sets out rules for controlling air emissions of sulphur dioxide (SO2), nitrogen oxides (NO_x), and dust from medium combustion plants, as well as regulating the monitoring of carbon monoxide (CO) emissions from these plants. With this directive, the potential harm to human health and the environment from plants with rated thermal inputs of 1 MWth or greater and less than 50 MWth is minimized. A requirement of Article 6 (10) of the Directive requires the

Commission to organize an exchange of information with the Member States and stakeholders regarding the emission levels and cost associated with the best available and emerging technologies.

Best Available Techniques (BAT) are usually established at the level of each industrial sector or activity to prevent or reduce emissions and the impact on the environment as a whole. Regulatory authorities typically set requirements for installation operations to prevent or reduce emissions to air, water, soil, energy and water consumption, and waste management through treatment or disposal. As shown in Figure 1, regulatory authorities tend to focus on installation activities that produce intermediate products or finished products depending on the size of the installation.



1-1.Figure_Illustration of BAT regulatory framework

Notes:
1. Dashed lines represent the industrial installation/activity regulated by BAT. Certain activities may supply materials to other regulated industries.
2. Grey dotted sections represent market interactions that may influence use of resources and products at each stage.
3. Framing the illustration are multiple regulations that protect natural resources, environment, and human health.

While procedures for establishing BAT aim to consider the most effective technologies and methods available considering the cost and the required site-specific environmental protection benefits, broad accounting of upstream and downstream interactions can be difficult. The extent to which particular countries and BAT policies consider the interactions within the value chain systematically or for specific sectors is unclear.

In general, establishing BAT takes 2 to 4 years with periodic review between 8 to 12 years, requiring resources and time for adequate consideration. When determining BAT for sector-specific activities, consideration of up- or downstream interactions of the sector's value chain may be limited. That is, a sector-specific activity may be impacted by upstream suppliers and affect downstream activities including further processing or consumer use that are not necessarily considered in BAT determinations. Additionally, the sector of focus could impose requirements upon upstream markets or be affected by downstream regulatory or market requirements.

Environmental regulation along with other regulatory requirements and market decisions define the framework within which an industrial installation operates. Sector activities, including essential inputs, are increasingly fragmented across the globe with installations carrying out a variety of different industrial processes. The different processes and installations from an individual production chain may be located in different countries

2.1 INDUSTRIAL EMISSIONS DIRECTIVE (IED)

A general framework based on integrated permitting has been developed by the EU in order to prevent and control industrial emissions. To avoid pollution being transferred from one environment medium to another, the permits must consider a plant's entire environmental performance. At the source, pollution should be prevented in the first place. Earlier pieces of legislation regarding industrial emissions are reformulated in the Industrial Emissions Directive (IED). In addition to preventing and controlling pollution into the air, water, and land (soil), it lays down regulations that ensure the efficient use of resources and avoid the generation of waste from large industrial installations.

The IED consists of the following **key elements** [7]:

• The best available techniques (BATs) must be applied to all installations covered by the IED in order to prevent and control industrial emissions. Furthermore, energy and other resources, such as water, must be used efficiently, wastes must be disposed of and accidents must be prevented and minimized.
• Unless they have an integrated permit, installations cannot operate. A permit condition set by the competent authority must be followed by the installations.
• These permit conditions are set in accordance with the BAT conclusions adopted by the Commission. To ensure pollutant emissions do not exceed the levels associated with BATs, emission limit values must be set at a level that keeps them within the limit values. Competent authorities are allowed some flexibility to set emissions limits under strict and justified conditions under the IED.
• Regular environmental inspections of the installations are required by the competent authorities.
• Permitting is subject to public participation.

The IED also sets EU-wide emission limit values for certain pollutants associated with certain activities (e.g. large combustion plants, waste incineration and co-incineration plants, solvent use and titanium dioxide production). A process of information exchange is undertaken by the European Commission in order to define BAT and BAT-associated environmental performance levels at EU level with experts from Member States, industry, environmental NGOs, and services of the Commission. Together, they form the Technical Working Group (TWG). European IPPC Bureau in Seville (Spain) is responsible for coordinating this work for the JRC Joint Research Centre. Located within JRC Directorate B's Circular Economy and Industrial Leadership Unit, the European IPPC Bureau contributes to that unit's research on the circular economy and industrial leadership. The Joint Research Centre (JRC) has six scientific directorates, including Growth and Innovation. Documents containing BAT reference information (BREFs) are produced during this process. EU law recognizes the BAT conclusions contained in BREFs as Implementing Decisions adopted by the Commission.

Using the IED, IPPC installations must be issued national permits containing emission limits based on BAT. It may be more effective to control pollution in air, water, and soil collectively than to control pollution in any one environment medium separately. In order to prevent and control emissions into air, water, and soil, to manage waste, and to conserve energy, the IED provides an integrated approach to these activities. Bringing environmental performance requirements for industrial installations into alignment will also help to create a level playing field in the European Union.

Pollutants to which the policy applies is separately settled for emissions to air, for emissions to water. In Annex II of the IED, substances are listed as air and water pollutants. The substance definition in the Directive does not directly relate to soil, but Articles 22 and 3 (18) refer to the classification, labeling, and packaging of soil substances. Due to the lack of explicit mention of the pollutants in Annex II of the IED, some boxes are not checked. IED may apply to them, however, if they exhibit certain characteristics (e.g. cancer-causing) or contain certain components (e.g. chlorine), or if they are emitted in significant quantities, based on the fact that they can be transferred between environments.

For each sector, TWG members identify key environmental issues for determining (or updating) BAT conclusions as described in the BREF guidance. Key environmental issues are defined as “issues for which BAT conclusions have the highest likelihood of resulting in noteworthy additional environmental benefits.” Sector (or activities) to which the policy applies are energy, production and processing of metals, mineral industry, chemical industry, wastewater management, paper and wood production and processing, intensive livestock production and aquaculture, animal and vegetable products from the food and beverage sector and other activities.

In terms of preventing and controlling industrial emissions, the IED represents a technology-based approach. Best available techniques (BAT) make up an important part of the IED. The term 'techniques' must be understood to encompass both the technology in use and the procedures involved in designing, building, operating, and decommissioning an installation. As a reference for setting the permit conditions, the European Commission has adopted BAT conclusions, including BAT and BAT associated performance levels. It is important to understand that the IED creates a very important relationship between permit conditions (technology-based) and emission limit values and environmental quality standards. In article 18, the following is stated: "In case an environmental quality standard requires conditions that are harder to meet than those achievable through the best available technique," additional measures may be included in the permit, without prejudice to any other measures that may be taken to comply with the standard. In this way, the IED entails a mandatory use.

2.2 EMAS REGULATION

The EMAS Regulation requires organizations to participate in EMAS, the Community's eco-management and audit scheme, on a voluntary basis. A key objective of EMAS is to help organisations improve their environmental performance by establishing and implementing environmental management systems. An organization's performance should be evaluated objectively, systematically and periodically, and information on environmental performance should be provided, along with an open dialogue with the public and other interested parties and training for employees. An organization must meet the following **requirements in order to receive EMAS registration** [7]:

• Review and identify the significant environmental aspects of the organization.
• Apply the best environmental management practices for the relevant sector after the environmental review and develop and implement an environmental management system.
• An internal audit should be conducted.
• Ensure that an environmental statement is prepared (reporting).

An accredited environmental verifier must approve the environmental review, management system, audit procedure, and statement. Public disclosure and registration are required for validated statements. Those organizations that successfully complete all stages may use the EMAS logo to demonstrate their dedication to improving their environmental performance. Environmental management systems (EMAS) promote best environmental management practices (BEMP). The documents that serve this purpose are referred to as Sectorial Reference Documents (SRDs). In addition to detailed technical information describing best environmental management practices to improve environmental performance, these SRDs also contain sector-specific environmental performance indicators and benchmarks of excellence or rating systems that identify environmental performance levels. When assessing the environmental performance of an EMAS registered organization, the relevant SRDs must be considered. A voluntary instrument for assessing, improving, and reporting an organization's environmental performance, EMAS is introduced by the EMAS Regulation. An organization's EMAS serves as a tool for management, planning, and reporting.

EMAS Regulations require organisations to report on their environmental performance based on generic and sector-specific performance indicators, focusing on key environmental aspects at production level, and comparing results with relevant benchmarks. By doing so, the organization will be able to compare its environmental performance over different reporting periods as well as against sectorial, national or regional benchmarks. There are several environmental aspects that should be considered, including: emissions to air; releases to water; production, recycling, reuse, transportation and disposal of solid and other wastes, particularly hazardous wastes; use and contamination of land; use of natural resources and raw materials (including energy); use of additives and auxiliaries as well as semi-manufactured goods; local issues (noise, vibration, odour, dust, visual appearance, etc.); transport issues (both for goods and services); risks of environmental accidents and impacts arising, or likely to arise, as consequences of incidents, accidents and potential emergency situations; and effects on biodiversity.

The following indicators apply to all types of organizations, for example: energy efficiency, material efficiency, water, waste, biodiversity, and emissions. The issue of emissions relates to greenhouse gas emissions (such as CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6), SO_2, NO_x, and particulate matter to the atmosphere. The consumption of water relates to water. Organizations are exempt from reporting if they demonstrate an appropriate justification for claiming that the indicator does not apply to their specific situation.

Initially, EMAS was only available to organisations in industrial sectors, and was available for participation since 1995. All organizations, regardless of size, type, or sector, have been able to participate in EMAS since 2001. **A number of SRDs have been developed** or are in the process of being developed, including:
• Car manufacturing,
• Electrical and electronic equipment manufacturing,
• Fabricated metal products manufacturing,
• Food and beverage manufacturing,
• Construction,
• Agriculture - Crop and animal production,
• Retail trade,
• Tourism,
• Telecommunication and ICT Services,

• Waste management.

Regulations such as the EMAS are considered technologies-based policies designed to manage and control industrial emissions. Every critical step of EMAS implementation is guided by "best environmental management practices" (BEMPs). SRDs and BEMPs are used by EMAS-registered organizations for developing and assessing their environmental management systems (Article 4) and for reporting their environmental performance (Annex IV). In addition, environmental verifiers are also responsible for verifying and validating the environmental management system (Article 18).

As part of the European Commission's Joint Research Centre (JRC), BEMPs are identified, evaluated and documented for different sectors in close collaboration with stakeholders. For this reason, the JRC follows what is called the frontrunner approach. Innovative solutions are implemented at full scale by frontrunners that allow them to achieve the best environmental performance. In order to identify the practices that are most advanced in terms of environmental performance, the JRC examines techniques, measures, and actions that are implemented by leading organisations in each sector. During this process, best environmental management practice sectorial reference documents (SRDs) are developed. So, learning from frontrunners is the essence of SRDs.

The term "**best environmental management practice**" (BEMP) refers to those techniques, measures and actions which result in the best possible environmental performance and have been proven to be technically feasible and economically viable. Among the sources of BEMPs are not only technical or technological ones but also soft actions and management choices. The environmental impacts of the products and services of the organizations of the sector are considered not only within the physical boundaries of their premises, but also throughout their entire value chain. Best practices must meet two key criteria: the best practice has been implemented or at least adopted by a number of organizations in the sector, or at least by one organization if replicable/applicable by others; and the best practice is viable economically and technically.

2.3 THE MEDIUM COMBUSTION PLANT (MCP) DIRECTIVE

MCP Directive is one of the policies´ option which are intended for prevention and control of industrial emissions to air. In the Medium Combustion Plant (MCP) Directive, rules are established to control air pollution from medium combustion plants, such as sulphur dioxide (SO_2), nitrogen oxides (NOx), and dust. Further, rules are established to monitor carbon monoxide (CO) emissions from these plants. The goal is to reduce emissions to the air and potential harm to human health and the environment from these plants. Annex II specifies emission limits. National permits for so-called MCP-installations must set emission limit values consistent with the MCP Directive, which serves as a command and control instrument. A plant that has a thermal output between 1 megawatt and 50 megawatts (MWth) is subject to the MCP Directive, which regulates pollutant emissions from combustion of fuel. There are various applications for medium combustion plants (electricity generation, heating/cooling of residential or commercial buildings, providing heat/steam for industrial processes, etc.).

An impact assessment based on EU's former air pollution strategy identified measures allowing MCPs to reduce emissions cost-effectively. A comparison was made between

different measures to achieve air quality objectives. Comparing the effectiveness, efficiency, and coherence of approaches based on qualitative and quantitative criteria was the basis of the comparison [7]:
- Effectiveness: Emission reduction,
- Efficiency: Pollutant abatement cost,
- Coherence: EU compliance with international obligations, administrative costs and impacts on SMEs.

The MPC Directive requires MCPs greater than 5MW to meet the emission limits for SO2, NOx, and PM which are set out in Annex II. MCPs greater than 5MW must comply with these emission limit values by 2025. A stricter emission limit value may be applied to installations located in areas (zones) that do not comply with EU air quality standards. In accordance with Directive 2008/50/EC, Member States should assess whether they should implement stricter emission limit values than the ones outlined in the Directive, when developing air quality plans. As part of such assessments, information about the best available and emerging technologies should be exchanged in order to determine the most effective emissions-reduction performance. A coordinated exchange of information should be arranged between the European Commission, Member States, industry stakeholders, and nongovernmental organizations, including those that promote environmental protection. Based on the latest technologies, the European Commission should assess whether Annex II emission limits should be amended for new combustion plants. A minimum energy efficiency standard should also be considered by the European Commission within this context, as well as specific emission limits for other pollutants, such as carbon monoxide.

Member’s states are allowed to introduce a number of (temporary) derogations and exemptions from the MCP Directive to comply with emission limit values, whether of new installations or existing ones. When assessing the need for stricter emission standards in order to comply with air quality standards, amendments to emission standards for new combustion plants, and setting minimum energy efficiency standards, best available and emerging techniques (BAT) and state-of-the-art technologies are taken into consideration. The MCP Directive was proposed by the European Commission, and adopted by the European Parliament and the Council of the European Union.

2.4 DIRECTIVE ON STAGE I PETROL VAPOUR RECOVERY (PVR)

European Parliament and Council of the European Union approved the Stage I PVR Directive initiated by the European Commission. During storage and distribution of petrol from terminals, the Directive on Stage I PVR aims to control volatile organic compounds (VOC) emissions. A requirement of the Directive is to reduce evaporative losses at terminals by implementing storage installations. Also, the Directive ensures vapours are recovered and returned to tankers or terminals when petrol is loaded onto tankers and transported to service stations [8]. A command-and-control instrument, the Directive on Stage I PVR represents a command-and-control system.

A key part of the Directive is the provision of harmonised technical provisions (design and use) for storage, loading and unloading installations at terminals, mobile containers, and loading installations at service stations. While the recitals acknowledge the importance of "available technologies", no reference is made to BAT or similar concepts. As part of the directive, several exceptions and derogations are allowed (based on throughput, location, and age of the installation).

2.5 POLICIES TO PREVENT AND CONTROL INDUSTRIAL EMISSIONS TO SOIL

The European Union lacks comprehensive, coherent rules to control and prevent soil pollution. The protection of soil is indirectly achieved by policies in other areas (agriculture, water, waste, chemicals, and prevention of industrial pollution). The primary goals and scope of each of these policies are, however, different.

3. STOCKHOLM CONVENTION AS A GENERAL GUIDANCE ON BAT

3.1 CONSIDERATION OF ALTERNATIVES IN THE APPLICATION OF BEST AVAILABLE TECHNIQUES

The Stockholm Convention provides general guidance on best available techniques and best environmental practices in which Parties are encouraged to give priority to the consideration of approaches that prevent the formation and release of the chemicals listed in Part I of Annex C of the Convention.4 The Convention addresses the "consideration of alternatives" with specific reference to best available techniques as follows [4]:
"When considering proposals to construct new facilities or significantly modify existing facilities using processes that release chemicals listed in this Annex, priority consideration should be given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of such chemicals."

Parties are obliged to require the use of best available techniques for new sources within source categories that a Party has identified as warranting such action in its action plan. Initial focus should be given to the source categories identified in Part II of Annex C of the Convention. When a Party implements this obligation, it should assure that priority consideration is given to alternative processes, techniques or practices that have similar usefulness but which avoid the formation and release of chemicals listed in Part I of Annex C. In this regard, the Stockholm Convention is ambitious. It encourages a search for processes, techniques and practices that avoid generation and release of persistent organic pollutants and it encourages Parties to give them priority consideration. This encouragement should not be interpreted to mean that facilities that have the potential to form and release to the environment chemicals listed in Part I of Annex C should always be avoided. Complete elimination may not be practical or feasible. Sources that are listed in Parts II and III of Annex C have useful purposes despite the potential to form and release persistent organic pollutants.

When a Party requires the application of best available techniques for a proposed new source of chemicals listed in Annex C, decision makers are encouraged to assure that consideration is also given to alternatives that avoid the formation and release of such chemicals. In doing this, they should undertake a comparison of the proposed process, the available alternatives and the applicable legislation using what might be termed a "checklist approach", keeping in mind the overall sustainable development context and taking fully into account environmental, health, safety and socio-economic factors.

3.2 GENERAL CONSIDERATIONS

Article 5 of the Stockholm Convention requires Parties to develop, within two years of entry into force for them, an action plan to identify, characterize and address the release of chemicals listed in Annex C. Currently listed are polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF), as well as hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) when produced unintentionally.

The action plan, which is also to be a component of a Party's national implementation plan to be developed pursuant to Article 7 of the Convention, will include strategies for meeting obligations to reduce or eliminate releases of chemicals listed in Annex C of the Stockholm Convention, and a schedule for the action plan. The plan will identify priorities for action, including for those source categories that provide the most cost-effective opportunities for release reduction or elimination. It will also include an inventory of releases of chemicals listed in Annex C.

In accordance with the implementation schedule of its action plan and taking into account the guidelines to be adopted by the Conference of the Parties, Parties are to promote and in some cases require the use of best available techniques and to promote the use of best environmental practices by identified sources of release. Parties are also to promote the development of and, where appropriate, require the use of substitute materials or processes to prevent the formation and release of chemicals listed in Annex C.

3.3 POLICY, LEGAL AND GOVERNANCE ISSUES

Just how a government promotes or requires the use of best available techniques and best environmental practices will vary from country to country, depending on its legal structure and socio-economic conditions. Possible implementation strategies would include release estimate reporting, public information and education programmes, voluntary industry programmes, economic instruments and regulation. These issues should be addressed in the Party's national action plan.

The types of measures that may be promoted or required as best available techniques to reduce or eliminate the release of Annex C chemicals can be categorized as follows: shifting to alternative processes; primary measures that prevent the formulation of chemicals listed in Annex C; and secondary measures that control and reduce the release of those chemicals.

3.4 SCIENTIFIC AND TECHNICAL ISSUES

The state of the science with regard to both the measurement of releases and levels present in the environment of chemicals listed in Annex C and what is considered "best" available techniques and "best" environmental practices will advance with time. This guidance will be periodically updated to keep up with these changes.

The Convention identifies the term "best" as "most effective in achieving a high general level of protection of the environment as a whole". Consistent with decision SC-1/15 of the Conference of the Parties of the Stockholm Convention efforts should be made to ensure that mechanisms are set in place for providing technical assistance and promoting transfer of technology. A particular case is that of Parties that currently do not have access to those techniques that are subject to intellectual property rights.

These guidelines should be taken into consideration, and the performance levels associated with best available techniques and best environmental practices for PCDD/PCDF releases, may be used by a Party in fulfilling its commitments to apply best available techniques. It is within the jurisdiction of each Party to establish its regulatory release limits based on such guidance.

3.5 ECONOMIC AND SOCIAL IMPLICATIONS

Depending on the process that is a source of chemicals listed in Annex C, economic and social conditions in a country are a factor in determining what are “best” available techniques and “best” environmental practices. Where processes are relatively large scale, capital intensive and involve large and continuous throughputs (e.g. cement kilns firing hazardous wastes, sinter plans in the iron and steel industry, fossil fuel-fired utilities, large waste incinerators) the technologies and practices used and enterprises that manage them are rather similar worldwide. In such cases, best available techniques and best environmental practices can be applied in much the same way in all countries. Where processes are relatively smaller in scale (crematoria, home heating and cooking, industrial boilers, motor vehicles) or involve smaller scale management of wastes (waste incineration, open burning), the technologies and practices available may vary greatly from country to country. In these cases, determining what are best available techniques and best environmental practices will need to include an analysis of economic feasibility of the various options available. As such, “best” may mean best option that is economically feasible under the socio-economic conditions present.

3.6 NEW VS. EXISTING SOURCES

For new sources of chemicals within source categories that warrant the use of best available techniques, as identified in their national action plans, Parties are to focus initially on source categories identified in Part II of Annex C. Parties shall phase in requirements for best available techniques for new sources in the categories in Part II of Annex C as soon as practicable, but no later than four years after entry into force of the Convention for the Party. For existing source categories, identified in the action plans as warranting the use of best available techniques, best available techniques are to be promoted. The use of best available techniques and best environmental practices are to be promoted for those new sources that do not warrant action in a Party’s action plan.

The use of best available techniques and best environmental practices for new sources ensures that releases of chemicals listed in Annex C are minimized to the greatest extent possible. It also allows such techniques and practices to be considered in the design and operation of the facility at a stage when they can be incorporated cost-effectively. Given the range of industrial and other activities involved, national sustainable development strategy should take into account the need to ensure that the investments into the national economy comply with this guidance and guidelines.

The use of best available techniques and best environmental practices for existing sources identified in a Party's national action plan are to be promoted in accordance with the Party's action plan. Addressing existing sources is a good opportunity for a Party to reduce overall releases. In considering priority existing sources identified in its national action plan, a Party will need to consider measures to encourage necessary changes to the process or management practices that could lead to eventual attainment of best available techniques and best environmental practices. Such modifications could be phased in over time and could be part of plans to modernize a facility.

3.7 GENERAL PRINCIPLES AND APPROACHES

When applying these guidelines and guidance to sources of chemicals listed in Annex C of the Stockholm Convention, Parties may find it useful to consider some general environmental management principles and approaches that may be supportive of the Convention. The following is indicative of some of these general environmental management principles and approaches [4].

1. **Sustainable development.** "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

2. **Sustainable consumption**. "The use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations."

3. **Development and implementation of environmental management systems.** "A structured approach for determining, implementing and reviewing environmental policy through the use of a system which includes organizational structure, responsibilities, practices, procedures, processes and resources."

4. **Use of science, technology and indigenous knowledge to inform environmental decisions.** "Increase the use of scientific knowledge and technology and increase the beneficial use of local and indigenous knowledge in a manner respectful of the holders of that knowledge and consistent with national law;" and "Establish partnerships between scientific, public and private institutions, including by integrating the advice of scientists into decision-making bodies to ensure a greater role for science, technology, development and engineering sectors."

5. **Precautionary approach.** "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

6. **Internalizing environmental costs and polluter pays.** "National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."

7. **Pollution prevention.** “The use of processes, practices, materials, products or energy that avoid or minimize the creation of pollutants and waste, and reduce overall risk to human health or the environment.”

8. **Integrated pollution prevention and control.** “This principle aims to achieve integrated prevention and control of pollution arising from large-scale industrial activities. It lays down measures designed to prevent or, where that is not practicable, to reduce emissions in the air, water and land from these activities, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole.”

9. **Co-benefits of controlling other pollutants.** For instance, pollution prevention and control of other contaminants may also contribute to the reduction and elimination of chemicals listed in Annex C.

10. **Cleaner production.** “The continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency and reduce risks to humans and the environment. Cleaner production can be applied to the processes used in any industry, to products themselves and to various services provided in society.”

11. **Life cycle analysis.** “A system-oriented approach estimating the environmental inventories (i.e. waste generation, emissions and discharges) and energy and resource usage associated with a product, process or operation throughout all stages of the life cycle.”

12. **Life cycle management.** “An integrated concept for managing the total life cycle of goods and services towards more sustainable production and consumption, building on the existing procedural and analytical environmental assessment tools and integrating economic, social and environmental aspects.”

13. **Virtual elimination.** “The ultimate reduction of the quantity or concentration of the toxic substance in an emission, effluent, or waste released to the environment below a specified level of quantification. The ‘level of quantification’ means, in respect of a substance, the lowest concentration that can be accurately measured using sensitive but routine sampling and analytical methods.”

14. **Community Right to Know.** “In the field of environment, improved access to information and public participation in decision-making enhance the quality and the implementation of decisions, contribute to public awareness of environmental issues, give the public the opportunity to express its concerns and enable public authorities to take due account of such concerns.”

4. A STANDARDISED METHODOLOGY TO ESTALISH BAT IN EU

This chapter presents the European Union's standardised methodology to develop BAT reference documents and BAT Conclusions, known as the Seville Process [8] and applied under the Industrial Emissions Directive. In addition, the chapter introduces variations of this approach, applying under other directives, regulations and for specific sectors.

The European Union (EU) has had a BAT-based policy to prevent and control industrial emissions since 1996. The principal framework to protect air, water and soil in the EU is provided by technique-based policies to prevent and control industrial emissions, in particular the Industrial Emissions Directive (IED) [9]. The IED provides a general framework to prevent and control industrial emissions based on integrated permitting, implying that permits must take account of a plant's complete environmental performance to avoid pollution being shifted from one environmental medium to another. The IED stresses that an integrated approach to prevention and control of emissions to air, water and soil, as well as to waste management, energy efficiency and accident prevention, is essential to achieve a level playing field in the EU by aligning environmental performance requirements for industrial installations. The basic premise of the IED is that installations must prevent and control industrial emission by applying BAT, efficient energy use, waste prevention and management and measures to prevent accidents and limit their consequences.

The EU has a standardised methodology for the procedure of selection and evaluation of techniques for the determination of BAT, known as the **Seville Process**. The BAT identified through this process form the basis for BAT-associated emission levels (BATAELs), which constitute the basis for the emission limit values (ELVs) in permits. The BAT and BAT-AELs are described in BAT reference documents (BREFs), while the latter also are presented in BAT Conclusions. Only the BAT-AELs are legally binding, and not the BAT. The Seville Process is defined under the IED and formalised in the EU [10] Commission Implementing Decision, known as the BREF Guidance Document, which lays down rules concerning guidance on the collection of data and on the drawing up of BREFs and on their quality assurance. The BREF Guidance Document incorporates the IED's Annex III, which lists the criteria for determining BAT. In addition to the Seville Process under the IED, there are analogous EU BAT identification systems under other pieces of legislation, using slightly different approaches for the selection of BAT to that used under the IED. This includes systems used under the Eco-Management and Audit Scheme (EMAS) Regulation [11], the Medium Combustion Plant Directive [12], the Mining Waste Directive (EU, 2006) [13] and for the Hydrocarbons BREF.

4.1 KEY CHARACTERISTICS OF PROCEDURES TO DETERMINE BAT

While the BAT policies around the world were adopted at different points in time and all have their unique design, the report pinpoints valuable insights on some key characteristics of approaches to establish BAT applying across countries.

Taking a BAT-based approach to setting emission limit values

The report explores how countries' environmental legislation defines the association between BAT and emission limit values (ELVs) [8], providing illustrative examples that can guide the development and review of such legislation in other countries. Constituting a key element for setting legally binding ELVs and other permit conditions, BAT serve as crucial technical guidance, helping industrial operators to design, operate, maintain and decommission their installations so as to prevent or control emissions to air, soil and water.

Engaging stakeholders in industrial pollution management

Official reference documents for BAT or similar concepts result from a series of exchanges of information between a variety of stakeholders, including governmental experts, industry representatives, members of NGOs and research institutes. This approach seeks to ensure enhanced understanding of each party's needs in the process to identify BAT [8]. The report highlights the advantages of multi-stakeholder procedures for the determination of BAT, while also stressing challenges associated with transparency throughout such a process.

Relying on diverse data sources to evaluate techniques

The report offers valuable reflections on essential aspects of the information collection and evaluation procedures involved in the establishment of BAT. Notably, this includes the weighing of environmental, economic and technical aspects of available techniques, the use of data from monitoring systems and other relevant sources, the balancing between preventive and end-of-pipe techniques, the steps for official approval of techniques as BAT, and the time and resources required to finalise BAT documents.

4.2 IED: BAT REFERENCE DOCUMENTS AND BAT CONLCUSIONS

The development of BREFs under the IED is steered by the European IPPC Bureau (EIPPCB) at the EU Joint Research Centre (JRC) in Seville, Directorate B - Growth and Innovation, which was established under the IPPC Directive [14], the predecessor of the IED. The procedures for identifying BAT under the IED are generally the same as those under the IPPC Directive. However, the BAT established under the latter were published as BREFs only, while there are two products of the IED BAT identification procedure: BREFs and BAT Conclusions. BAT Conclusions are published in the Official Journal of the European Union as standalone Commission Implementing Decisions, describing the techniques selected as BAT and the expected environmental performance of those techniques.

The BREF Guidance Document [10] foresees that the technical stages of BREF elaboration can take up to 39 months; on top of which the opinion of the Article 13 Forum1, the vote by the Article 75 Committee and formal adoption can add up to another 12 months. Thus, the development of a BREF and BAT Conclusions for one sector should in theory take about four years. This timescale has been achieved for some sectors; e.g. production of wood-based panels; however, in practice, there can be technical and procedural difficulties that impinge on this ideal planning.

The BREFs are adopted and published by the European Commission, and made publically available on the EIPPCB's BREF website **(**http://eippcb.jrc.ec.europa.eu/reference/**)**. The documents are published in English; some are partly or fully translated into other languages by national authorities in the EU Member States. In accordance with the IED recitals, the EIPPCB aims to review BREFs every eight years; the BREF website displays the status of each of the BREFs, showing which BREFs are finalised and which are under review. **BREFs** are used by permits issuers, but also by industrial facilities, and typically **contain the following information**:

• General information about the concerned sector;
• Applied processes and techniques;
• Current consumption and emission levels;

• Techniques to consider in the determination of BAT;
• BAT Conclusions (see description below);
• Emerging techniques;
• Concluding remarks and recommendations for future work; and
• A glossary.

The BAT Conclusions, constituting a separate and standalone product of the BAT identification process, **aim to contain the following elements** (as prescribed by Article 3(12) of the IED):

• A description of the techniques;
• Information to assess their applicability;
• The environmental performance levels (BAT-AEPLs) associated with the use of BAT, usually including legally binding associated emission levels (BATAELs), expressed as a numerical range of emission levels, including ‐ if the data submitted allows doing so ‐ short-term and long-term averages (information can be added to explain under what conditions the lower end of the BAT-AELs can be achieved or to reflect the performances of different techniques);
• Associated monitoring;
• Associated consumption level; and
• Relevant site remediation measures (where appropriate).

The BAT Conclusions constitute the references for setting permit conditions, including ELVs. ELVs must be set at a level ensuring that pollutant emissions do not exceed the BAT-AELs. The IED allows competent authorities in the EU Member States some flexibility to grant derogations in individual permits that set less strict ELVs, in exceptional and tightly defined circumstances. Such derogation may apply only where an assessment shows that the adoption of techniques as described in the BAT Conclusions would lead to disproportionately high costs compared to the environmental benefits, due to the geographical location, local environmental conditions or technical characteristics of the installation concerned.

Furthermore, the techniques listed and described in the BAT Conclusions are neither prescriptive nor exhaustive; other techniques may be used if they ensure at least an equivalent level of environmental protection. Consequently, industrial operators have the flexibility to use their own technique, or choice of techniques, as long as the end result is the same. The procedure to determine BAT Conclusions is summarised in the preface of each BREF and includes the steps listed below. The procedure guides the approach to collection of information on techniques and identification of BAT.

• Identification of the Key Environmental Issues for the sector concerned;
• Examination of the techniques most relevant to address these key issues;
• Identification of the best environmental performance levels, on the basis of the available data in the EU and worldwide;
• Examination of the conditions under which these environmental performance levels were achieved, such as costs, cross-media effects, and the main driving forces involved in the implementation of the techniques; and
• Selection of BAT, their associated emission levels (and other environmental performance levels) and the associated monitoring for this sector according to Article 3(10) of, and Annex III to, the IED.

4.3 EXTRACTIVE WASTE DIRECTIVE: BAT REFERENCE DOCUMENT

The review of the BREF on the management of tailings and waste-rock in mining activities (MTWR BREF) [15], originally elaborated over the period 2001-2004 and published in 2009, after the entry into force of the Mining Waste Directive [13], is scheduled for completion in 2018. Contrary to other EU BREFs, the review of MTWR BREF did not take place under the IED framework; however, the procedure for the review of the document is largely aligned to the Seville Process developed for IED BREFs and the review was carried out by the European Commission's Joint Research Centre (JRC) in Seville, Directorate B - Growth and Innovation.

4.4 EMAS: SECTORIAL REFERENCE DOCUMENTS AND BEST PRACTICE REPORTS

The Eco-Management and Audit Scheme (EMAS) Regulation [11] establishes the voluntary participation by organisations in EMAS, the European Community's eco-management and audit scheme. The Regulation seeks to promote continuous improvements in the environmental performance of organisations by the establishment and implementation of environmental management systems, the systematic, objective and periodic evaluation of the performance of such systems, the provision of information on environmental performance, an open dialogue with the public and other interested parties and the active involvement of employees in organisations and appropriate training. The Regulation promotes the use of Best Environmental Management Practice (BEMP), defined as "the most effective way to implement the environmental management system by organisations in a relevant sector and that can result in best environmental performance under given economic and technical conditions". For this purpose, the European Commission's Joint Research Centre (JRC) develops two different documents describing the BEMPs for each sector: a concise Sectorial Reference Document (SRD) and a detailed Best Practice Report (BPR).

An organisation wishing to participate in EMAS must go through a procedure to obtain an accredited environmental verifier's approval of their environmental review, management system, audit procedure and statement. The validated statement is registered and made publicly available. An organisation successfully completing all stages may use the EMAS logo to demonstrate its commitment to improving its environmental performance.

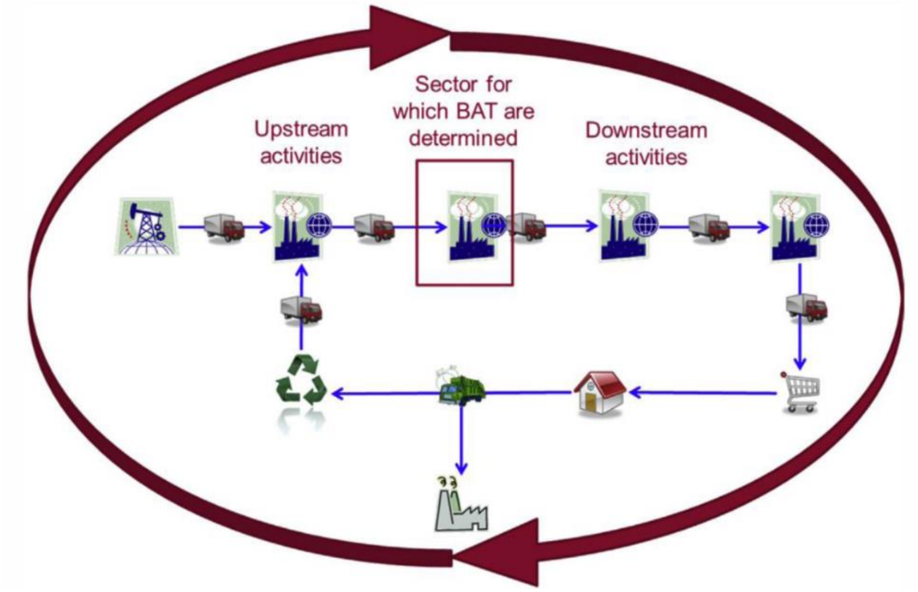
The SRDs, as stipulated in Article 46.1 of the EMAS Regulation, briefly describe all the BEMPs identified for a specific sector in addition to the conditions under which they can be applied. An EMAS-registered organisation must take into account the relevant SRDs when assessing its own environmental performance. For each BEMP, the SRD also contains environmental performance indicators and benchmarks of excellence [16]. The presentation of each BEMP is structured as follows:

- Description;
- Achieved environmental benefits;
- Appropriate environmental indicators;
- Cross-media effects;
- Operational data;
- Applicability;

• Economics;
• Driving force for implementation;
• Reference organisation; and
• Reference literature.

The BPRs constitute a more detailed and elaborate report presenting the results of the research conducted by the JRC for the production of a specific SRD. Organisations wishing to apply the BEMPs listed in a certain SRD are recommended to refer to the comprehensive guidance offered in the BPRs. Both the SRDs and the BPRs, including main draft versions, are publically available on the website of the JRC (**http://susproc.jrc.ec.europa.eu/activities/emas/index.html**), along with other relevant working documents for each sector.

SRDs are based on a cradle-to-grave approach and are designed for all actors along the value chain within a given sector and not only industrial facilities. In cases where an SRD and a BREF, published under the IED, have a similar scope, the SRD will refer to the BREF where possible, in addition to focusing on non-BREF areas such as environmental impacts from the whole life cycle, i.e. upstream and downstream in the value chain, as well as smaller installations.



4-1. Figure_Current application of BAT

In the figure above, the box is representative of established BAT requirements or guidance for a given sector. Global assessment across the value chain (significant up-stream and/or connected operations, and relevant earlier steps of associated activities with a technical connection) may indicate that the prescribed BAT-associated emission levels optimise environmental performance in one industrial process while at the same time have negative environmental implications on, influence the costs of, or the need for new techniques in, other parts of the value chain. While the multi-stakeholder groups in charge of establishing BAT – known as Technical Working Groups in some countries – may consider value chain effects in the development of some BREFs, this is usually not done systematically.

4.5 HYDROCARBONS SECTOR: BAT REFERENCE DOCUMENT

The European Commission is currently developing a BREF on hydrocarbons exploration and extraction [17]. The document will outline BAT already applied under economically viable conditions in the hydrocarbons sector, so as to help create a common understanding of high-level performance in the sector. The Hydrocarbons BREF is not directly linked to the implementation of a particular Directive, and will not result in a set of legally binding BAT Conclusions. The document will address installations linked to actual wells in the extractive oil and gas industry, i.e. the development and operation of offshore facilities or onshore well pads, including directly related activities such as onsite storage prior to distribution, but excluding delivery infrastructure such as pipelines. Notably, the BREF will concentrate on BAT to manage impacts of releases of pollutants and best risk management techniques to manage risks of releases of substances as a result of incidents for the purpose of protecting human health and the environment [18].

The Hydrocarbons BREF is considered an opportunity to create a level, predictable and transparent playing field for oil and gas activities, in order to help tackle public concerns associated with domestic oil and gas production and facilitate an exchange with and across competent authorities.

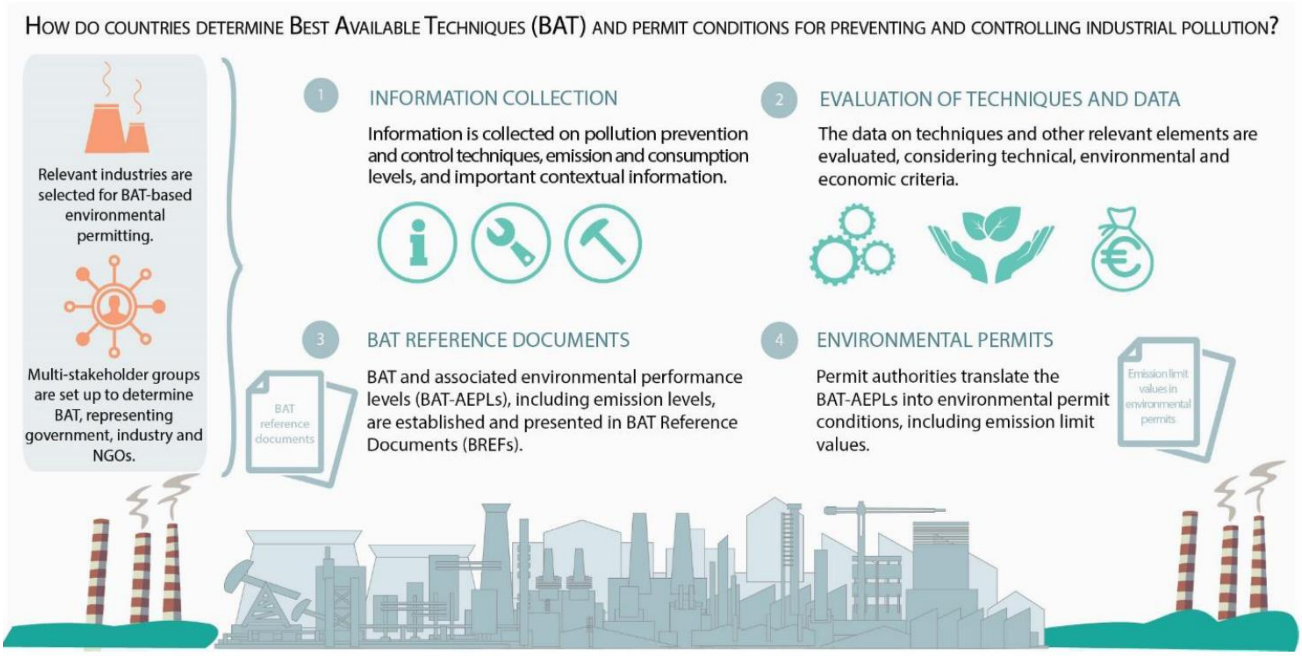
4.6 MCP: REPORT ON BEST AVAILABLE, AND EMERGING TECHNOLOGIES

In order to fulfil its obligations under the Medium Combustion Plant (MCP) Directive [12], the European Commission has committed to engage contractors to identify the environmental performances and costs of best available, and emerging, technologies used in medium combustion plants. The terms of reference for the project [19] were published in November 2017, stating that the contractor shall facilitate an information exchange process between EU Member States, the industries concerned, including operators and technology providers, NGOs promoting environmental protection and other relevant organisations. The objective of the information exchange will be to collect information on the environmental performance and costs of best available, and emerging, technologies for MCPs.

The contractor engaged by the European Commission will be relying on data collected through the information exchange and other means to indicate the emission levels and costs that can be associated with the use of best available, and emerging, technologies, before validating these through an information exchange Working Group. Furthermore, the contractor will be documenting any significant general potential of further reducing emission from new MCPs, the advantages and limitations of regulating CO and of setting minimum energy efficiency standards reflecting best available technologies under the MCP Directive. The information exchange and the contractor's conclusions on the environmental performance and costs of best available, and emerging, technologies for MCPs, will be summarised in a report.

4.7 GUIDANCE DOCUMENT ON BAT

The process of establishing BAT and BAT-associated environmental performance levels (BAT-AE[P]Ls) as well as BAT-based permit conditions, consists of several consecutive steps. A simplified illustration of these steps is provided in Figure 4-2. The steps are based on best practices from OECD member and partner countries.



4-2. Figure_The steps to establishing BAT, BAT-AE(P)Ls and BAT-based permit conditions

Recommended prerequisites for determining BAT include defining BAT in national legislation, selecting the industrial sectors and activities to which BAT-based permitting will apply, and setting up a multi-stakeholder Technical Working Group (TWG) for each sector at an early stage. One of the first tasks of a TWG is to reach consensus on the environmental scope of the BAT for the concerned industrial activity.

Assisted by a technically competent and independent body (i.e. a BAT Bureau), the TWG should identify well-performing plants, collect comprehensive data on their pollution prevention and control techniques, emission and consumption levels, and other indicators of environmental performance, as well as important contextual information (e.g. specific background of data gathered such as monitoring specifications). The process of collecting and exchanging information in order to establish BAT is described and discussed in the next section. Also, the technical, environmental and economic criteria on which the determination of BAT is based, are here described. Based on the selection of BAT, the TWG should derive BAT-AELs, and ‑ where appropriate and feasible ‑ other BAT-AEPLs related to e.g. consumption of material, water or energy, the generation of waste, abatement efficiency on pollutants and duration of visible emissions. The BAT and BAT-AE(P)Ls should be documented and described in BREFs, or the equivalent, and published once approved by relevant authorities. The BREFs should be reviewed on a regular basis to reflect technological progress. National, regional and/or local permitting authorities should use the BAT and BAT-AE(P)Ls as a basis to determine ELVs and other conditions in environmental permits for industrial installations.

4.7.1 KEY RECOMMENDATIONS FOR COUNTRIES WISHING TO ESTABLISH A BAT-BASED PERMITTING SYSTEM

BAT-based permitting should build on an integrated pollution prevention and control (IPPC) approach, i.e. integrating emissions to air, water and soil, as recommended by the OECD Council Act on IPPC from 1991 [22]. This ensures that pollutant emissions and other environmental pressures are mitigated rather than shifted between different environmental media. In order for the integrated and holistic approach to be implemented in practice, it needs to be reflected in the individual BAT-AELs.

The BAT framework should aim to improve the environmental performance of all industrial installations, and to introduce increasingly more stringent permit conditions, rather than simply harmonising performance levels across installations. This requires, inter alia, that BAT and BAT-AE(P)Ls be derived from information pertaining to those industrial installations with the best environmental performance, and from multiple countries.

BAT-associated emission and environmental performance levels should be technically driven. That is, they should reflect the environmental performance levels that can be achieved by implementing BAT or a combination of BAT, rather than be based on e.g. politically negotiated levels.

The process to determine BAT and BAT-AE(P)Ls should be based on multi stakeholder dialogue, and build on principles of open government, including transparency and participation, as outlined in the OECD’s Council Recommendation on Regulatory Policy and Governance [23]. This helps secure that all relevant interest groups are allowed to participate and get opportunities to voice their opinion. A participatory approach tends to result in better outcomes as it allows building a mutual understanding of relevant environmental challenges and of the means to address those, securing that different interests are understood and reflected in the BAT documents produced.

BAT and BAT-AE(P)Ls should be at least as stringent as those standards set out under relevant international conventions, such as the Stockholm Convention on Persistent Organic Pollutants, the Convention on Long-Range Transboundary Air Pollution and the Minamata Convention of Mercury. These conventions all provide requirements relating to BAT.

The difference between new and existing industrial installations should be taken into account. When developing, revising or adapting BREFs, countries may want to distinguish between existing plants - which often have a fixed investment cycle and require adapted pathways reflective of the retrofit aspect - and new plants, or those that have undertaken major upgrades, which can implement modifications more easily.

Rather than developing their own BREFs, countries can consider adopting those of other countries or adapting them to their national circumstances. Producing BREFs can be a very time-consuming and resource-intensive process. Therefore, countries wishing to adopt BAT-based permitting do not necessarily have to develop their own BREFs; they could choose to use the BREFs of another jurisdiction as is, or to adapt a set of existing BREFs to their national circumstances. Countries wishing to pursue a BAT-based approach should reflect on the most appropriate approach in their circumstances, and use this guidance document accordingly by referring to those elements that are applicable to their situation. All countries are advised to follow the steps regarding the selection of sectors for application of BAT-based permitting and for determining BAT-based permit conditions. Furthermore, it is recommended to set up of a multi stakeholder Technical Working Group that can support the possible adaptation of BREFs, and/or the overall implementation of a BAT-based permitting system.

The pros and cons of taking a value chain approach should be considered. BAT are usually established at the level of each industrial sector or activity, with little consideration given to the interactions with the value chain. Thus, BAT are often identified without systematically considering the up- or downstream interactions between sectors, nor the environmental impact of an industrial activity on other parts of the value chain or on the value chain as a whole. That is, each industrial activity is dealt with separately, and only limited consideration is given to the interactions with other industries and actors in the value chain. As a consequence, BREFs may prescribe BAT-AE(P)Ls that optimise environmental performance in one industrial process while at the same time could have negative environmental implications on, influence the costs of, or the need for new techniques in, other parts of the value chain. Thus, researchers have called for the necessity to ensure that BAT form a driver, rather than a barrier, to greening of global value chains and sustainable supply chain management [24]. Introducing a more thorough examination of value chain aspects by Technical Working Groups could be one way of addressing this issue. However, this requires addressing the trade-offs between considering a vast number of environmental aspects in a BREF, and settling on an adequate amount of time and resources, and level of difficulty, needed to address them. Whether life cycle or value chain aspects are important depends on how significant they are in relation to the other environmental aspects that need to be covered. Furthermore, if a value chain approach is introduced, governments must ensure that the BAT in BREFs remain applicable at the level of each industrial installation.

4.8 SELECTING SECTORS FOR APPLICATION OF BAT-BASED PERMITTING

Before BAT can be established, it is necessary to select the industrial sectors and activities to which BAT-based permitting shall apply. Having a defined list of sectors and activities for regulation can make for a more targeted and cost-effective approach to emissions reduction, as it allows focusing on those emission sources that account for the largest share of external damage costs [25]. The selection of sectors and activities should be published in an easily available document and be legally binding. The list of sectors and activities should be reviewed periodically. In the process to select sectors, the following indicators should be considered:

Observed pollution load and/or consumption quantities of each sector, and their impact on the environment as a whole. PRTRs or other emissions monitoring databases are essential sources of the most recent information on the emissions and environmental performance of various sectors. In the absence of such databases, pollution and consumption figures need to be based on calculations of assumed performance or on sectors that have been targeted in other countries.

The feasibility of implementing new techniques or practices to reduce emissions and/or to improve resource efficiency within a given manufacturing process.

Production capacity, given that this is reflective of an industry's environmental impact and potential for improvement.

Scale, i.e. age and size of the industry. This may have an impact on national priorities and BAT determination.

Existing national or regional priority lists of chemicals and pollutants of concern and associated requirements defined by international conventions, notably those relating to the Stockholm Convention on Persistent Organic Pollutants, the Convention on Long-Range Transboundary Air Pollution and the Minamata Convention of Mercury. This will help assess which sectors emit those pollutants.

Relevant upstream and downstream activities whose environmental performance would be affected by the principal activity. These upstream and downstream activities should be considered by the TWGs when establishing BAT and BAT-AE(P)Ls. This could facilitate a comprehensive BAT assessment and prevent the transfer of environmental impacts across the different parts of a value chain.

Depending on the approach taken to determine the sectors for BAT-based permitting, this selection process could be considered in parallel with the process to define the environmental scope of the BREF for each sector

4.9 THE PROCESS TO ESTABLISHING BAT

4.9.1 IDENTIFYING WELL-PERFORMING PLANTS FOR DATA COLLECTION

In order to determine BAT and BAT-AEPLs, emission and consumption data along with the necessary contextual information should be collected from a set of real plants in operation worldwide with optimal environmental performance, i.e. considered representative for the sector at stake that, under normal operating conditions, display good environmental performance in one or more environmental aspects (e.g. low pollutant emissions, low usage or high recovery/recycling of energy/water/material), including best performers.

It is recommended that TWG members start the process of selecting plants for the data collection as early as possible with the aim of having a draft list available in time for their first meeting. Further, it is recommended that each TWG member's organisation be invited to propose a list of well-performing plants (including best performers) for the data collection via questionnaires. Well-performing plants refer to plants that are considered to reflect good environmental performances in one or more environmental aspects, e.g. low pollutant emissions, low usage or high recovery/recycling of energy/water/material. **Criteria for selecting plants for the plant-specific data collection could include**:

• Environmental performance;
• The use of candidate BAT;
• Production capacity - both small and large;
• Age - both newer and older;
• Processes - single and multi-product, continuous and batch;
• Plant categories - representative of all plant categories once decided upon;

• Geographical distribution - representative for all regions that have plants in a given subsector, especially when climatic conditions are relevant; and
• Products/processes that might require a dedicated approach.

4.9.2 COLLECTING DATA

Once the plants for the data collection have been identified, the TWG should - assisted by a technically competent and independent body (i.e. a BAT Bureau) - collect comprehensive information on their manufacturing techniques, pollution prevention and control techniques, emission and consumption levels, other indicators of environmental performance as well as important contextual information. PRTRs and emission monitoring databases can greatly facilitate the collection of emissions data and sometimes associated information, as described in Measuring the Effectiveness of BAT Policies [20].

The data should be collected, inter alia, through a survey drafted by the BAT Bureau. Recommended key elements for such surveys are included in Annex B. Provided that a broad enough range of industrial installations participate in the evidence gathering and submission, the process to determine BAT and derive associated environmental performance levels will be rooted in evidence as well as expert judgement. In addition to collecting data at the national level, TWGs should consider data from multiple countries, including by consulting the BREFs (or the equivalent) of other jurisdictions or pertaining to international conventions, in order to allow setting BAT and BAT-AE(P)Ls that are based on international best practices and existing research, whilst taking into account national circumstances and specificities. This helps support the harmonisation of environmental performance requirements across countries or regions, and thus BAT-based permitting can create a level playing field for industry, provided consistent application in their own and other jurisdictions. In line with Principle 12 of the OECD Council Recommendation on Regulatory Policy and Governance [23], consideration should be given to all relevant international standards and frameworks for co-operation in the same field and, where appropriate, their likely effects on parties outside the jurisdiction.

It might be challenging to obtain disaggregated emissions data from the regulated community, e.g. due to industry operators' reluctance to sharing such information and/or intellectual property rights. This could be addressed through legal obligations or international initiatives to monitor certain pollutants, and/or by estimating emission levels through comparison with data from other countries.

Further, the gathering of information on techniques can be facilitated by adapted tools such as dynamic online environments that enable the sharing of technological advances. An example is the US' RACT/BACT/LAER Clearinghouse [26]. To encourage sharing of data at the international level, parties involved in determining BAT could consider promoting conditions that facilitate the exchange of relevant information in a centralised, user friendly and publicly available online portal, allowing stakeholders acting at national or regional levels to get easy access to BREFs from several jurisdictions, along with information on the benefits of costs of different BAT and on the environmental performance of installations that have installed those techniques. Such a portal would facilitate and support the information collection and exchange in each jurisdiction, including by saving TWGs a lot of time, and could enhance transparency and opportunities for benchmarking. To ease the set-up of such a portal, it could initially cover just one or a few selected sectors, and focus on a selected set of techniques. The quality of the information would have to be controlled in a suitable manner.

4.9.3 VALIDATING AND EVALUATING THE DATA

The data provided during the data collection have to be validated by competent authorities. These authorities should prepare to address possible challenges related to securing the quality of collected data, especially for data concerning water and energy consumption, as these often are confidential. The information collection and analysis should be followed by discussions in the TWG and the elaboration of drafts prepared in collaboration with the BAT Bureau. The information exchange should involve a thorough assessment of technical, environmental and economic criteria, allowing to determine BAT and BAT-AE(P)Ls. The TWG ’ s final draft could be considered and approved by a separate decision making body, provided the main criteria of decision making are human health and environmental protection, performance outcome oriented and based on an integrated approach.

The BAT Bureau should ensure the greatest possible extent of transparency of information, while protecting sensitive data such as confidential business information. The level of sensitivity might be higher related to consumption data, e.g. on energy and materials use, than in relation to emissions data. Another challenge related to consumption data can be the comparability across plants. Adequate measures should be taken to address these issues, such as clearly defining the types of information considered confidential, the procedures used to determine whether confidential treatment should be granted, and the methods used to protect confidential information.

The information collection and exchange should be carried out according to the principles of open government, i.e. by actively engaging all relevant stakeholders, and providing meaningful and effective opportunities, including online, for the public to contribute to the process of preparing draft proposals as well as to maximise the quality of the supporting analysis [23]. Therefore, governments are encouraged to allow members of the public observe the TWG meetings, or provide input at the BREF drafting stage e.g. through BREF mirror groups. Furthermore, governments should conduct public consultations on the draft BREFs well before a decision on the issue is taken. In summary, TWGs are advised to use a multi-step model for determining BAT in order to allow for participation by a broad number of stakeholders while securing a sufficient level of expertise. Ideally, a first draft of a BREF should be developed by professionals with relevant engineering expertise, followed by review and approval by relevant stakeholders such as ministries, industries and NGO, and subsequently a public consultation period. The final BREFs should be made publicly available.

4.10 THE CRITERIA FOR DETERMINING BAT

General principles for determination of BAT:

• The determination of BAT should be **based on a comprehensive information exchange process and decisions taken based on consensus** in the TWG, based upon an agreed definition of BAT. The definition of BAT combined with the approach to identifying BAT-AELs determines the overall environmental stringency of the approach.

• In order to ensure a reduction in emissions, BAT should **solely be based on those techniques used by a selected set of well-performing plants**, and not the whole operating range of current performance of all installations. This will allow generalising the performance of the well-performing plants and secure an improvement overall. The choice of techniques should not be limited to e.g. installations in a specific country.

• The determination of BAT should **consider all emission prevention and control techniques that are available for purchase on the global market**, and not only those that are produced or sold domestically, provided that they are not covered by a restricted patent. This allows setting BAT-AE(P)Ls that are harmonised across countries or regions and internationally competitive, and to ensure a global level playing field for industry, provided consistent application. Similarly, when considering the level of economic availability of a technique according to the economic situation of the implementing country, it is important not to compromise the global level playing field.

• BAT should not only concern the prevention and control of emissions of pollutants, but also **address the environmental impact of industrial activities more broadly**, such as through adjusted resource use, waste prevention, toxic substances substitution and improved manufacturing processes, while minimising impacts that could hamper normal operations.

• BAT should **not only encompass production and abatement technologies, but techniques more widely**; that is, both the technology used and the way in which an installation is designed, built, maintained, operated and decommissioned. This enables improved environmental management of industrial operations as a whole.

• When determining BAT, TWGs should ‐ based on the collected information – **first and foremost identify preventive (e.g. green chemistry practices) and process integrated measures** and ‐ as a second best option ‐ end-of-pipe techniques. Generally, process-integrated techniques are resource-efficient, and therefore cost efficient and often a first choice of operators. End-of-pipe techniques are usually more expensive and generally entail cross-media effects and, unlike preventative techniques, are fundamentally limited in that they do not obviate formation of pollution.

4.11 REVISING BAT, BAT-AELS AND BAT-AEPLS

An important aspect of a BAT-based permitting is the regular review of BAT reference documents (BREFs), to ensure the dynamism of the BAT system and thus that the BAT and BAT-AE(P)Ls are updated according to the most recent technological developments and environmental performance data from reference installations, so as to reflect technological progress, and allow for permit conditions to be updated accordingly. However, how rapidly BREFs, and thus permits, are reviewed is a choice of the overall regulatory regime, and a number of trade-offs need to be considered when determining the frequency of reviewing BREFs, such as the resources required to operate the process versus the change expected. Reviewing a BREF is a resource-incentive and time-consuming process, due to the thorough examination of available information, procedures related to determining the scope of the BREFs, as well as the participatory assessment of the technical, environmental and economic criteria of candidate BAT. Another trade-off relates to certainty for operators (e.g. in terms of payback on investment) versus improved environment performance. Furthermore, it is essential to consider expectation of how fast techniques will evolve in a given sector - if it is slow, frequent BREF reviews probably will not result in any significant changes. Therefore, it is important that countries settle on an optimal review cycle, e.g. every five-ten years. Finally, the frequency of BREF reviews is not the only consideration, added to that is the time allowed to update permits and meet the new operating conditions.

According to the Industrial Emissions Directive, BREFs should be revised every eight years. The process to review a BREF is based on the same steps as those to draw up a BREF for the first time reviewing a BREF requires reactivating a TWG. Environmental NGOs in the EU suggest that the BREF review process could be sped up by enabling a fast-track procedure for the revision of the sections on candidate BAT, in particular emerging techniques, prior to the publication of the final, revised BREF.

4.12 DETERMINING BAT-BASED PERMIT CONDITIONS

4.12.1 KEY POINTS ON BAT-BASED PERMIT CONDITIONS

• Environmental permits for industrial installations should take an **integrated approach** to pollution prevention and control, as stipulated by the OECD Council Act on IPPC (OECD, 1991[3]). Detailed guidance for permitting authorities is available in the OECD's Integrated Environmental Permitting Guidelines for EECCA Countries [25].

• Permits should include **emission limit values (ELVs) and other BAT-AEPL based permit conditions as well as monitoring standards**, such as on frequency, reference conditions and reporting periods, and relevant technical requirements.

• Permit conditions should be set by **adequate environmental permitting authorities**. Such authorities should also be in charge of conducting inspections and compliance assessment.

• Local permitting authorities can be a good means to ensure that **essential local knowledge** is taken into account, so as to determine permit conditions in a robust manner and based on detailed site-by-site assessments.

• As an alternative to setting permit conditions at the local level, or in order to support a level playing field within countries where permits are issued at local level, **governments can consider setting BAT-based requirements through general binding rules** that apply at country level as a minimum standard. This approach may reduce flexibility for deviation, thereby ensuring a level playing field for industry. Furthermore, the general binding rules may be presented in a format the permitting authorities are more acquainted with, and thus facilitate the implementation of BAT-AE(P)Ls within the desired timeframe for compliance.)

• In order to avoid that permitting authorities face technical and interpretational challenges when determining ELVs, e.g. in the face of seemingly incompatible or conflicting standards, **governments should make available adequate guidance on how to interpret the BAT-AELs and other BAT-AEPLs**. Such guidance may in particular be helpful to permitting authorities that lack broad knowledge due to limited exposure to a large number of installations or if they only occasionally issuing a permit for a specific sector. Governments should aim to provide guidance on how to ensure compatibility between ELVs and those permit conditions that are based on BAT-AEPLs, in order not to compromise important circular economy objectives, such as energy and resource efficiency as well as the reuse of materials or other relevant environmental quality standards such as WHO air quality standards and good ecological and chemical status of water bodies.

• Industrial operators with an environmental permit are not obliged to apply those techniques defined as BAT, as long as they **ensure at least an equivalent level of environmental protection**. That is, although the emission levels associated with BAT have legally binding effects, industry operators and permitting authorities enjoy some flexibility at the implementation stage.

• Because of the differing circumstances and configurations of installations, there will always be some uncertainty over how equal the obligations on two installations are. To the degree that judgment is required by permitting authorities, there will be a risk that the stringency is not the same. Therefore, additional requirements such as **comparing permit conditions or other parameters may be needed as part of the overall regulatory framework**.

4.12.2 GENERAL CONSIDERATIONS FOR PERMITTING AUTHORITIES

• **Predictability** is crucial in order for industry operators to plan investments, and thus permitting authorities should aim to accommodate for this by preparing permits in a timely - albeit thorough - manner. Defining clear milestones and improvement conditions also helps operators make adequate investment decisions. Furthermore, permit conditions should be measurable and enforceable, so that accurate installation data can feed into the next review of BREFs.

• Permit authorities should **seek information on possible upcoming permit applications**, i.e. those that are expected during a certain period, e.g. through regular communication with permit holders and industry associations, and/or inspections of installations. Permitting authorities should also make sure to stay informed of changes to BREFs and/or relevant BAT legislation.

• Permit authorities must take measures to **prevent inconsistencies** as well as be careful not to be influenced by potential pressure from industry operators when setting permit conditions, whilst maintaining dialogue with local industry.

• Permitting authorities should aim to use **digitalised procedures** for permitting, as this greatly facilitates the procedures for all involved parties. Information on permit conditions as well as annual compliance performance information should be supplied electronically and disseminated to the public.

• BAT are derived from, and thus apply to, normal operating conditions. When a disruption occurs and causes increased emissions, the operation enters a state of “other than normal operating conditions” (OTNOC). Thus, permitting authorities **also need to regulate periods of OTNOC** (other than at start-up and shut-down), i.e. how such periods are to be registered, and how to limit the number of hours per year of operation allowed under these circumstances. IED Chapter III Article 37 provides an example of good practice: the allowed operation time under breakdown in abatement equipment is limited to 120 hours.

4.12.3 HOW TO SET ELVS OR OTHER PERMIT CONDITIONS

ELVs should not exceed the upper value of the range of BAT-AELs defined in the applicable BREF or BAT Conclusions (i.e. ELV ≤ upper value BAT-AEL range). The upper end of the BAT-AEL range should not be considered a default option when establishing ELVs; the permitting authorities should aim to set the lowest achievable (i.e. as stringent as possible) ELVs for each installation. ELVs should be set at the upper end of the BAT-AEL range only in exceptional cases, e.g. in case of application of new technology or uncertainty related to an installation's performance. ELVs should - as a minimum - be based on current performance, and preferably be more stringent. If an installation has shown good recent performance, e.g. over the last three years, the ELV should be set lower than the top of the BAT-AEL range.

Further, when setting ELVs, permitting authorities should take into account the **following aspects**, whether the installation is existing, or if it new or has undergone major upgrades:

• The **technical characteristics** of the installation;
• **Emissions monitoring data** for the installation for the preceding years, while paying attention to any measurement uncertainty;
• **Local conditions** and **geographical specificities** of the installation;
• **Cross-media effects, cross-pollutant effects** as well as the **cumulative effects of pollutants** discharged by the same facility or upstream pollution load from other sources in a systematic manner; and
• Relevant **environmental quality standards** at the local, national and regional levels.

In cases where applicable environmental quality standards or health-based standards require stricter conditions than those achievable by implementing the techniques defined as BAT, more stringent ELVs and/or additional measures shall be included in the permit, going beyond the lower end of the range of BAT-AELs, if feasible and necessary to protect ecosystems, aquatic life and human health. This contributes to the coordinated use of technology-based and health-based standards, facilitating long-term improvements in environmental quality and public health [27]. To stimulate installations to go beyond compliance with the BAT-AELs, permitting authorities, and/or regulators, should quantify and communicate to industry operators the benefits of optimised performance.

5. KEY ELEMENTS OF EFFECTIVENESS OF BAT POLICIES

Industrial pollution prevention and control policies can achieve significant environmental, financial and human health gains. A growing number of countries use Best Available Techniques (BAT) to set industrial emission levels that are rooted in evidence and based on multi-stakeholder dialogue. BAT policies are a trusted means to preventing or reducing emissions from the world's most polluting industries [20, 28]. They are also a tool to address the environmental impact of industrial activities more broadly, such as through adjusted resource use, waste prevention, toxic substances substitution and improved manufacturing processes, while minimising impacts that could hamper normal operations.

Evaluating the effectiveness of BAT-based policies is essential to enhance their impact and strengthen future policy design. Failing to evaluate the effectiveness of environmental policies can result in governments wasting time and resources on the implementation of inappropriate or inadequate measures. By seeking to understand and assess the impact of a BAT policy, governments can inform and develop tailored and more effective emission limit values in the permits of industrial installations [20, 28]. An evaluation exercise can also facilitate enhanced communication with key stakeholders and the public about the objective, operation and impact of the BAT policy.

The evaluation of a BAT-based policy can aim to assess its effects on industrial emissions, analyse the policy's costs and benefits, or provide useful information to review BAT reference documents. An assessment of how a BAT policy affects emission and consumption trends relies on high-quality monitoring and activity data. A cost-benefit analysis would, in addition, consider the gains accruing to society as a result of the emissions reduction ensured by the policy, such as improvements to human health, the environment and economic indicators, as well as the costs to industry operators of implementing new techniques [20, 28]. Reviews of existing BAT reference documents (BREFs) aim to assess whether the techniques identified as BAT and the associated emission levels (BAT-AELs) reflect the most adequate means to reaching defined emissions reduction targets.

Many countries do not have the most appropriate datasets for an adequate analysis of the effectiveness of BAT-based policies. Governments can facilitate the effectiveness evaluation of BAT-based policies by collecting and publishing data on industrial emissions, production and consumption volumes, environmental permit conditions and techniques installed by individual facilities, whilst taking into account possible confidentially issues. An optimal evaluation of the impact of a BAT policy on emission trends requires readily available emissions monitoring data disaggregated at the level of each installation of an industrial facility, and corresponding activity data [20, 28]. Data from Pollutant Release and Transfer Registers, i.e. publicly available facility level data, can also be an option for the assessment of the BAT policy ´ s impact on industrial emissions. However, even where detailed activity and emissions monitoring data exist, it can be hard to determine whether observed emission trends can be attributed merely to the BAT policy. One way to draw a conclusion in this regard is to assess which other external factors could also affect emission trends, such as other policies or changes to economic activity.

The majority of countries evaluate the effectiveness of their industrial emissions policies, but the methodologies vary greatly. For example, the European Union (EU) has an objective to review its BREFs every eight years in addition to frequently conducting assessment studies of the impact of its Industrial Emissions Directive (IED) at the supranational and national levels [20, 28].

There are several advantages of existing BAT-based policies, with positive implications for the environment as well as industry. European industry representatives highlight that the IED creates a level playing field for industry, aligning environmental performance requirements for industrial installations. Case studies show that the implementation of BAT can ensure considerable savings to society, due to improved air quality, but also to industry, as a result of more efficient operations [20, 28]. Representatives of the European Commission further note that the integrated approach to pollution prevention and control is an important advantage of the EU ´ s BAT policy. Other stakeholders highlight that the participatory approach is gaining traction as a result of BAT-based projects.

Measures could be taken to leverage the untapped potential of BAT policies. For example, although beyond the current European legal definition of BAT, the European Commission notes that there might be value in looking at a wider life cycle approach to BAT determination. Whilst already a highly cooperative process, representatives from European industry associations and environmental NGOs advocate increasing the transparency of the procedures for the determination of BAT and BAT-AELs. The European Environmental Bureau recommends that more adequate emissions monitoring systems and user-friendly databases be established, enabling easy and timely gathering of performance data for compliance assessment, policy development and public awareness raising. Recent OECD research [20, 28] concludes that, for some countries, having wider inclusivity in the selection of industry experts involved in the determination of BAT would be of value, to ensure that techniques identified as BAT are the best available techniques worldwide, developed at a scale that enables implementation in the relevant sector under economically and technically viable conditions.

Further research is needed to strengthen existing and future BAT-based policies. To that end, the OECD will continue its ongoing BAT project by developing guidelines on how to determine BAT, derive BAT-AELs and translate BAT-AELs into emission limit values in permits. Further, the OECD will be conducting a study on value chain approaches to determining BAT for industrial installations, and cross-country comparisons of BAT and BAT-AELs for selected industrial sectors, in order to foster enhanced knowledge sharing.

5.1 EVALUATING THE EFFECTIVENESS OF BAT POLICIES

Evaluation of governmental programmes and policies is an essential tool to understanding and assessing their effectiveness [29], [30]. Feedback and evaluation allow the effects of past actions to be measured, including both process and substantive programme outcomes, as well as to strengthen future decisions, and thus benefit governments and the public alike by helping develop faster and better solutions [31], [32]. The performance evaluation of a policy instrument can enable strengthened administration of current policy, and feed into a process of policy reappraisal and enhancement based on empirical evidence. Notably, evaluations can help improve the choice of future policy instruments by demonstrating and analysing the functioning of a certain instrument in a specific context, often facilitating policy makers' learning from approaches adopted in other countries [33].

Evaluation can also facilitate enhanced communication with relevant stakeholders and the public about the objective, operation and impact of a policy, programme or specific instrument [33]. According to the World Bank, with policy makers and civil society demanding accountability from public programmes, impact evaluations can provide robust and credible evidence on performance as well as on whether a particular programme has achieved its desired outcomes [34]. The European Commission observes that "[e]valuation is a key Smart Regulation tool, helping the Commission to assess whether EU actions are actually delivering the expected results and ultimately improving conditions for European citizens and businesses and contributing to the EU´s global role" [30].

Evaluation of BAT policies are an invaluable tool to policy makers and industry operators, as it informs and facilitates the development of more effective and tailored BAT and emission limit values in permits. Moreover, BAT policy impact assessments can be beneficial in order to demonstrate that environmental policies deliver adequate results in an effective manner, so as to convince the public and politicians about their importance.

An adequate BAT policy impact assessment aims to analyse the causal relationship, and show any gap, between the policy's objectives or desired outcomes and the trajectory of the results derived from the evaluated instrument - i.e. BAT - or the lack thereof. The objective of a BAT policy is generally to reduce the environmental impacts of industrial operations in a cost-effective manner without hampering other aspects of the operations (as opposed to reducing the environmental impact by closing industrial facilities), contributing to a high level of environmental protection. This objective is often accompanied by specific, quantified targets with a clearly defined timeline for attainment.

Evaluations are more likely to result in meaningful evidence about the performance of a policy instrument if they are well informed, objective and based on good research practice [33]. While quantitative data provide for the most robust assessment of the effect of BAT policies, qualitative data may complement the analysis and provide useful insights into different stakeholders' perception of the policy. Qualitative data can, however, be subject to bias.

5.2 APPROACHES TO EFFECTIVENESS EVALUATION OF BAT POLICIES

Evaluating the effectiveness of a BAT policy can involve assessing the policy's impact on emission trends, i.e. on the concentration, mass or percentage of industrial emissions, assessed against the policy's defined objectives and a business as usual scenario. The assessment may also consider the impact of declining emission trends on the negative externalities associated with industrial pollution, by measuring improvements in human health, the environmental and economic indicators. This could include assessing changes in concentrations or relative proportions of key indicator pollutants in environmental media, and the amount of hazardous substances generated in production processes, as well as the resulting changes in, inter alia, environmental impacts, resource use, mortality and morbidity rates attributed to environmental quality.

The effects of industrial air emissions on human health and the economy have been projected by the OECD [35] by assessing the market costs of outdoor air pollution, i.e. on productivity, health care expenditures and changes in crop yields, and the non-market health impacts of pollution, including on individual willingness-to-pay for reducing health risks, using the OECD ´s ENV-Linkages model. ENV-Linkages is a multi-sectorial, multiregional model that links economic activities to energy and environmental issues. Industrial emissions constitute one of the key sources of air pollution, together with fossil-fuel based power generation, transport and burning of traditional biomass in the residential sector [35]. For example, in OECD countries, emissions from power stations, industrial combustion, and industrial processes and product use, accounted for approximately 90% of SOx emissions, 40% of NOx emissions and 20% of PM10 emissions over the period 2014-16. (Fugitive emissions from production processes come in addition to this) [36]. Therefore, this kind of model could feed into an analysis of the impact of air pollution caused by industrial emissions on human health and the economy, and thus be part of a BAT policy effectiveness assessment.

A comprehensive and detailed process-level cost-benefit analysis of a BAT policy could involve comparing the likely benefits of the policy, i.e. reduced industrial emissions, gains in productivity, and health and environmental costs (i.e. damage costs) avoided, to the cost to industry operators of implementing improved techniques in order to comply with permit conditions. For a cost-benefit analysis, emission reductions should be estimated for a period equivalent to the lifetime of the emissions reduction techniques and/or the envisaged operating time of the operator, and taking into account the conditions of use of the techniques. A cost-benefit analysis would allow quantifying whether the emission reductions and other benefits achieved through the policy outweigh the costs of its implementation, and thus help assess the policy' s value to society.

Fully understanding and obtaining supporting data on industry operators´ costs to BAT implementation can be difficult, notably if industry operators cannot provide such data, e.g. due to legal requirements or confidentiality issues. Even where such data are available, the proportion of the cost due to BAT-related requirements relative to other factors can be uncertain. Further, it may not be obvious how these costs compare to industry operators´ costs under a business as usual scenario. Estimating the damage costs avoided can also be challenging, both in terms of data access and methodology. For example, available methodologies and data for monetising the complete health and environmental benefits of the avoided emission of certain pollutants, accounting for short-term or long-term effects and local situations, create uncertainties in the estimates [37].

An alternative to a process-level cost-benefit analysis of a BAT policy is a high-level assessment of its impact on emissions trends. In many cases, this can be based on publicly available data. The object of such an analysis is to investigate the emission reductions that can be achieved by reaching compliance with BAT-associated emission levels. While a high-level emissions assessment cannot estimate the cost-benefit of a BAT policy, it can determine the practical effects of the measures deployed.

In addition to evaluating the impact of BAT policies overall, it is essential to assess the effectiveness of the BAT themselves, as part of regular reviews of BAT reference documents (BREFs). Such evaluations consist of assessing whether the techniques defined as BAT are indeed still the best available techniques, reflective of the most recent technological developments of the concerned industrial sector, or whether there would be more optimal ways of reaching the defined objectives. The frequency with which BREFs are reviewed varies across countries. The EU Industrial Emissions Directive sets the objective to review each BREF every eight years in order to reflect technical progress.

The effectiveness of a BAT policy can be assessed ex post or ex ante. Ex post analysis is based on historical observations and seeks to quantify the impact of a BAT policy after its implementation, while ex ante analysis aims to predict the quantified impact of a policy prior to its implementation. There is a long tradition for ex ante regulatory impact assessment in many OECD countries, with established analytical steps [38] and opportunities for public engagement to hold governments accountable for conducting analysis before regulations or policies are issued [39]. Ex-ante assessments aim to determine whether something that has not yet been done should be done, e.g. whether public money should be spent on the introduction of a certain policy [40]. Ex-ante analyses relies on hypotheses, i.e. unverifiable assumptions and models, of what the world would look like without a given governmental policy, and how responses to, and effects of, the policy will alter those conditions. With strong ex post policy evaluations conducted after the introduction of a policy, stakeholders could test the hypotheses from the ex-ante evaluation against actual outcomes. This would not only inform decisions related to the effectiveness of existing policy, but would provide feedback that would improve future ex ante analyses and future policies [41].

Ex post evaluations take a retrospective approach, seeking to verify whether a policy that has been implemented should have been implemented, i.e. assess the actual outcomes of a policy after its implementation [40], [41]. While it is impossible to reverse actions already taken, an ex post assessment can help cast light on the accuracy of the conclusion of an ex ante evaluation, the policy modifications that are needed to deliver the original aims or on the decision that originally was used to justify the introduction of the policy or programme. In both cases, the outcome of the ex post assessment is designed to contribute to learning about what does and what does not contribute to achieving progress towards defined objectives and thus improve future policies [40]. By verifying hypotheses and assumptions regarding causation and outcomes, an ex post evaluation also helps inform future ex ante evaluations [41]. It can, however, be difficult to conduct an ex post evaluation, as it is not always obvious what the world would have looked like without the policy that is being evaluated (the so-called “counter-factual”); measuring benefits and opportunity costs can be hard. Further, once a policy or regulation is in place, regulators or policy makers do not necessarily have strong incentives for examining its effect [41].

Many countries have BAT policies that have not yet taken full effect, making it preferable to opt for an ex ante assessment of their possible effectiveness, be it at a national, sectorial or operator level. Prior to taking measures to prevent and control industrial emissions in order to ensure compliance with BAT-based emission standards, an industry operator may want to conduct an ex ante evaluation of these measures as well as a baseline assessment of current emissions. Such assessments can serve as a basis for future ex post assessment, for example at the operator ´ s level. If no baseline is established or the necessary data are not gathered through the implementation period, conducting an ex post evaluation will not be possible. The data that will have to be collected, from the baseline and forward, in order to inform an ex post evaluation of the effectiveness of a BAT policy include emissions monitoring data at facility level or, ideally, at installation level, activity data at a corresponding level, and BAT-associated emission levels and/or the emission limit values of individual facilities. The effectiveness evaluation is further facilitated if information on the emission reduction techniques installed by facilities is also collected.

5.3 VALUE CHAIN APPROACHES TO DETERMINING BAT FOR INDUSTRY

In the transition towards a non-polluting, resource efficient industry, greater consideration of value chains shows potential to deliver greater overall environmental benefit than less integrated approaches that focus on individual stages, such as installation or sectorial emissions. Actions taken at the design and manufacturing, or other product life phases, can influence environmental impacts at other stages such as material processing, and waste recycling. The overall life-cycle impacts need to be accounted for at the outset.

Reflecting its origins in sectorial and installation level emissions control, BAT policy does not generally mandate a systematic approach to considering factors beyond the defined industrial manufacturing activities, although it can and often does rely on ad hoc wider systems thinking. As a result, BAT determinations often take into account industry trends and environmental understanding such as innovations to enhance the environmental performance of products and services, although they are not specifically designed to take account of value chains.

Value chain refers to the process of adding incremental value to products and services as they are generated and transformed at each step along the production cycle. The benefit of taking more holistic value chain approaches to BAT determinations is the opportunity to consider broader sustainability goals, where the focus is not on "**less emissions**" or "**reduced environmental impacts**" from the installation, but rather upon finding overall solutions that reduce negative environmental impacts on a whole-system basis, whilst still providing local emissions control and the intended output, and hence benefits of the value chain as a whole (i.e. including the service or product output of the industrial activity). This chapter describes how value chain approaches are/should be incorporated in BAT determinations and related environmental regulatory and policy concepts to accelerate progress toward identifying practices that more effectively consider an industry's entire value chain to reduce overall environmental impacts as well as individual manufacturing sites within a given sector. **Four concepts for expanding BAT determination** through a value chain perspective were considered [28]:

• Green chemistry
• Resource efficiency
• Circular economy
• Decarbonisation

Using the commonalities among these four concepts as a lens, overarching BAT policy and three sector examples were then assessed, namely the Textiles, Paints and Coatings, and Food Industries. Environmental issues associated with their value chains were then considered including the upstream and downstream impacts from each sector. Some impacts arising from a lack of value chain consideration were also noted. Some regulatory bodies have already responded to address value chain gaps appearing from a sectorial/installation BAT approach by overlaying them with cross-cutting initiatives including the application of other chemical safety legislation, voluntary programs such as the EU Eco-Management and Audit Scheme (EMAS), or specific BAT or other regulatory updates that address certain issues.

Value chains describe the full range of value-adding activities required to bring a product or service through the different phases of its production, including procurement of raw materials and other inputs, assembly, physical transformation, acquisition of required services such as transport or cooling, and ultimately response to consumer demand [42]. As such, value chains include all vertically linked, interdependent processes that generate value (or something useful) for the consumer, as well as horizontal linkages to similar processes that provide goods and services serving the same customer. Sustainable value chain can be described as the "full life-cycle of a product or process, including material sourcing, production, consumption and disposal/recycling processes." Value chains focus on value creation – typically via innovation in products or processes, as well as marketing – and also on the allocation of the incremental value [43]. It is called a value chain because value is being added to the product or service as it is being transformed [44].

Whilst BAT are designed for implementation at the level of industrial installations to prevent and control direct industrial emissions, the question posed is whether more could be done at the installation level to consider value chains more broadly and uniformly under the varying authorities that determine BAT for a particular sector.

Existing BAT policies and efforts encourage more holistic accounting of potential environmental impacts, seeking to study upstream and downstream interactions when establishing sector BATs. However, to date, broader assessments systematically considering industrial sector interactions have not been conducted uniformly across BAT policies and in an efficient manner.

Various concepts can be described as value chain approaches designed to holistically minimize and prevent impacts to the environment and human health. Such concepts include green chemistry, resource efficiency, circular economy, and decarbonisation and could be applied as a lens by which to assess sector interactions during the BAT determination process. Brief descriptions are provided below.

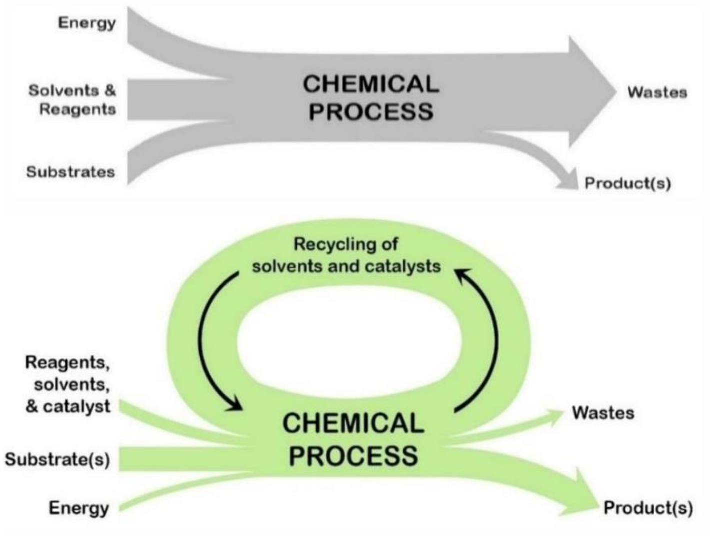
5.3.1 GREEN CHEMISTRY

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances by looking across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal [45]. Twelve principles demonstrate the breadth of green chemistry as focused on the prevention of waste and reduction of hazard in the inputs and products of chemical synthesis.

Even prior to the 'establishment' of green chemistry as a concept in the 1990s, industry has successfully applied these principles to a variety of syntheses and chemical processes to reduce their environmental impacts, resource intensity, and associated operating costs and continues to do so. The concept of green chemistry is closely related to sustainable chemistry, which is defined by the OECD as a scientific concept that seeks to improve the efficiency with which natural resources are used to meet human needs for chemical products and services [46]. Sustainable chemistry is sometimes slightly broader in scope, seeking to minimize environmental impact and stimulate innovation across all sectors through design of new chemicals, production processes, and product stewardship practices. Nine golden rules summarize the most important principles of sustainable chemistry [47].

Certain principles of green chemistry may impact value chains in a variety of ways. For instance, substitutions of input materials with renewable or safer alternatives occur through changes in upstream material supply and may impact downstream activities such as waste management or product use. It is key to carefully evaluate these downstream impacts to avoid regrettable substitutions. Principles such as designing for waste prevention and resource efficiency may also impact downstream activities; the quantity and characteristics of waste can have a dramatic impact on the efficiency of treatment operations. Similarly, designing for degradation may affect the types of materials available for downstream reclamation, reuse, and recycling.

Considering BAT determination through a green chemistry lens might result in identification of alternative chemicals and technologies that are economically competitive and offer advantages for industry and consumers, and (of course) are environmentally advantageous. Figure 5-1 illustrates how chemical use can be optimized through a green chemistry approach. In a 'typical' conventional chemicals process (in grey), a large amount of waste is produced relative to the amount of product. Implementation of green chemistry principles (in green) can lead to greater resource and energy efficiency, waste minimization, and recycling and regeneration of certain inputs.



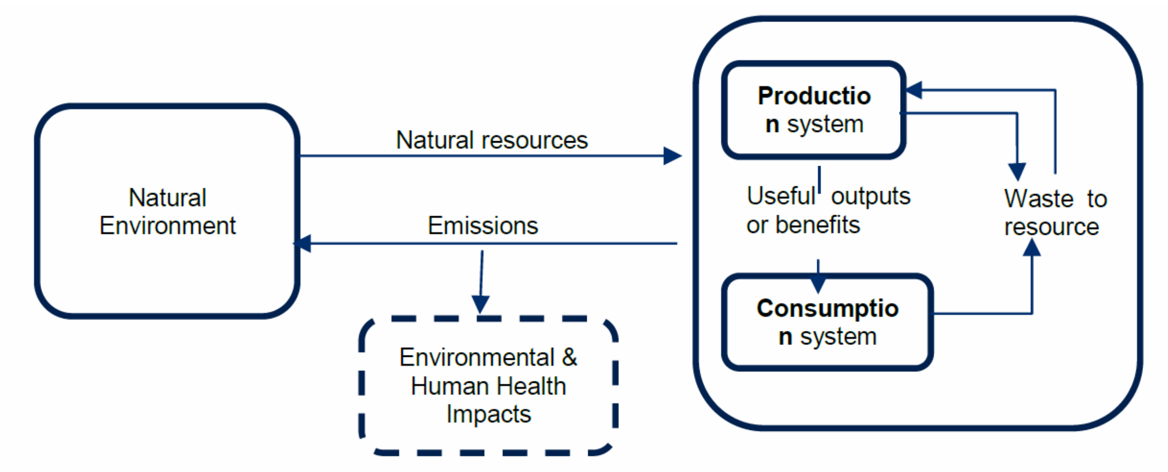
5-1. Figure_Green chemistry example [28]

5.3.2 RESOURCE EFFICIENCY

While definitions of resource efficiency may vary greatly depending on scope and scale, the European Commission notes that the goal of resource efficiency is to "deliver greater value with less input" [48]. As such, resource efficiency can be considered as the ratio of the benefits derived from a process (generally as value added) to quantity of resources used and/or the environmental impact associated with resource use [49]. In common terms, resource efficiency can be defined as a unit of resource input per unit of product output [50], e.g., kilogram clay (input) per kilogram ceramic tiles (output), and cubic meter water (input) per ton meat produced (output). Therefore, maximizing for resource efficiency can achieve cost savings and reduce emissions. The concept of resource efficiency is illustrated below, in Figure 5-2. At the scale of the individual installation, resources include natural and processed natural resources (industrial resources). These resources generally include some combination of the following: raw materials, water, chemical agents, process residues, packaging, and equipment. Additionally, energy efficiency is often considered a component of resource efficiency.

The concept of using and re-using resources more efficiently is also addressed through similar approaches including EPA's and OECD's Sustainable Materials Management, which considers the impacts of materials throughout the entire life cycle to reduce environmental impacts at each stage and throughout [51].

Considering BAT determination through a resource efficiency lens (including through the use of BAT environmental performance levels) might result in efficiencies throughout the product's life cycle such as process or technology adjustments to reduce water and energy consumption, and the use of toxic substances. Moreover, consideration of resource efficiency may facilitate identification of renewable feedstock's and raw materials for product manufacturing, resulting in the extraction of more sustainable materials upstream and detoxification of the overall materials used, reducing toxic or hazardous properties as it continues through product use and eventual reclamation or final disposition.



5-2. Figure_Illustration of the resource efficiency concept [28]

5.3.3 CIRCULAR ECONOMY

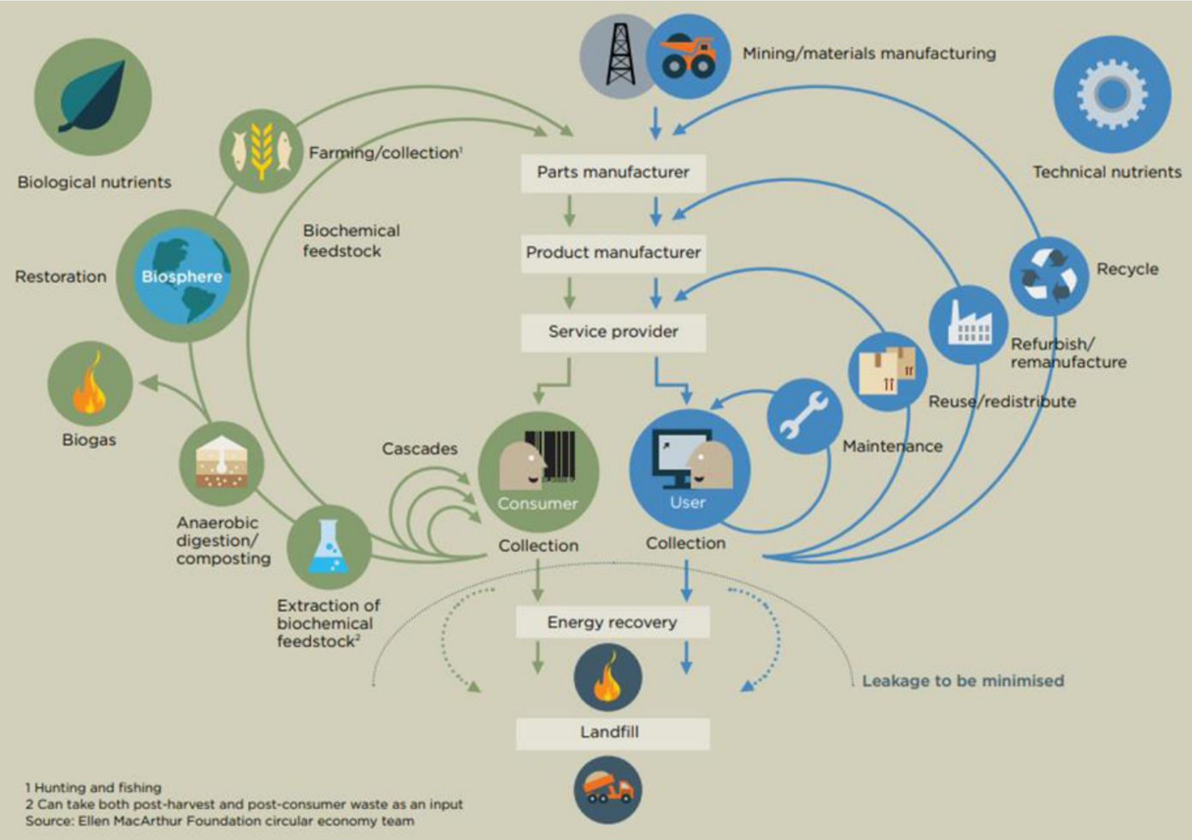
Although there is no single commonly accepted definition for the term “circular economy” [52], the three main features of circular economy are often highlighted as: closing the loops of material flow by recycling and remanufacturing; slowing loops by increasing the working life of goods and products; and narrowing loops by using natural resources and goods more efficiently within linear systems (e.g. buildings and cars) [53], [54].

Circularity can also be described as two parts: biological and technical cycles. A circular biological cycle involves the consumption and movement of bio-based materials, ultimately feeding back into the system through processes such as composting and anaerobic digestion, serving to regenerate natural systems such as soil. Circular technical systems keep materials and products in use longer through strategies such as reuse, repair, and remanufacturing, focusing on recovery of materials through recycling [55]. Figure 5-3 illustrates the conceptual basis of circular economy along with biological and technical cycles within it. Considering BAT determination through a circular economy lens might result in identification of alternative materials and technologies that can contribute to waste reduction and recycle, the use of secondary and reusable materials and energy efficiency throughout the whole value chain.

5.3.4 DECARBONISATION

Climate change mitigation is a crucial global environmental issue. The Paris agreement sets the target to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels [56]. To achieve global reduction targets of greenhouse gas (GHG) emissions, there is a need for mitigation actions from all industrial sectors.

The term “decarbonisation” is generally used in the context of power supply. Here, the main strategies for reducing GHG emissions are use of renewable energy resources in place of fossil carbon-containing fuels, and implementation of carbon capture and storage [57]. These strategies apply to any sector which requires power generation; the main strategy for decarbonizing manufacturing sectors is to meet their energy needs through decarbonized power supplies, be they on or off site.

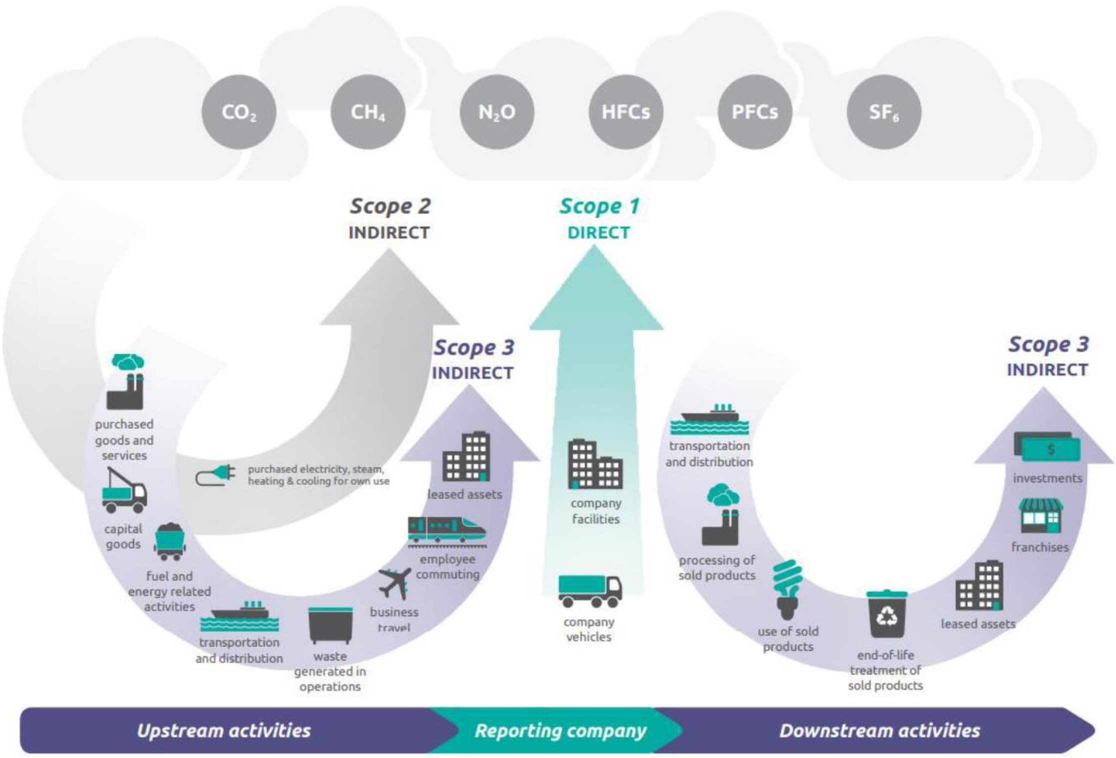


5-3. Figure_Illustration of the circular economy concept [28]

Other important strategies for decarbonisation include use of hydrogen as a fuel such as in transportation and electrification of industrial processes which traditionally rely on fossil fuels for power. For full decarbonisation of such processes, the energy requirements to generate hydrogen or electricity must be met with decarbonised power sources [58], [59].

The GHG Protocol is widely used across the world for accounting and reporting of carbon dioxide (CO2) and other GHGs emissions. It classifies GHG emissions into three categories: Scope 1 (all direct GHG emissions); Scope 2 (indirect GHG emissions from consumption of purchased electricity, heat or steam); and Scope 3 (other indirect emissions not covered by Scope 2). Examples include the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transmission and distribution losses) not covered in Scope 2, outsourced activities, waste disposal, etc. These scopes thus try to cover the whole GHG emissions through the value chain (Figure 5-4) [60].

Considering BAT through decarbonisation and GHG reduction lens might result in the identification of further potential for the reduction of GHG emissions, not only at the industrial installation, but also throughout the value chain, e.g. through consistent application of BAT-associated environmental performance levels for energy efficiency. Moreover, measuring the GHG emissions of an entire value chain could help determine which raw materials or techniques should (and should not) be used in a given industrial activity in terms of GHG emission reduction through the whole process including material production, transportation, product use, and waste disposal. Such approaches also allow consideration of product benefits. For example, the production of isocyanides to produce insulation is energy consuming, but then saves energy when used. Similarly, certain plastic packaging, although itself fossil fuel derived can lead to wider overall environmental benefits by preserving food and this avoiding food waste impacts.



5-4. Figure_Overview of GHG protocol scopes and emission across the value chain [28]

5.3.5 COMMON THEMES AMONG VALUE CHAIN APPROACHES AND EXAMPLES

While value chain approaches described here vary significantly, all are guided by the ultimate goals of environmental sustainability. Some of the approaches focus on specific resources; green chemistry pertains to the production and use of chemicals, whereas decarbonisation focuses on fossil fuel resources. Compared to these more targeted frameworks, resource efficiency and circularity are much broader in scope. Circularity, in particular, seeks to reframe current patterns of consumption, use, and disposal. Regardless of differences in target and scope, common themes underlie many of these value chain approaches. These themes are as follows:

Pollution prevention and waste minimisation - The first principle of green chemistry is "Prevent waste: design chemical syntheses to prevent waste. Leave no waste to treat or clean up." Similarly, "designing out waste" is a principle of circularity. Much of decarbonisation is aimed at designing fossil fuel combustion out of energy production.

Resource efficiency - The green chemistry principle “maximizing atom economy” is guided by resource efficiency to ensure that more of the starting materials in a chemical process are incorporated into the product. Similarly, catalysis is a strategy to avoid the inefficient use of stoichiometric reagents during synthesis, often with reaction conditions closer to ambient conditions. The reframing of waste as a resource in resource efficiency is one of the main principles of a circular economy, where the waste from any process may serve as an input for another use, displacing other raw material usage.

Use of renewable feedstock and raw materials - All approaches highlight the importance of renewable feedstock and raw materials. Decarbonisation seeks to eliminate the use of fossil fuels and petroleum-based resources through use of renewable feedstock and resources. The concept of a circular economy relies on the use of renewables as a key link in the biological cycle (e.g., composting and anaerobic digestion of consumer waste for production of renewable chemical and energy resources).

Recycling and material recovery - Reframing waste as a resource is a common theme in the approaches. A goal of resource efficiency is to decouple production from consumption of natural resources with recycling and material recovery necessary to achieve this end. In the concept of a circular economy, these strategies ensure minimal leakage of resources from the system. In biological cycles, waste collection is key in the production of biochemical feedstock and the restoration of biological systems for renewable feedstock production. In technical cycles, the recovery and recycling of metallic and mineral resources is necessary to maintain circularity for part and product manufacturing.

Hazard reduction - Green chemistry focuses heavily on hazard reduction in terms of chemical inputs as well as products. Similar themes appear in resource efficiency and circularity, where minimizing the hazard associated with inputs may be a strategy to minimize use of resources dedicated to risk management at the installation level. Minimizing hazard associated with products is also key in ensuring that materials may be recycled and reused at other links in the value chain. Material substitution is a key strategy for hazard reduction, but usually requires a priori knowledge of any potential impacts on other links in the value chain and during product use to avoid regrettable substitutions.

Together, these value chain approaches aim to consider relevant industrial interactions, be they upstream of the installation as an input, downstream of the installation as a product to another producer or consumer, or mutually beneficial operations that enable greater capture and reuse of resources, and post-consumer recapture and re-integration in the production. These approaches share a common goal of helping industry achieve greater sustainability through pollution prevention, waste minimization, resource efficiency, recycling and material recovery, and hazard reduction.

5.3.6 IMPLEMENTATION OF VALUE CHAIN CONCEPTS

At an installation level, these concepts could be implemented in various ways to help find sustainable solutions and designing for e.g. waste prevention and resource efficiency. Collectively, these individual design objectives inform policy and BAT determinations, and applying the value chain lens may aid in:

• identifying safer chemical alternatives for hazardous raw materials and auxiliaries;

• prioritizing the use of renewable feedstock which may effectively incorporate agricultural products or recycled materials;
• highlighting more efficient processes to optimize the conservation of water, energy and other resources through synergistic activities promoting manufacturing processes or technologies that reduce net global impact;
• reducing impacts from pollutants of special concern;
• designing products for downstream applications and requirements that limit impact to consumers and enable waste prevention and reclamation.

When determining BAT and operating requirements for specific industries, taking a broader value chain perspective may shed light on movement towards more sustainable practices in related or connected industries These forces could be regulatory, or market driven as society aims to respond to sustainability goals and reduce our footprint. The next section considers existing BAT and whether they are efficient from a value chain perspective.

5.4 ANALYSIS OF BAT EFFECTIVENESS FROM A VALUE CHAIN PERSPECTIVE

Many current regulatory frameworks for BAT determination imply consideration of value chain concepts, particularly the common themes previously outlined. Specifically, guidance documents, legislation, and statutes point to pollution prevention, hazard reduction, and resource efficiency as guiding principles for these decisions. Additionally, these frameworks may be designed to favour low waste technologies or those which reduce the consumption of virgin materials. Directives highlighted below point towards systems thinking of installation operations.

The Industrial Emissions Directive [3], which is currently under review provides the framework for the determination of BAT in the European Union (EU) and requires techniques to “reduce emissions and the impact on the environment as a whole.” One main goal of the IED is “to prevent, where that is not practicable, to reduce and as far as possible eliminate pollution arising from industrial activities” [3]. Under its revision, IED targets to enhance the value chain perspective, promoting decarbonisation and circular economy which are more prominently addressed in the more recent BREFs. Several principles in the EU’s BREF Guidance Document [61] and the parent directive IED correspond to value chain concepts:

• Art. 1 of the IED reads “and to prevent the generation of waste”.
• Techniques will “reduce the use of raw materials, water and energy” and “prevent or limit the environmental consequences of accidents and incidents”
• “Techniques will cover both pollution prevention and control measures, recognizing that emission prevention, where practicable, is preferred over emissions reduction [3]”.

Further, the Technical Working Groups are instructed to consider the following criteria for the determination of BAT as outlined in Annex III of the IED:

• The use of low-waste technology for production processes
• The use of less hazardous substances
• The furthering of recovery and recycling of substances generated and used in the process and of waste
• The extent of consumption and nature of raw materials and energy
• The need to prevent or reduce the overall impacts of emissions on the environment

• The need to prevent accidents and to minimise the consequences for the environment [3].

A number of studies have analysed the extent to which value chain concepts are integrated into BREF documents, sectoral guidance, and regulations. For instance, studies assessing how the EU Industrial Emissions Directive (IED) [3] considers value chain approaches to determining BAT, e.g. contributes to circular economy objectives, facilitates resource efficiency, and otherwise considers value chains, are discussed below along with other research.

BAT is not usually used to directly address greenhouse gas (GHG) emissions. This is partly due to policy decisions to use market-based approaches, such as the emissions trading system (ETS) in the European Union. Provisions in the IED framework and EU-ETS Directive prohibit the setting of emission limits for GHG in permits, for the installations covered by the ETS. While this approach may limit the potential for 'double-regulation', it is possible that it can lead to certain sectors not taking into full account available options for the control of GHGs when determining BAT for sectors and installations.

Most BREFs aim for decarbonisation and GHG emission reduction as a co-benefit through BAT on energy use and efficiency. Fuel choice is a fundamental BAT, discussed in many BREFs. Further, some BAT Conclusions aim to replace the use of refrigerants that harm the ozone layer or have global warming potential, supporting prevention of climate change.

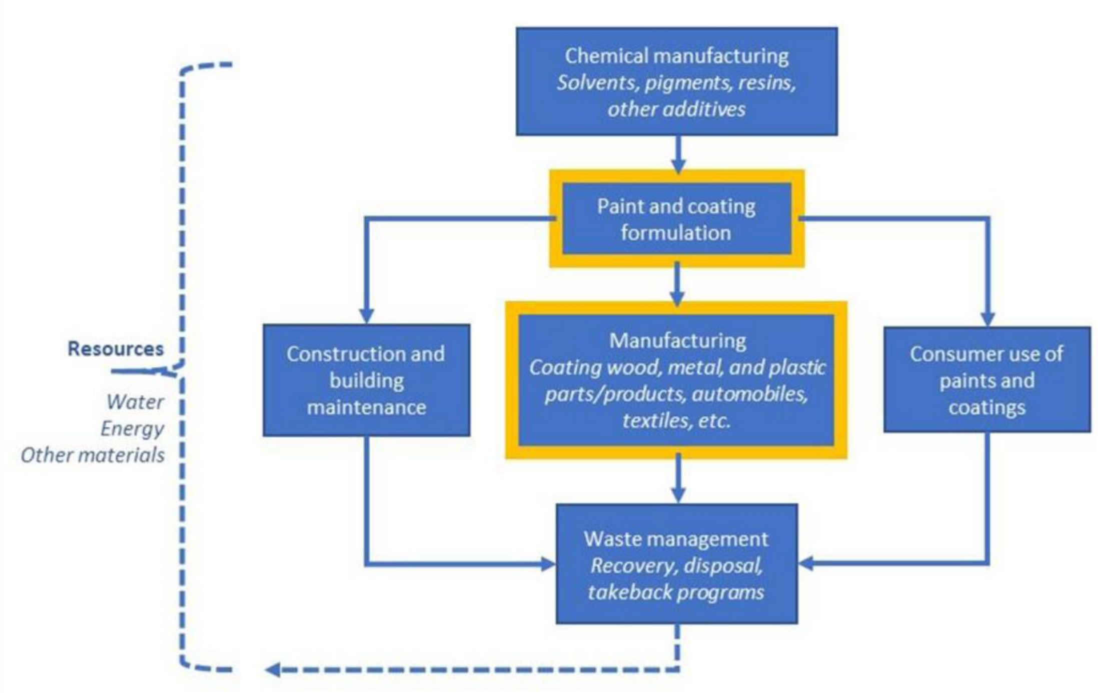
To extend the findings presented above, analysis of selected sectors (related to automotive) and pertinent BREFs as an example is described below to determine the extent of value chain considerations.

5.4.1 PAINTS AND COATINGS INDUSTRY

As a subsector of the chemical manufacturing industry, paints and coatings manufacturing generally focuses on mixing formulations of various components (see Figure 5-5). These components can be roughly grouped into four categories: solvents, binding resins, pigments, and miscellaneous additives. Most components are products of upstream chemical manufacturing, although some may be produced in the installation or at co-located facilities. Roughly 55% of all coatings are used in construction and maintenance of buildings, 35% are used in manufacturing, and the remaining 10% are specialty coatings [62]. Environmental issues stemming from the industry include solvent use, emissions of VOCs from application, and use of harmful additives such as certain plasticisers.

While the formulation step of paint and coating manufacture may be covered under some BAT regulations, it is generally the application of paints and coatings in industrial settings that is regulated through these policies.

• The EU BREF on surface treatment using organic solvents10 covers the activities of surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating with a solvent consumption capacity above certain thresholds. The main covered activities include coating of new vehicles, aircraft, ships, other metal and plastic surfaces, textiles, wooden surfaces, metal packaging as well as printing processes [63].



5-5. Figure_Paint and coating manufacturing flow diagram [28]

• The US technology-based regulations for air emissions from paint and coating manufacturing cover mixing binders, solvents, and pigments into paints and other coatings, adhesive manufacturing, and manufacturing other allied coating products. Technology-based standards for discharges to water from paint production cover the manufacturing of oil-based paints where tanks are cleaned with solvents.

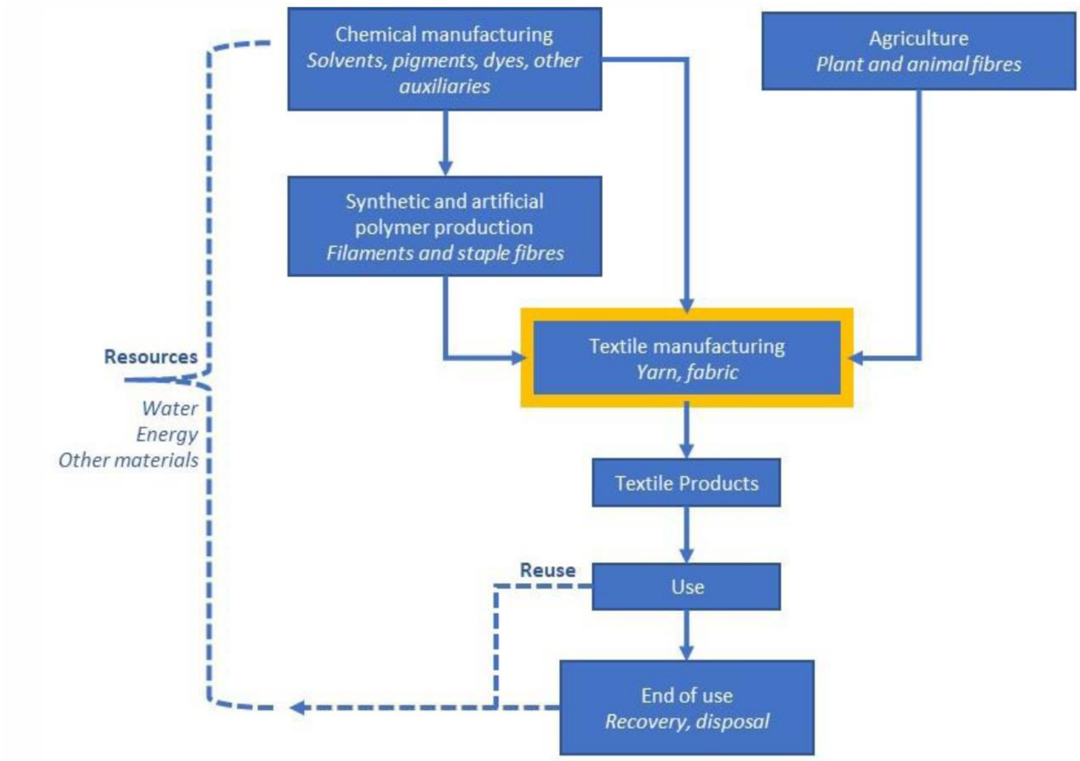
• US Technology-based standards for air emissions from the application of paints and coatings cover auto and light duty truck surface coating, metal can surface coating, metal coil surface coating, metal furniture surface coating, miscellaneous metal parts and products surface coating, paint stripping and miscellaneous surface coating operations, plastic part surface coating, printing and publishing surface coating, shipbuilding and ship repair surface coating, wood building products surface coating, and wood furniture surface coating. Additional air emission standards apply to new or reconstructed facilities which participate in furniture surface coating, auto and light duty truck surface coating, large appliance surface coating, metal coil surface coating, surface coating plastic parts for business machines, polymeric coating of substrates, coating of flexible vinyl and urethane, and beverage can surface coating. Technology-based standards for discharges to water from paint and coating application apply to coil coating.

The above documents and regulations address environmental issues associated with the paints and coatings value chain in various ways. Strategies for minimizing environmental impacts include resource efficiency and green chemistry approaches. Additionally, upstream or downstream industries may be considered to varying degrees.

5.4.2 TEXTILE INDUSTRY

The textile industry covers a variety of activities, including yarn and fabric production, wet processing (bleaching, dyeing, etc.), finishing, and coating. Upstream chemical manufacturing supplies a number of commodities and fine chemicals to these processes. Polymer production supplies man-made and artificial fibres, whereas agricultural activities supply natural fibres (e.g., cotton) to the industry. Design concept plays a crucial role in the textiles manufacturing [64] as it highly influences the environmental impact of the end products and therefore, all the downstream steps and implications. Downstream activities include apparel, carpet, and automobile manufacturing, among others. Figure 5-6 gives an overview of textiles manufacturing with some of its components.

Environmental issues stemming from the textiles industry include use of hazardous chemicals, polluted effluent, micro plastic releases as well as water, energy, and material consumptions. Additional environmental considerations include land use and degradation for the production of agricultural raw materials, their consumption, and energy used during processing [65]. Additionally, these activities include use of hazardous chemicals such as fertilizers, pesticides, and chemicals used during processing (e.g. for production of artificial fibres).



5-6. Figure_Textile manufacturing flow diagram [28]

These issues may be addressed in BAT regulations for the textile manufacturing industry. Relevant regulations include:

• The 2019 draft EU BREF document for the textiles industry6 scope includes some of the textile value chain, including yarn and fabric production, pre-treatment (washing, mercerizing, bleaching, etc.), dyeing, fabric printing, coating, finishing, and lamination. Additionally, certain aspects of wool textile production are also covered, including wool scouring, carbonizing, and fulling. Selected activities related to waste management are also covered [66].

• The US technology-based standards8 for air emissions from the textiles sector cover web coating and printing, slashing, and dyeing, and finishing as three separate subcategories. New or reconstructed facilities must also comply with polymeric coating standards to woven, knit, and nonwoven textiles as well as cord and yarn. Standards for discharges to water cover wool scouring and finishing, low water use processing, woven fabric finishing, knit fabric finishing, carpet finishing stock and yarn finishing, nonwoven textile manufacturing, and felted fabric processing.

The above documents and regulations address the textile value chain in various ways. Strategies for addressing the environmental impacts from textile production often include chemical selection and increasing processing efficiency. Assessment of textile-related BREFs show instances where solutions from other links in the value chain were considered in addressing environmental issues from the textiles industry.

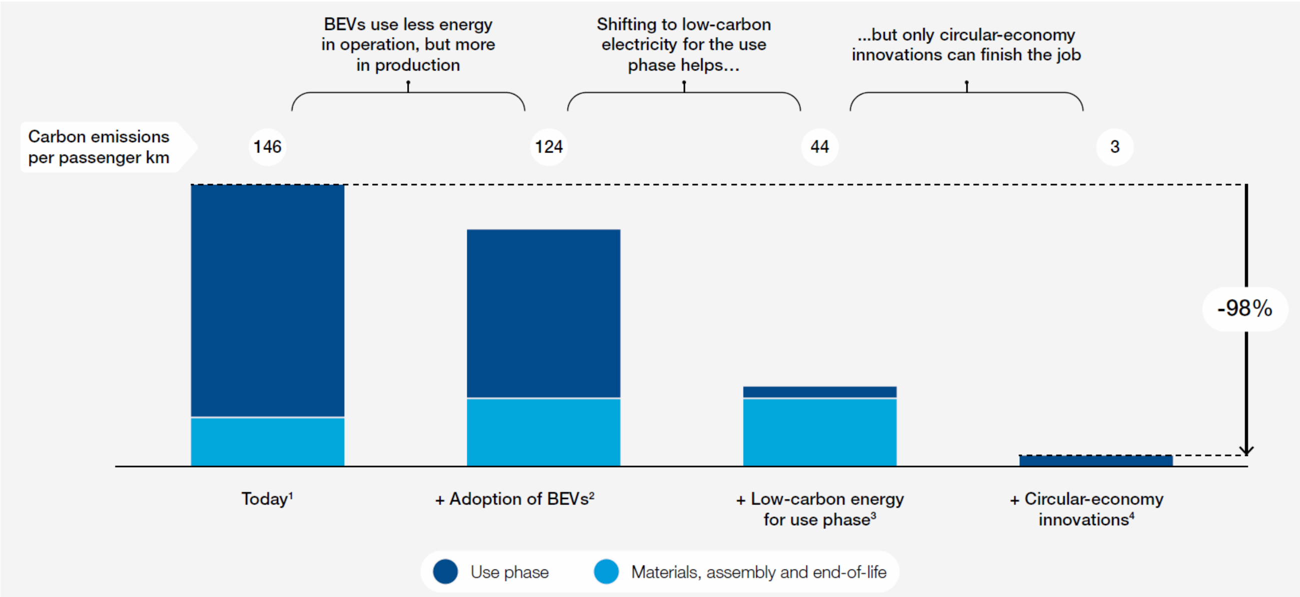
6. BEST AVAILABLE TECHNIQUES RELATED AUTOMOTIVE INDUSTRY

The automotive sector has integrated circular economics into its business practices for decades. But now is the time to raise ambitions on the sector's approach to circularity to effectively address climate change and resource depletion. For the world to experience less than 1.5°C of global warming, the automotive industry needs to target around a 50% reduction in absolute carbon emissions by 2030. In the same period, we expect mobility demand to increase by 70% globally. Circularity and electrification will be the core strategies that enable the industry to decarbonize and prepare for this increased mobility demand. Circularity means using cars more efficiently, shifting to fleets and coordinating value ecosystems more effectively [67]. All of these aspects of circularity can add value for the industry and for society, and enhance the broader ecosystem that humans inhabit.

Original equipment manufacturers (OEMs) have already set ambitious roadmaps towards carbon neutrality in the next two decades. The Circular Cars Initiative (CCI) represents the first organized industry effort to systematically address the opportunities and challenges of circularity with an eye towards fundamentally remaking automotive value chains and business models [67].

The term "circular car" refers to a theoretical vehicle that has maximized materials efficiency [67]. This notional vehicle would produce zero materials waste and zero pollution during manufacture, usage and disposal – which differentiates it from today's zero-emission vehicles. While cars may never be fully "circular", the automotive industry can significantly increase its degree of circularity. Doing so has the potential to deliver economic, societal and ecological dividends. Indeed, the convergence of technology, environmental and economic megatrends is propelling the modern automotive industry towards just such a transformation. The Circular Cars Initiative has assembled a broad coalition of participants from the automobility ecosystem committed to leading this transformation and increasing the environmental sustainability of global mobility by harnessing the power of new technologies, materials and business models.

In model year 2021, the average estimated real-world CO_2 emission rate for all new vehicles fell by 2 g/mi to 347 g/mi, the lowest ever measured. Real-world fuel economy remained at a record high 25.4 mpg [68]. Since model year 2004, CO_2 emissions have decreased 25%, or 114 g/mi, and fuel economy has increased 32%, or 6.1 mpg. Over that time, CO_2 emissions have improved in fourteen of seventeen years [68].



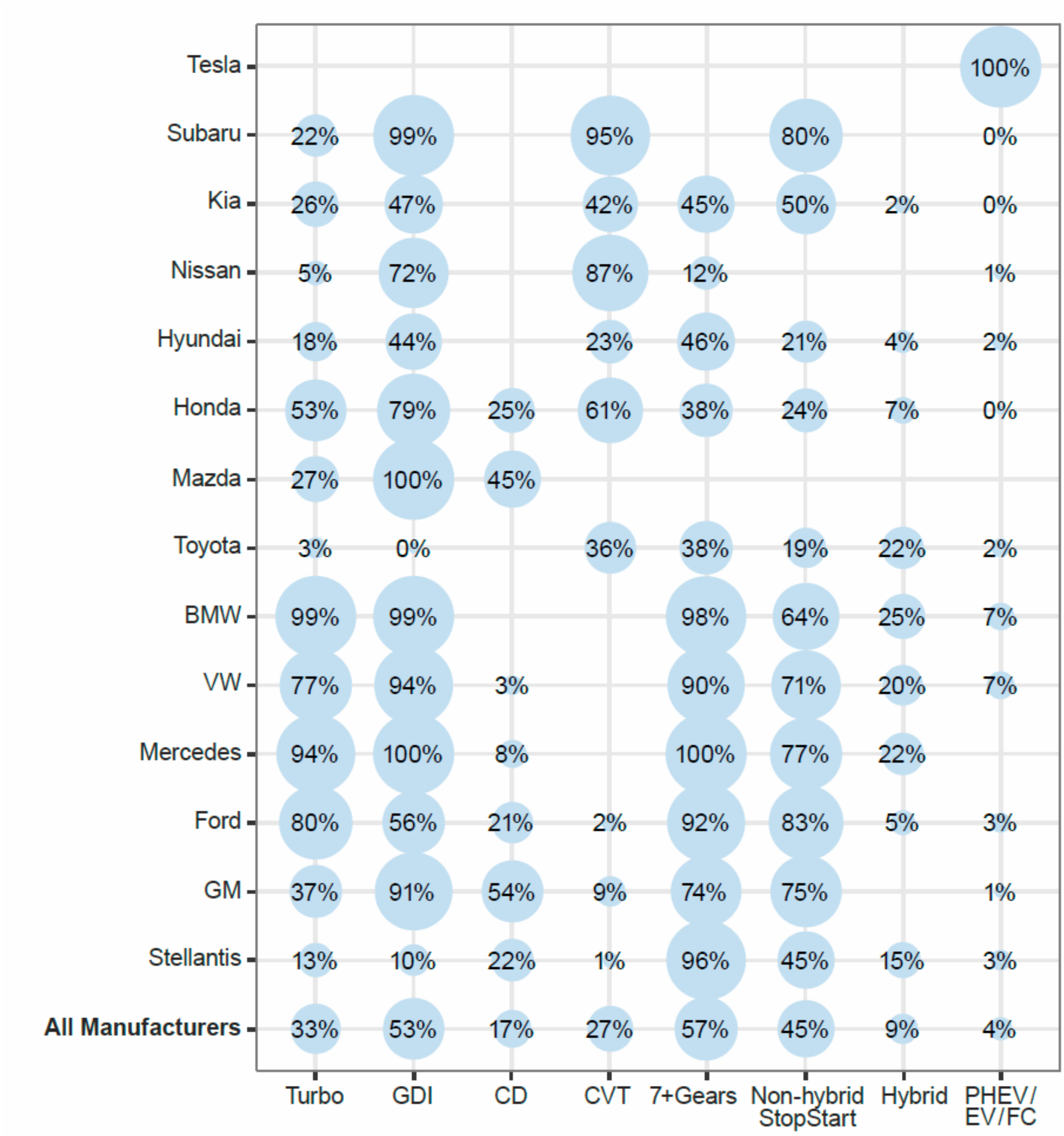
6-1. Figure_Decarbonizing the car [67]

Notes
[1] ICEV hatchback (level 1) with 1.70t weight (incl. repair components), 0.90t steel, 0.15t aluminium, 0.29t plastics, 200,000 life-cycle km and average occupancy of 1.5
[2] BEV hatchback (level 1) with 1.90t weight (incl. repair components), 0.70t steel, 0.19t aluminium, 0.32t plastics, 0.32t EV battery, 250,000 life-cycle km and average occupancy of 1.5
[3] Requires decarbonization of electricity grid with additional renewable energy as per consumption requirement by BEVs
[4] Circular-economy innovations consider level 4 circular BEV (fully circular)

Overall vehicle trends are influenced both by vehicle technology and design, and by the changes in the distribution of vehicles being produced. For a specific vehicle, increased weight or horsepower is likely to result in higher CO_2 emissions and lower fuel economy, all else being equal. Larger vehicles, in this case measured by footprint or the area enclosed by the four tires, also tend to have higher CO_2 emissions and lower fuel economy. Footprint is also the basis for determining regulatory standards under the GHG and CAFE regulations. Electric vehicles produce zero tailpipe emissions; however, weight, horsepower, and vehicle size can still impact the vehicle fuel economy (as measured in miles per gallon of gasoline equivalent).

In the two decades prior to 2004, technology innovation and market trends generally resulted in increased vehicle power and weight (due to increasing vehicle size and content) while average new vehicle fuel economy steadily decreased and CO2 emissions correspondingly increased [68]. Since model year 2004, the combination of technology innovation and market trends have resulted in average new vehicle fuel economy increasing 32%, horsepower increasing 20%, and weight increasing 4%. Footprint has increased 5% since EPA began tracking it in model year 2008. These metrics are all at record highs and are projected to increase again in model year 2022 [68].

The changes within each of these metrics are due to the combination of design and technology changes within each vehicle type, and the market shifts between vehicle types. For example, overall new vehicle footprint has increased within each vehicle type since model year 2008, but the average new vehicle footprint has increased more than the increase in any individual vehicle type over that time span, due to market shifts towards larger vehicle types. Fuel economy has also increased in all vehicle types since model year 2008, however the market shift towards less efficient vehicle types has offset some of the fleet wide fuel economy and CO2 emission benefits that otherwise would have been achieved through improving technology.

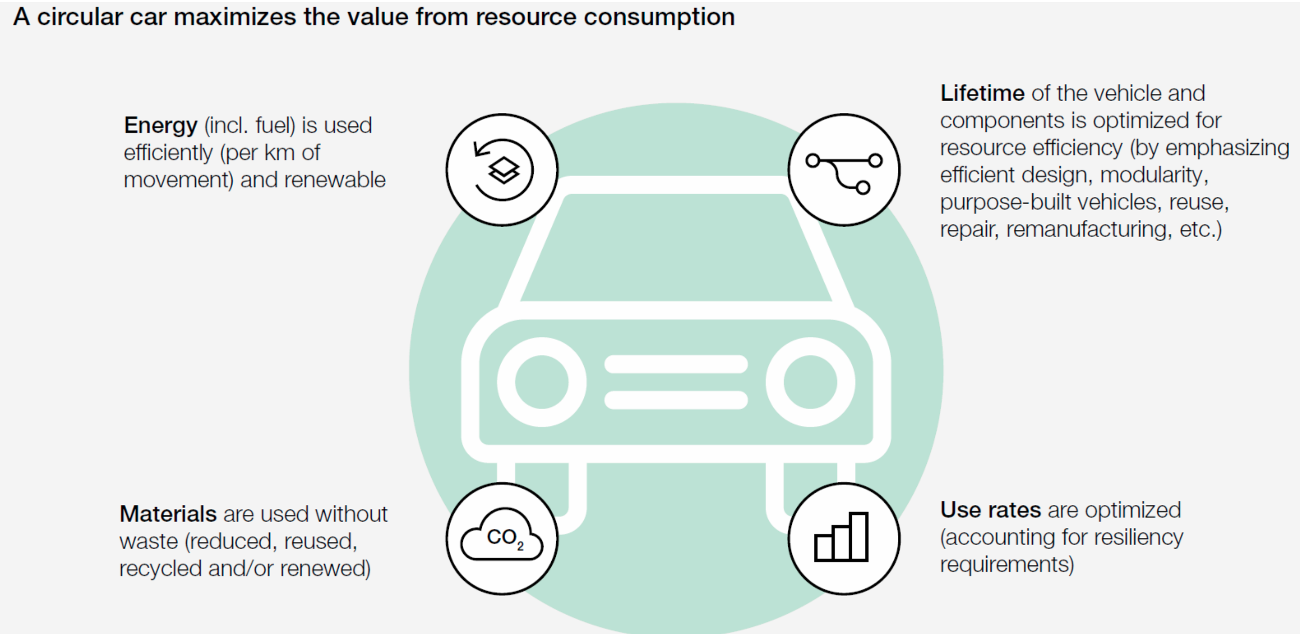


6-2. Figure_Technology share for large manufacturers, model year 2021 [68]

Innovation in the automobile industry has led to a wide array of technology available to manufacturers to achieve CO2 emissions, fuel economy, and performance goals. Figure 6-2 illustrates manufacturer-specific technology usage for model year 2021, with larger circles representing higher usage rates [68]. The technologies in Figure 6-2 are all being used by manufacturers to, in part, reduce CO2 emissions and increase fuel economy. Each of the fourteen largest manufacturers have adopted several of these technologies into their vehicles, with many manufacturers achieving very high penetrations of several technologies. It is also clear that manufacturers' strategies to develop and adopt new technologies are unique and vary significantly. Each manufacturer is choosing technologies that best meet the design requirements of their vehicles, and in many cases, that technology is changing quickly.

Engine technologies such as turbocharged engines (Turbo) and gasoline direct injection (GDI) allow for more efficient engine design and operation. Cylinder deactivation (CD) allows for use of only a portion of the engine when less power is needed, while stop/ start systems can turn off the engine entirely at idle to save fuel. Hybrid vehicles use a larger battery to recapture braking energy and provide power when necessary, allowing for a smaller, more efficiently operated engine. The hybrid category includes "full" hybrid systems that can temporarily power the vehicle without engaging the engine and smaller "mild" hybrid systems that cannot propel the vehicle on their own. Transmissions that have more gear ratios, or speeds, allow the engine to more frequently operate near peak efficiency. Two categories of advanced transmissions are shown in Figure 6-2: transmission with seven or more discrete speeds (7+Gears), and continuously variable transmissions (CVTs).

In model year 2021, hybrid vehicles reached a new high of 9% of all production. This increase was mostly due to the growth of hybrids in the truck SUV and pickup vehicle types. The combined category of electric vehicles (EVs), plug-in hybrid vehicles (PHEVs), and fuel cell vehicles (FCVs) increased to 4% of production in model year 2021 and are projected to reach 8% of production in model year 2022, due to expected growth in EV production across the industry [68].



6-3. Figure_Definition and elements of a circular car [67]

A circular car maximizes value to society, the environment and the economy while efficiently using resources and public goods. Its value is measured in terms of its ability to provide mobility, and its efficiency is measured in terms of carbon emissions, non-circular resource consumption and use of public goods, such as space or clean air. Our definition focuses on four relevant variables: energy, materials, lifetime and use (see Figure 6-3).

To measure progress over the five levels of circularity, this study proposes carbon efficiency and resource efficiency as primary measures. Efficiency is increased by reducing carbon emissions and non-circular resource consumption, as well as by increasing the service delivered by a vehicle – mostly in the form of passenger kilometres.

CARBON EFFICIENCY: LIFE-CYCLE CO2 EMISSIONS PER PASSENGER KILOMETRE

Carbon efficiency takes a holistic view of a vehicle's carbon footprint – not merely exhaust emissions or carbon intensity of materials. This methodology accounts for both: a) total life-cycle emissions, including materials, production, use phase and end of life; and b) service delivered (as opposed to kilometres driven). The entire automotive fleet's carbon efficiency should align with a 1.5°C climate scenario.

RESOURCE EFFICIENCY: NON-CIRCULAR RESOURCE CONSUMPTION PER PASSENGER KILOMETRE

Resource efficiency considers the amount of non-circular resources consumed to deliver one unit of service. It takes into account the inflow of resources into a car (recycled, biobased and renewable materials would be considered circular, while virgin materials are non-circular), as well as the outflow of resources. Circularity can be increased through strategies including reuse, remanufacturing and high-quality recycling. Improving resource efficiency often has an indirect impact on carbon efficiency as well.

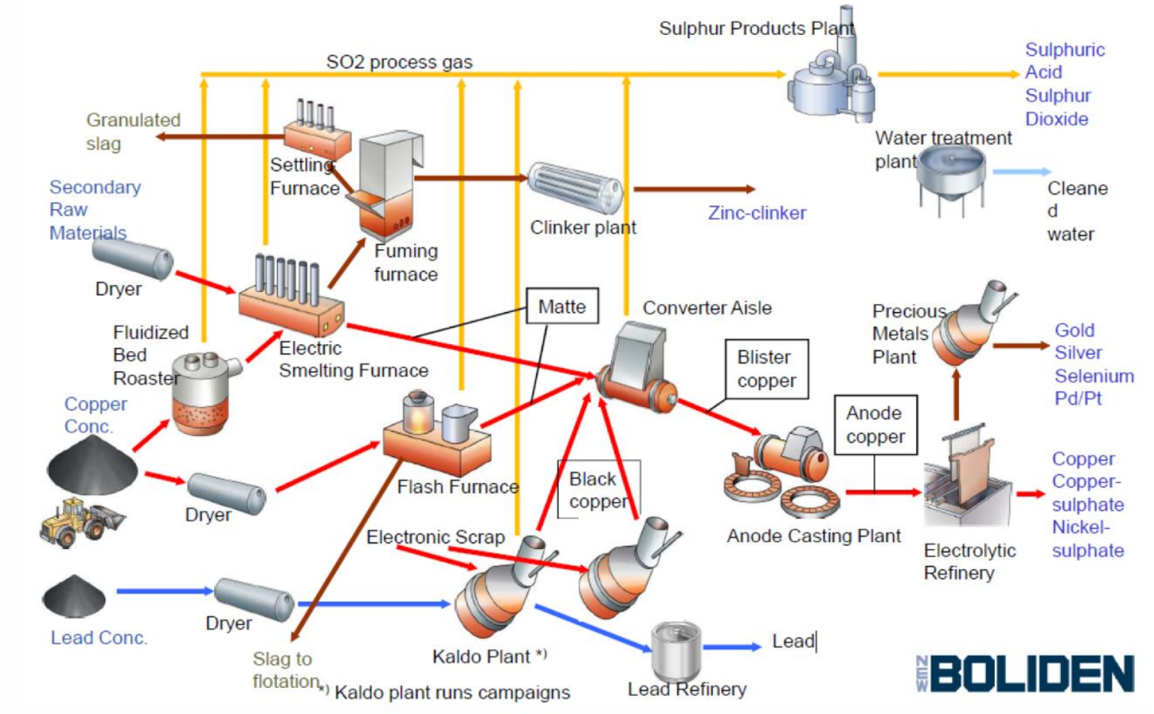
These trends and new technological possibilities have created a generational disruption in the automotive sector. The confluence of electrification, autonomy and mobility business models has created a plastic moment during which OEMs can capture new revenue streams. Slowly but surely, we are witnessing a shift away from traditional business models focused on production and sales: Cars are increasingly bought online and flexibly "subscribed" to for shorter time periods; revenue streams are shifting towards the use phase; and the drive towards circularity is slowly picking up speed. It is clear that future sustainable mobility solutions require a modal shift away from cars, especially in urban areas, but the future automotive industry will have a key role to play in meeting this mobility demand while still reducing its life-cycle carbon footprint. Electrification of vehicles will progressively cut tail pipe emissions and shift the decarbonisation onus onto the manufacturing processes, which is where circularity and climate goals can be mutually reinforcing. On the one hand, shared, connected autonomous vehicle technologies will enable new products and services for more sustainable and economically efficient use of the vehicle stock, disrupting the current private ownership model and softening demand for passenger cars in the medium and long term. In other words, as digital services and software capture more value added at the expense of manufacturing parts and vehicles themselves, road transport emissions will naturally fall. On the production side, circularity refers to a cross-cutting minimization of raw material inputs through innovative processes and substitution with end of life and/or waste material and coordinating value ecosystems more effectively. These circularity segments can add value not only for society but incumbent and emerging companies. The growing demand for more fuel efficient, lighter, and safer vehicles that is re-shaping the global automotive industry landscape is driven by regulators and customers, pushing vehicle manufacturers to focus on design efficiencies using advanced technologies and materials. These factors have made vehicle material composition a vital part of every OEM's overall manufacturing strategy.

6.1 BAT IMPLEMENTATION AT A COPPER SMELTING PLANTS – CASE STUDIES

The Aurubis production site in Hamburg is located on an area of about 870 000 m^2 on the Elbe island Peute, only about four kilometres as the crow flies from Hamburg ´ s city hall. The plant was constructed in 1908 in Peute, as an industrial inland harbour area in the Veddel district [20]. The production facilities were continuously expanded and steadily modernised. Today, Aurubis ´ s Hamburg site is one of the world ´ s state-of-the-art primary and secondary copper smelters. The main raw materials in copper production are copper concentrates and recycling materials (including electrical and electronic scrap). Pure copper is produced from the different raw materials following pyrometallurgical smelting and refining and copper electrolytic refining. Additionally, precious metals, nickel sulphate, lead as well as iron silicate products and sulphuric acid are obtained from ‐ in some cases ‐ very complex input materials in the scope of multi-metal recycling. Aurubis uses the properties of copper and other metals to enable recycling without a loss of quality. In view of the variety and the complexity of feed materials treated, the operations in Hamburg cover [20]:

- Primary copper smelter including concentrate dryers (steam and natural gas), Flash smelting furnace, Peirce-Smith converters, electric slag cleaning furnace and anode furnaces. It processes copper concentrates from various mines of the world as well as copper scrap in the converters;
- A three-line double catalysis sulphuric acid plant complex for the treatment of SO_2 gases of the different plant sections;
- Electrolytic copper refinery for copper cathode production;
- Secondary smelter with electric furnace and converters for the treatment of lead/copper containing secondary materials including internal recycles;
- Pyrometallurgical lead refinery for the production of refined lead;
- Precious metals refinery, including top blown rotary converter furnaces, electrolytic processes and hydrometallurgical processes for refining gold, silver, selenium, tellurium and platinum group metals concentrate;
- Production facilities for metal salts (copper sulphate and nickel sulphate);
- Continuous casting plant for copper billets and slabs/cakes; and
- Copper wire rod plant.

The Boliden ´ s Rönnskär smelter, located in northern Sweden, extracts metals and chemicals from mineral concentrates and recycling materials [20]. The main products are copper, lead, gold, silver and zinc clinker, with by-products such as liquid sulphur dioxide, sulphuric acid, selenium and nickel sulphate. The process flow sheet of the smelter is presented in Figure 6-4. Over the period 1998-2000, the Rönnskär smelter underwent a transformation of its operations and technologies, using BAT to turn the plant into a state-of-the-art smelter, producing and recycling base and precious metals, including high-purity copper, at a low cost and with minimal environmental impact. The transformation process, titled Rönnskär +200 Expansion Project, led to 100 000 tonnes increase in copper production capacity, resulting in a total capacity of 240 000 tonnes. The project required investments of approximately USD 220 million, out of which an estimated 30% covered the cost of environmental considerations.



6-4. Figure_Process flow sheet for the Rönnskär smelter in Sweden [20]

The improvements were triggered by new permit conditions that were imposed due to expansion projects for increased production beyond the limits of the previous permit (before 1998), as well as other investment and expansion decisions made by the company. When environmental investments have been decided upon, compliance with the BAT Conclusions have been one of the factors taken into account. Some examples of major environmental improvements between the years 1998-2017 are listed below [20]:

• Upgraded infrastructure: expanded harbour and closed belt conveyors system for copper-concentrates in order to reduce diffuse dust emission (1999);
• Closed converter hall and new bag filter for ventilation air in the hall (2000);
• Process water pipes pumping polluted water from the different process unites to water treatment plant where lifted above ground (2000);
• New sulphuric acid plant including two new processes for Hg-cleaning (2001);
• Large production expansion (+70%) with a new flash furnace and modernised process units (1998-2000);
• Improvement in gas cleaning at lead plant to reduce mercury emissions (2002);
• Major improvements in energy efficiency (2000, 2006);
• New gas treatment adopted for dioxins (2005, 2007, 2016);
• Large reservoir installed to be able to buffer storm water even during very heavy rains (2013);
• New electrostatic precipitators to improve gas cleaning and reduce emissions to air (2015);
• New water treatment plant (2016);
• Several storages and other measures for efficient indoor handling of material; and
• Constant work to improve "best practice" in maintenance and operation of equipment.

6.2 THE WORK OF THE NORDIC COUNCIL OF MINISTERS BAT GROUP

BAT is a concept that has gained international acceptance and been integrated in national, EU and international environmental regulation. The Nordic countries have been active in promoting the use of BAT in various industrial activities in the Nordic countries, within the EU and in international negotiations. The Nordic cooperation on BAT has had two main aims [69]:

1) To prepare information about BAT and cleaner technologies in sectors with many Nordic and particularly small and medium sized companies.

2) To contribute to the work of the EU on BREF documents with up-do-date information from the Nordic countries.

The reports on cleaner technologies and BAT have also aimed at giving companies and authorities an overview and easy access to information, with the hope that the techniques would be implemented and the environmental impact reduced. The reports have had a significant effect on the international BAT work. The fact that in several cases the Nordic countries had already published a report when international negotiations began meant that the Nordic countries were in a position to provide valuable information. This has resulted in a better representation of Nordic values and interests than would otherwise have been the case. For instance in relation to BAT in the food industry, the Nordic reports are some of the most referenced documents in the EU BREF documents. The Nordic Council of Ministers has made 16 BAT publications in different industrial sectors over the last 12 years, and the publications have maintained their relevance. The fundamental requirements in all Nordic environmental regulation and the EU IPPC Directive are that companies must minimise pollution as much as possible by using BAT.

Traditionally in the Nordic countries, authorities and companies work together, as far as possible, to solve environmental problems that may arise. In this cooperation between authorities and companies the Nordic BAT reports are good tools and sources of inspiration for giving a common overview of the available possibilities. Experience has shown that using the BAT reports and BREF documents means [69]:

• A more qualified dialogue between the authorities and the company,
• That more environmental activities are initiated than earlier,
• That some issues are included on the agenda earlier than before.

6.2.1 BAT IN AUTO REPAIR SHOPS

In 2007 the Nordic Council of Ministers published the report ”Best available techniques (BAT) in Auto Repair Shops” (TemaNord 2007:544), (in Danish “Bedste tilgængelige teknikker (BAT) i autoværksteder”, TemaNord 2007:545). The report presents an overview of processes and products which are used in auto repair shops, and describes the existing possibilities of implementing cleaner technologies or best available techniques for avoiding or reducing emissions and environmental impacts.

Auto repair shops produce noise, waste and wastewater and contribute to air pollution primarily from the use of volatile organic solvents (VOC) through under sealing of cars and painting of cars, but VOCs are also emitted from degreasing agents, filling agents and glue. Wastewater from auto repair shops may have a high content of oil, heavy metals and other hazardous substances. The amount of waste from auto repair shops may be large and could consist of many types of hazardous waste. Also, there is a significant risk of soil pollution from oil and heavy metals. Cars themselves and many car maintenance products, spare parts and other materials used in auto repair shops contain substances which from an environmental and health point of view are particularly concerning. These substances are of significance to health and safety and are emitted to the environment not only from the auto repair shops, but also from cars being used and when they are scrapped.

The report describes potential BAT techniques in the following areas [70]:

• Wastewater, especially from sand and grit traps, oil separators and catching and control wells.
• Water usage, primarily in case of recirculation in connection with car washing and washing of spare parts and engine parts.
• Energy, where energy saving can be achieved from an efficient weather screen and optimization of the use of electrical tools.
• Chemicals and oil products, where especially methods for choosing more environmentally sound products are described.
• Waste management, where the report shows ways of sorting, storing and disposing.
• Noise, which mainly refers to the possibilities of reducing noise while testing engines, tools and compressors etc.
• Air emissions, where possibilities of minimising emissions of dust, welding smoke, exhaust fumes and paint vapour are described.
• Soil pollution, where suitable surface types under storage facilities and impervious materials are described.

6.2.2 BAT – CAR WASHING FACILITIES

The Nordic Council of Ministers published in 2007 the report "BAT - Car Washing Facitilities" (TemaNord 2007:547), (in Swedish: "BAT – fordonstvätt", TemaNord 2007:546). The aim of the report has been to identify BAT for reducing the environmental impacts from car washing sites in the Nordic countries.

More than half of all car washings in the Nordic countries occur outside car washing sites and with no treatment of the waste water, which carries a risk of polluting groundwater or other recipients of pollution. Pollution from car washing arises from washing chemicals, road surfaces, oil products from cars etc. and consist for instance of oil, detergents (tensides), complex binders and metals. Plasticizers such as diethylhexylphtalat (DEHP), for instance from caulking compound, and polyaromatic hydrocarbons (PAH) which are found in tires, have been found in wastewater from car washing.

One of the report's conclusions is that if many more carwashes were done at car washing sites rather than in private homes, pollution could be reduced considerably. Furthermore the report describes potential BAT techniques at car washing sites, for instance [69]:

• Use of more environmentally sound chemicals, for instance avoiding the use of solvent based degreasing agents and nonylphenol.

• Installation of closed systems including collection of all residuals and waste.
• Installation of further treatment techniques including rinsing and recirculation of washing water and chemicals etc.
• Training of personnel in self-monitoring, recordkeeping and environmentally sound behaviour.
• Sorting of waste and disposal at approved treatment site.

6.2.3 ENVIRONMENTALLY ACCEPTABLE METALWORKING PROCESSES

In 2002 the Nordic Council of Ministers published the report ”Environmentally acceptable metalworking processes” (TemaNord 2002:528) (In Swedish: “Miljövänligare mekaniska metallbearbetningsprocesser” (TemaNord 2002:527)). The report describes the possibilities of reducing the environmental impacts from metalworking processes. The report primarily goes through the metal-working processes in which metalworking fluids are used, such as cooling oils and lubricants. The opportunities for substituting chemicals and procedures for minimising fluid losses are described in the report.

Metalworking fluids are used in metalworking processes to reduce friction, wearing, process stops and increased use of energy. The fluids are needed to ensure well-functioning cooling, lubrication and removal of turnings and chips. The fluids often consist of a base of mineral oil including some additives related to the function of the fluid. Most of the losses of fluids (75%) are collected and treated (burned) at licensed incineration plants, but the rest are carried over on the machined products, turnings and chips, which are degreased at a later stage. Mineral oil is classified as non-degradable and among the additives there are a number of hazardous substances, for instance the so called EP (extreme pressure) additives, which could be chlorinated paraffin, chlorinated fatty acids or sulphur compounds. There are phenolic compounds used in emulsifying agents and ditiocarbonates, lead and boron compounds used in anti-wearing compounds. The environments in which the fluids shall be active are very easily infected by microorganisms, which increase the need for using biocides, which could cause health problems and later environmental impacts.

To minimise the losses of fluids and the impact on the environment the report recommends [69]:

• Substitution of poorly refined fluids including polycyclic aromatic hydrocarbons (PAHs), chlorinated paraffin, phenolic compounds.
• Use of products with additives which are well documented and well declared.
• Improved design of tanks and piping to storage of the fluids to increase lifetime of the fluids and reduce waste.
• Treatment of used fluids by ultrafiltration supplemented by reverse osmosis, so they can be recycled.
• Closed degreasing systems, minimising the amount of oil and additives in the waste water.
• Use of alternative metalworking processes with no need of fluids through development of advanced materials for machine tools.

6.2.4 BAT IN THE SURFACE TREATMENT INDUSTRY

In 2002 the Nordic Council of Ministers published the report ”DEA – an aid for identification of BAT in the inorganic surface treatment industry” (TemaNord 2002:525). The report is an update of an earlier report on the same issue: "Possibilities for reducing environmental impacts from the surface treatment industry" (TemaNord 1993:560). The report describes the latest technical developments and presents the results of a new benchmarking method to identify BAT and the possibilities of reducing environmental impacts from surface treatment.

The report uses a new benchmarking method known as the Data Envelopment Analysis (DEA). The advantage of the method is that it can identify BAT from existing material without having first to apply a priori weighting of a large number of variables such as emissions, use of energy and raw materials in order to make them mutually comparable. A survey among metal plating companies shows that high productivity and a good environmental performance are easily combined. The best environmental results are achieved by low water consumption combined with low energy consumption, because it gives best efficiency and the lowest spillage of metals. Some of the BAT techniques presented are [69]:

• Separate material flows give the best possibilities for recycling.
• Zero-effluent processes, which minimises water consumption and loss of metals.
• Post-processing and rinsing technologies, which reduce the content of metals in the wastewater.
• Alternative energy sources, for instance oil and gas replacing the use of electricity for heating of processing baths.

The report shows that the most environmentally sound and efficient surface-treatment industries often are specialised and have quality and environmental management systems and an efficient network with suppliers and authorities.

6.3 BAT IN MOTOR VEHICLES, PARTICULARLY THOSE BURNING LEADED GASOLINE

The major fuels used in motor vehicle transportation are gasoline and diesel. Liquefied petroleum gas, vegetable oil-based and other biofuels, and alcohol-oil mixtures are gaining importance. Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are unwanted by-products of combustion engines and have been found in the emissions from motor vehicles fuelled with gasoline or diesel. The higher concentrations identified in emissions from vehicles run on leaded gasoline are due to the presence of chlorinated and brominated scavengers in the fuel. For motor vehicles, the process description is relatively straightforward. The gasoline engine derives its power from the explosion of a mixture of air and gasoline, whereas in the diesel engine the fuel burns rather than explodes. The air-fuel mixture, when ignited, expands rapidly in a cylinder, forcing a piston from the top of the cylinder to the bottom. After its release from a vehicle, the exhaust gas is diluted approximately a thousand fold in the first few seconds and cooled down very rapidly.

Best available techniques to reduce PCDD/PCDF emissions from motor vehicles may include the following [71]:

• Prohibition of halogenated scavengers;
• Prohibition of the use of leaded gasoline;
• Installation of diesel oxidation catalysts, particulate filters and catalytic converters;

• Alternatives to gasoline engine (electricity, solar light and fuel cell).

Best environmental practices may include [71]:

• Avoidance policies such as greater fuel efficiency should be encouraged. Alternative modes of transport, including cycling, rail and other public transportation, should be promoted;
• Separation of transport containers according to the fuel (for example, do not transport leaded gasoline containing halogenated scavengers in containers that are also being used for the transport of diesel or unleaded gasoline);
• Prohibition of the use of leaded gasoline;
• Promotion of vehicles with low fuel consumption;
• Education to identify driving conditions that have low pollutant formation and release;
• Good maintenance of the vehicle.

6.4 BAT IN SMOULDERING OF COPPER CABLES

Scrap copper is often recovered by open burning of plastic coatings from electrical cable and wiring. Chemicals listed in Annex C of the Stockholm Convention are probably formed from plastic and trace oils with copper as a catalyst at mouldering temperatures between 250°C and 500°C. Best available techniques include mechanical cable chopping, stripping or high temperature incineration >850°C. A consideration is to set premium pricing for unstripped cables and wiring and encourage sending the feed material to copper smelters using best available techniques for treatment. Performance levels associated with best available techniques are not applicable, as the smouldering process is not a best available technique or best environmental practice and should not be practised.

Smouldering of copper cables involves the open burning of plastic coatings from electrical cable and wiring to recover scrap copper and other constituents of the cables. This process is labour intensive, and is performed by individuals or in small facilities without any abatement measures for air emissions. Smouldering is conducted in burn barrels or on open ground. No means of temperature control or oxygen addition are used to achieve complete combustion of plastic compounds. The smouldering of copper cables is becoming prevalent in developing nations due to the recycling of computer scrap using manual methods. However, the process is not limited to developing countries and should be addressed on a global scale. Legislation has been implemented by many developed and developing countries to ban open burning, but the practice continues.

Smouldering of copper cables releases various contaminants besides PCDD/PCDF, such as carbon monoxide (CO), sulphur dioxide (SO_2), polycyclic aromatic hydrocarbons, hydrogen chloride, heavy metals and ash. Incomplete incineration occurs because of the low burning temperature (250°C to 700°C), resulting in the generation of hydrocarbons and particulate matter. Lead stabilizers, often included into the PVC polymer matrix of the plastic cable coating, are released during smouldering. Lead-coated copper cables are also burnt, releasing additional lead. Contaminants are emitted to air, water and soil.

To prevent the generation of PCDD/PCDF, smouldering of copper cables should not be conducted. Alternative treatment processes to open burning are discussed below. The insulation material, for example PVC, may also be recovered by using these processes. Cable chopping allows for the separation of plastic coatings from cables without the generation of PCDD/PCDF through thermal methods. This process is able to treat cables of mixed type and different gauges. The products recovered are granulated copper and PVC. Cable chopping involves pre-sorting, cable chopping, granulation, screening and density separation [72].

Cable stripping is a cheaper method for copper cable recovery than chopping, but at lower throughput. PCDD/PCDF generation is not of concern in this process. This technique is preferred in developing countries due to the lower cost. Pre-sorting of cables should also be conducted before stripping according to metal type, insulation material, conductor diameter and length. Despite the lower production rate, copper can be completely recovered as no residual metal remains in the plastic insulation. Careful segregation by insulator type can produce waste material consisting of only one type of polymer, allowing for easier recycling of both the metal and plastic fractions. Cable stripping machines can process only single strands of cable at rates up to 60 m/min or 1,100 kg/min with cable diameter ranging from 1.6 mm to 150 mm.

High-temperature incineration should only be used for treating cable that cannot be recovered by chopping or stripping. Materials such as fine wire and grease- or tar-filled cables are burnt in controlled atmosphere incinerators to ensure complete combustion of plastics. Effective flue gas cleaning systems should be utilized. Furnace off-gases contain contaminants such as PCDD/PCDF, carbon dioxide (CO_2), sulphur dioxide (SO_2), hydrogen chloride and fluoride, and dust. Because PCDD/PCDF adsorb on particulate matter, dust should be collected using efficient methods such as fabric filters and recycled to the furnace. Post-incinerator afterburning and quenching should be considered if incineration is ineffective in eliminating PCDD/PCDF. SO_2 and hydrogen chloride and fluoride should be removed by wet alkaline scrubbing. Incinerated scrap metal has less value due to oxidation from thermal treatment. A high potential for PCDD/PCDF generation exists with incineration. Cable chopping and stripping are preferred to high-temperature incineration as these processes are more economical and environmentally sound [72]. Cable types unsuitable for chopping or stripping can also be treated in primary or secondary copper smelters.

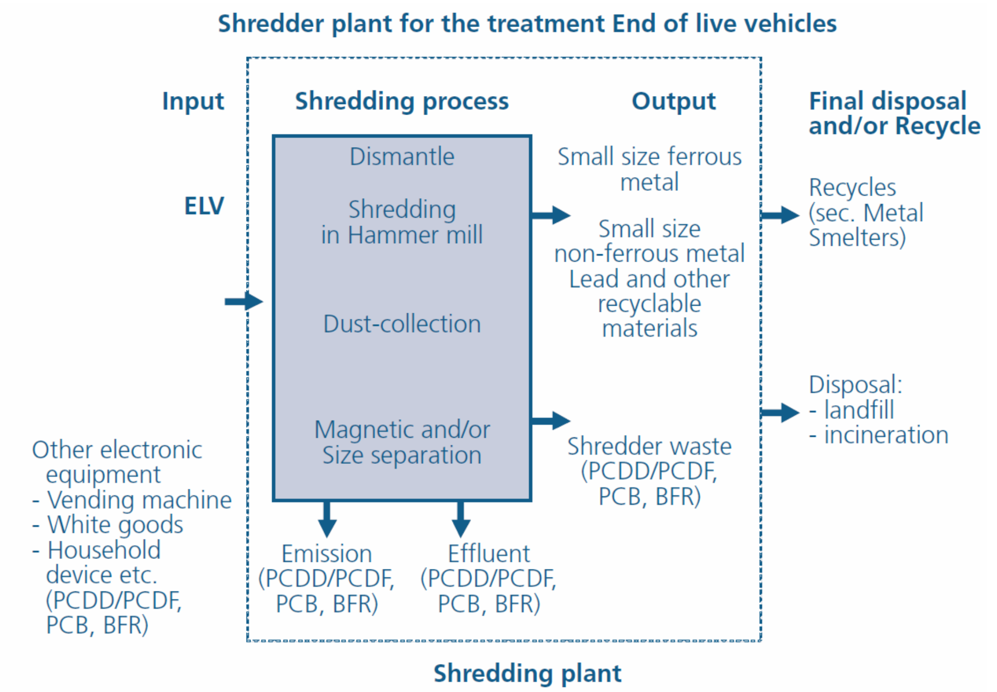
6.5 BAT IN SHREDDER PLANTS FOR THE TREATMENT OF END-OF-LIFE VEHICLES

Shredder plants for treatment of end-of-life vehicles are listed in Annex C of the Stockholm Convention as a source that has the potential to form and release chemicals listed in Annex C. Shredders are large-scale machines equipped inside with one or more anvils or breaker bars and lined with alloy steel wear plates. An electric motor drives the rotor with the free-swinging alloy steel hammers. Beneath the shredder is a vibratory pan, which receives the shredded material discharged through the grates. Typically a ferrous metal stream is produced, which is relatively clean and consists of small (50 mm) pieces of steel and a “fluff” stream, which contains the fragments of non-ferrous metals and other materials that entered the shredder (also known as fragmentizer).

Very few data of stack emission measurements at shredder plants are available. However, the results of some studies have shown levels of dioxin compounds greater than 0.1 ng I-TEQ/m^3. At present there is not sufficient evidence that in the (mechanical) shredding of vehicles, household electrical equipment or other electrical appliances new formation occurs of polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF) or polychlorinated biphenyls (PCB). The data available indicate that the PCDD/PCDF and PCB released from shredder plants are from industrial, intentional production and have been introduced with oils, dielectric fluids, and other materials contained in these vehicles or consumer goods and which are simply set free through this mechanical process.

In any case, measures to prevent accidental fires (which could result in the formation of chemicals listed in Annex C) should be in place at shredder plants. Shredder light fluff consists of flammable plastic films and fibrous dust, which forces a careful plant operation for the prevention of accidental fire. Systems for dust suppression (e.g. wet shredding) or dust collection (e.g. cyclones, venture scrubbers or baghouse) are normally installed on shredder plants for the treatment of end-of-life vehicles. Dust suppression or collection systems would help to reduce potential emission of persistent organic pollutants. To improve emission control of the dust, fine dry residues should be stored in such a way that dispersion is minimized. Other sources of dioxin precursors that may result in the formation of PCDD/PCDF when burnt include PCB-containing condensers, PCB- or chlorobenzene-contaminated waste oils or textiles, and polymers containing brominated flame retardants (formation of polybrominated dibenzo-p-dioxins (PBDD) and polybrominated dibenzofurans (PBDF) as contaminants).

End-of-life-vehicles are processed through shredders. The practice is to shred them along with other end-of-life metal products (such as bicycles, office furniture, vending machines and so-called white goods, such as household devices). In the plant, a high-performance- hammer mill produces sized pieces of ferrous scrap of a high physical and chemical purity. The ferrous scrap is sought after by steel makers and other secondary metal producers. An overview of the process is shown in Figure 6-5.



6-5. Figure_Overview of the shredder process [73]

Many components of vehicles and other electrical devices are made of non-ferrous materials, such as copper, aluminium and zinc. In the shredding process, magnetic separation is used to remove the magnetic ferrous fraction from other materials. The non-ferrous metals, such as copper and aluminium, are normally sorted out at a later stage. The remainder is the so-called shredder waste and is estimated at between 25% and 35% of the weight of end-of-life vehicles. Shredder waste consists of glass, fibre, rubber, automobile liquids, plastics and dirt. The composition of shredder fluff will vary considerably from batch to batch and shredder to shredder – due to the different mixes of raw materials being processed and the differing levels of pre-processing and inspection by shredder operators. It should be noted that shredder fluff is likely to vary significantly between shredders due to varying requirements under state and territory licensing conditions and the changes in those conditions over time.

A report on a European dioxin inventory stated that measured dibenzo-p-dioxins and dibenzofurans data exist for a few shredder installations [73]. Generally, very low concentrations (<0.01 ng I-TEQ/m³) were found in a plant investigated in Sachsen- Anhalt (Germany). A further investigation from Belgium considered potential specific sources of unintentionally released PCB and PCDD/PCDF from a shredder plant turning end-of-life vehicles and waste from electronic and electrical equipment into various reusable fractions. An overview of a number of stack emission measurements of dibenzo-p-dioxins and dibenzofurans and unintentionally released polychlorinated biphenyls is given in table 3. The shredders are equipped with at least a cyclone filter system for de-dusting the flue gases. Flue gas flow rates are typically about 75,000 Nm³/h. All dibenzo-p-dioxins and dibenzofurans concentrations, except one, were below 0.1 ng TEQ/Nm³. Dioxin precursors which may result in the formation of polychlorinated dibenzo-pdioxins and dibenzofurans (PCDD/PCDF) when burnt include polychlorinated biphenyls -containing condensers, polychlorinated biphenyls or chlorobenzene contaminated waste oils or textiles, and polymers containing brominated flame retardants (formation of polybrominated dibenzo-p-dioxins (PBDD) and polybrominated dibenzofurans (PBDF) as contaminants).

An important best environmental practice is to strengthen the responsibility of the operators of shredders. An analysis should be undertaken to identify hazardous components and fluids with incoming material and to provide facilities to remove them before the shredder process. It is crucial to control treated scrap, especially electric devices, transformers and condensers, which must be identified, dismantled and eliminated separately to avoid the introduction of polychlorinated biphenyls into the plant. This is also a measure to reduce the contamination of shredder residues by polychlorinated biphenyls. Nevertheless, shredder residues are always contaminated and must only be disposed of in an incineration dedicated plant. By dismantling and recycling big plastic parts, for instance bumpers, a considerable reduction of the remaining plastic fraction in the end-of-life vehicles and in the resulting shredder waste can be achieved. By further treatment of shredder wastes, for instance by eddy current separation, a considerable proportion of the metals contained in the waste, such as copper and aluminium, can be recovered. In order to achieve a higher proportion of recyclable fractions, the use of recyclable material and simple disassembles should be encouraged in the stage of product design. This is not only valid for end-of-life vehicles.

Sites have to be constructed to prevent the contamination of soil, water and air. For this reason, appropriate storage facilities, including impermeable surfaces with spillage collection facilities; decanters and cleanser-degreasers should be provided, as well as equipment for the treatment of appropriate storage tanks for water, including rainwater. In addition, appropriate storage for dismantled spare parts, including impermeable storage for oil-contaminated spare parts, appropriate containers for the storage of batteries (with electrolyte neutralization on site or elsewhere), filters and PCB/PCT-containing condensers and appropriate storage tanks for fluids are necessary.

Fluids, like brake fluid, petrol, steering fluid, motor oil, coolants and transmission fluid should generally be removed from the end-of-life vehicle or other devices before shredding. This is especially applicable in the case of PCBs, which should be identified and removed from any device to be shredded. Specific attention should be given to transformers and condensers. **Measures should include** [73]**:**

• The removal of batteries and liquified gas tanks;
• The removal or neutralization of potential explosive components, (e.g., air bags);
• The removal and separate collection and storage of fuel, motor oil and oil from other components;
• The removal of catalysts;
• The removal of tyres and large plastic components (such as bumpers, dashboards, fluid containers, etc.), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials.

Measures to prevent releases of persistent organic pollutants at shredder plants include [73]**:**

•The advanced treatment of flue gas (with bag filters and activated carbon filters to remove both gaseous and particle emissions);
•The proper disposal of residuals and liquid shredder wastes containing a mixture of organic materials, heavy metals such as copper and, in many cases, polychlorinated biphenyls and other chlorinated substances. Treating this waste in an inappropriate manner will lead to emissions of unintentionally released persistent organic pollutants. This is especially the case in open burning. Shredder wastes should be never burned in an open fire or in inappropriate facilities;
•The appropriate treatment of shredder waste is incineration in a facility meeting the requirements for best available techniques and best environmental practices. If such a facility is not available, disposal in a sanitary landfill may be preferred to other forms of disposal.

7. TEST QUESTIONS

1.) What does it mean BAT? Explain this therm.
2.) In which areas should BAT be considered?
3.) Most important BAT related policies in EU are?
4.) Key elements of IED are?
5.) What are the basic requirements in order to receive EMAS registration?
6.) What does it mean BEMP? Explain this therm.
7.) General considerations of Article 5 of the Stockholm Convention are?
8.) General principles and approaches when applying guidelines from Annex C of the Stockholm Convention are?
9.) Key characteristics of procedures to determine BAT are?
10.) What does it mean BREFs?
11.) Describe the key recommendations for countries wishing to establish a BAT-based permitting system.
12.) Describe the indicators when selecting a sectors for application of BAT-based permitting.
13.) Describe the key activities of the BAT establishing process.
14.) Describe the criteria for selecting plants for the plant-specific data collection.
15.) General principles for determination of BAT are?
16.) Key point on BAT-based permit conditions are?
17.) Describe the general considerations for permitting authorities?
18.) Key elements of effectiveness of BAT policies are?
19.) Describe the main approaches to effectiveness evaluation of BAT policies.
20.) Describe the basic concepts for expanding BAT determination.

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