Making the case: A holistic plastic strategy

Addressing polymers and plastics under the ESPR

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Summary

Plastics and polymers should be included as an intermediate product in the first working plan under the Ecodesign for Sustainable Products Regulation (foreseen for early 2025). By prioritising plastics and polymers in the first ESPR working plan, the EU will take a major step in addressing the plastic pollution crisis, working to minimise the environmental footprint of plastic and polymer production. This paper showcases the need to do that and shed lights on the missing pieces of the puzzle and limitation of current methodology that look into polymer production.

Plastic has an outsized impact on human health and the environment, as evidence by numerous studies. As the ESPR is intended to improve the environmental impacts of many different product streams, plastics is significantly present in many of them (for example, paints, textiles, electronics, furniture, and others). It is evident that plastics and polymers should be addressed as an intermediate product to ensure these other products are well-designed from the foundation. Other intermediate products will be addressed in the working plan, including the chemical sector, which has overlaps with plastics and polymers. It is therefore a clear opportunity to set up minimum requirements for plastics and polymers, thing that ECOS has advocated for since 2019 with our report "For Better Not Worse: Applying Ecodesign Principles to Plastics in the Circular Economy". There are drawbacks and risks associated to each part of the entire lifecycle of plastic. In order to minimise the environmental footprint of one of the most widely used materials in countless products, plastic requires a comprehensive ecodesign approach.

It is projected that plastics production and consumption are likely to grow over the coming decades, with deleterious effects. By prioritising the sector under the ESPR, this trend could shift. There are many product parameters established in the ESPR's Annex I that are relevant to the plastic and polymer sector, including: (d) design for recycling; (f) use of substances; (g) use or consumption of energy, water, and other resources; (l) environmental footprint of the product; (m) carbon footprint of the product; (ma) the material footprint; (o) emissions to air, water or soil, and others.

In our analysis, we reviewed the JRC's preliminary study on new product priorities, which often referred to the Polymer Best Available Techniques Reference Document (POL BREF) for claiming that plastics is already being taken care for in this framework. We then analysed in detail the POL BREF, highlighted its limitations and determined that it is no longer fit for purpose and no longer upholds the aims of the EU's environmental priorities. We also recommend that the POL BREF is comprehensively revised and updated to reflect advances in technology and knowledge.

Addressing the plastic and polymer sector in the first working plan would be advantageous for several reasons.

- It would align several EU policy priorities, providing regulatory certainty to an industry under much scrutiny. As the Packaging and Packaging Waste Regulation will also create requirements for plastic products in delegated acts to be delivered by 2028, including this sector under the ESPR will ensure work is not unnecessarily duplicated.
- The EU and its Member States are playing a key role in the United Nations negotiations for the new instrument to address plastic pollution. Addressing the plastic and polymer sector under the ESPR would show that the EU will continue to lead the way in improving the environmental performance of this sector. Establishing performance and information requirements for plastic and polymers in the European market would provide a roadmap for work at the global level.

A case for ecodesign for plastics and polymers

This paper is intended to support the argument to include the intermediate product sector “plastics and polymers” in the first ESPR working plan. As an environmental NGO, ECOS has advocated for this sector to be included due to the outsized impact of the sector: the way we currently design, produce, consume and dispose of plastic is highly unsustainable and inefficient. There are drawbacks and risks associated to each part of the entire lifecycle of plastic. In order to minimise the environmental footprint of one of the most widely used materials in countless products, plastic requires a comprehensive ecodesign approach.

ECOS has been advocating to expand ecodesign principles to plastics and polymers since 2019 with the report “For Better Not Worse: Applying Ecodesign Principles to Plastics in the Circular Economy”. That report looked into different design approaches that can be taken to set up minimum requirements for plastics and polymers.

Design for...

...sustainable sourcing

1. Virgin raw materials from sustainably managed production processes
2. Sourcing renewable raw materials from sustainably managed sources
3. Traceable recycled materials as secondary raw materials

...optimised resource use

1. Avoid unnecessary plastic use
2. Reduce amount of plastic material
3. Use recycled material not containing hazardous substances
4. Use of biobased plastic materials from sustainable sourcing
5. Use plastics with lower embedded energy

...environmentally sound and safe use phase

1. Minimise exposure to substances of concern during use
2. Minimise particle emissions during use
3. Minimise likelihood of littering

...prolonged product use

1. Reusable plastic containing products
2. Repairable plastic containing products, including modularity, easy disassembly and availability of spare parts
3. Durable and upgradable plastic containing products

...recycling

1. Collectable & sortable products
2. Easy dismantling of products
3. Use of recyclable polymers and polymer blends using existing recycling infrastructure
4. Targeted and informed re-use of specific technical properties including specific functional additives
5. Eliminate substances of concern

We were pleased to see that the JRC included plastics in its product study, but upon review, we found that the analysis and scoring for the sector did not meet our own assessment. Although the sector was prioritised by the JRC, it was scored as third from bottom of the other seven prioritised intermediates, putting it overall behind iron and steel, non-ferrous metal, aluminium, and chemicals. We undertook the work of this paper to understand the reasoning behind the JRC study’s outcomes.

How did we go about it?

1. Using as a launching point the preliminary study on Ecodesign for Sustainable Products Regulation[1] (ESPR) priorities by the Joint Research Centre (JRC)[2], this report first investigates aspects of the ESPR legislation with regard to requirements and parameters for intermediate products in the context of polymer production.

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1. European Commission, 2022. Proposal for a regulation of the European Parliament and the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC.
2. Faraca, G., Spiliotopoulos, C., Ranea alma, A., Pérez-Camacho, M.N., Alfieri, F., Bernad Beltran, D., Lag Brotons, A., Delre, A., Pérez Arriba, Z., Arcipowska, A., La Placa, M.G., Wolf, O., Sanye Mengual, E., Amadei, A., Maury, T., Ardente, F., Mathieux, F. 2023. Ecodesign for sustainable products regulation – preliminary study on new product priorities. Joint Research Centre of the European Commission: Seville.

2. Then, it looks at the JRC study and how the report assessed the opportunities for improving the environmental performance of polymer production and plastics under its self-imposed metrics.
3. The report then analyses definitions of plastic as well as the implications of addressing plastics and polymers as an intermediate product in the ESPR alongside other relevant legislation.
4. It then considers, in detail, the EC's Best Reference Document for the Production of Polymers (POL BREF)[3] which was developed twenty years ago. This section is contained within Annex 2.

The JRC study repeatedly refers to the POL BREF as the method by which environmental emissions of polymers are controlled, yet in our analysis, we found that this document is not fit-for-purpose for its original aim nor is it able to be a stand-in for improvement that could be achieved under the ESPR.

Text Box 1: Rationale for Prioritising Plastics in the ESPR First Working Plan

1. Global growth in plastics production is exponential. Annual production was at 169 Mt twenty years ago when the POL BREF was created. By 2019 the value had almost tripled to an estimated 460 Mt, and assuming the status quo it is expected to almost triple again to 1231 Mt by 2060 (OECD, 2022). This rate of growth is orders of magnitude higher than other industries and much larger than iron and steel, and aluminium (Charmin, 2019) both of which were considered a higher priority by the JRC.

2. The JRC graded plastics as 2 (out of a possible 5) for "*biodiversity*" and "*human toxicity*" impacts. This, according to its own definition, aligns with a medium environmental impact score, defined as: "*…issues caused are relevant but are being addressed: some improvement potential can be identified for ESPR and foreseen to give modest but tangible results".* The biodiversity impact score for plastics was graded by the JRC as lower than that assigned to glass, pulp and paper, and aluminium.

3. Carrying additives into the biosphere, an estimated 8 million pieces of plastic debris reach the oceans daily; with the oceans estimated to contain 25 trillion macro– and 51 trillion microplastics, more than 500 times the number of stars in the Milky Way (Da Costa et al., 2020). Yet, the JRC scored plastics as 3 (out of 5) for water impacts, scoring it again as of only medium relevance.

4. Plastic production is a major driver of climate change. It emits an estimated 2.24 Giga tonnes of CO_2eq. per year, which equates to almost four times the emissions from the whole of the global aviation sector (Karali et al., 2024). Though this is acknowledged by the JRC, they scored plastics as 4 for "*Climate change*", above only one other intermediate product: glass.

➔ **The ESPR framework is an immense opportunity to improve the environmental performance of products sold in the EU. Many products are made of or based upon plastic and polymers. The sector has an outsized environmental impact across many different indicators, therefore, prioritising the plastic and polymer sector within the first ESPR working plan is a necessary step to the successful implementation of the ESPR' and the European Green Deal.**

3. European Commission, 2007. Reference document on best available techniques in the production of polymers.

1. Analysis of JRC preliminary study for plastics and polymers

While the ESPR Commission proposal did not stipulate specific groups of "*products*" or "*intermediate products*" in its original text published January 2023, the Joint Research Center developed a methodology to identify high impact products and intermediate product , including "*Plastics and polymers*".[4] The JRC then shortlisted and prioritised these groups against eight environmental impacts – water, air, soil, biodiversity, waste, climate change, energy use, human toxicity"[5] – along with also their improvement potential in each impact area.

"*Plastics and Polymers*" **was initially shortlisted by the JRC (p. 21). However, the sector was scored as third from bottom of the other seven prioritised intermediates, putting it overall behind iron and steel, non-ferrous metal, aluminium, and chemicals.** This finding appears misaligned with the scientific consensus on the environmental impact of plastic across its whole life, magnitude of growth in plastic production, its lack of design for recycling, and its potential for improvement. **The POL BREF was frequently referenced by the JRC research as a pre-existing mechanism that addressed many of the JRC's identified environmental impacts as list above. However, and as will be seen in our analysis, the BREF has a limited role in addressing only certain types of emissions for certain types of polymers, and it is not comprehensive even in its limited capacity. Furthermore, the BREF does not address the use of substances of concern, recyclability, material efficiency, or most other product requirements that are laid down in the ESPR.**

Scoring "*Plastics and Polymers*" – limitations of the JRC study

Scores and subjectivity

The method employed for short-listing had a qualitative component: grading was via scores of "*low, medium,* or *high*" for each of the eight environmental impacts. This might be made robust if the study had explained in sufficient detail how the scores were arrived at, but it does not adequately do this. Subjectivity is increased by the scores then being combined with sub-scores for improvement potential to give an overall grade of between 1 and 5 for each of the eight categories. Again, how the numerical scores were derived from the qualitative sub-scores is not specifically explained, so the study's findings cannot be reproduced, a fundamental requirement of any scientific report. The text merely states that the method used for scoring was from "*relevant literature sources*", but scores are not assigned to sources so this cannot be followed [p.19]. This is exacerbated by the definition of "*Plastics and polymers*" being imprecise and, perhaps more importantly, the **boundary of the plastic production line ill-defined.**

Exclusion of packaging

Packaging was excluded from the JRC's study [p.17]. The document does not however make it apparent whether this means that just a separate product group of "*packaging*" was not created; or whether all aspects of packaging applicable to intermediate products, such as glass, aluminium, and plastics was excluded from consideration too. **This could have had a significant effect on the scoring of plastics, since packaging comprises an estimated 42% share in all non-fibre plastic products** (Hamilton et al., 2019). While the PPWR will improve the performance and recyclability of packaging, it does not make sense to exclude this sector from the scoring of plastics and polymers given that so much of the sector goes toward producing plastic packaging.

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4. This list is for "*intermediate products*". The JRC also assessed "*products*" against two more impacts: "*material efficiency*" and "*lifetime extension*", but according to the JRC's method these were deemed not to apply to plastics. https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2023-01/Preliminary%20ESPR%20WP%20Report_MERGED_CLEAN_.pdf

Aspects of packaging are covered with the ESPR, with product parameters in Annex I (i) addresses the weight and volume of a product's packaging as well as the product-to-packaging ratio and (p) amounts of waste generated, including plastic waste and packaging waste and their ease of re-use, and amounts of hazardous waste generated;

Overlap with chemicals

Chemicals production is intrinsic to and inseparable from plastic production since the polymers are made from multiple stages of petroleum refining, then monomer production, and purification, along with other chemicals, all of which is usually is combined on one large site (Bauer and Nielsen, 2021). **The JRC created a separate intermediate product group of "*Chemicals*", but the text does not address the issue of overlap.** For example, it does not elaborate on how scores were assigned to the types of environmental impact associated with the plastics or chemicals group, whether to one or the other, or both. Importantly, no other intermediate category had such cross-over, and this potentially diluted the overall scores for both "*Plastics*" and "*Chemicals*".

Not including the full production line

Since the boundary of plastic production is ill-defined in the JRC study, it is not possible to know whether the JRC study included or excluded essential stages, such as steam cracking, petroleum refining, and the routes of other chemicals necessary for plastic production; or whether these stages were factored in for the "Chemicals" group. For example, chlorine (a major component of PVC) is extracted from sea-water by electrolysis, using a tremendously energy intensive process (greenhouse gas (GHG) emitting, as it burns natural gas) but one with wider adverse impacts on marine ecology due to water extraction and saline discharge (Dawoud and Mulla, 2012).

In October 2023, the Commission proposed a "Regulation on preventing plastic pellet losses to reduce microplastic pollution". It will address the later stages of plastic production. This regulation should address losses in the form of emissions to the environment by all actors handling plastics, which will close gaps that the POL BREF does not address. The Commission's proposal suggested to introduce minimum requirements for best handling practices, mandatory certification and self-declaration, and provide for the development of a harmonised methodology to estimate losses. The European Parliament adopted a position that reinforces minimum requirements by extending their scope to the maritime transport sector. The regulation is expected to be adopted by the end of 2024, following the legislative procedures.

Exclusion of "substances of concern"

"*Substances of concern*" is a principle term in the proposed ESPR text, but it is not mentioned in the JRC study. This issue is perhaps at the crux of improving the sustainability and design for recycling of plastics. Identifying and reducing the use of these additives and contaminants is in line with the rationale behind the ESPR. The ESPR could address these issues, in that the release of additives is inversely proportional to the size of the monomer, while darker plastics also usually have more additives (Da Costa et al., 2023). However, because the JRC did not address the issue, these improvements are not considered within the scoring of plastics and polymers.

An updated ESPR-ready POL BREF could provide information on how essential these additives are, how to mitigate inclusion of non-intentionally added substances (NIAS) such as machine lubricants, alternatives to them, reducing use and waste.

Exclusion of "chemical safety"

Inextricably linked to "*substances of concern*", **the JRC did not consider aspects of "*chemical safety*" when it shortlisted intermediate products for prioritisation.** In contrast to "*substances of concern*" where no explanation is given as to why, here the JRC wrote that it is because chemical safety is "*excluded from the scope of ESPR*", though this is not entirely true in the final text of the regulation. Because of the broad brush approach, the impact of this action reduces all group "*human toxicity*" scores.

But it will likely have given a disproportionate reduction of the score for "*Plastic and polymers*". This is due to the greater use of toxic additives in plastic than other intermediates, i.e. glass, aluminium, pulp and paper, iron and steel. The JRC make no assessment as to the potential for removing many of these toxic additives, a subject that is largely unresolved and seldom discussed, but which would provide major positive impact on the environment and recyclability, though it might reduce durability.

Text Box 2. The importance of addressing plastic additives in the ESPR

Each week, it seems, a new study adds to the list of thousands of undisclosed additives in plastic products. It should not be the case that currently researchers have to extrapolate back using analytical techniques to identify the many substances embedded in plastic materials (Schlossnikl, 2024). And, it turns out that many of these additives are chemicals of potential concern based on their hazardous properties (Weber et al., 2023). Yet at the same time as the annual growth rate of plastic additives market is 5.8%, studies show that the marine ecotoxicity of microplastics is mainly due to the release of additives, with the polymers behaving as vectors (Da Costa et al., 2023).

This issue is not however simply about chemical safety with regard to human health or the environment; the additives have a negative impact on plastic recycling too (Rigamonti et al., 2018; Kusenberg et al., 2022a). For example, in plastic labels alone, 21% of identified additives were highly toxic, and a further 6% were moderately toxic, with many being mutagenic substances; while it was estimated that the inclusion of just 10% of labels (due to both pigments and adhesives), would compromise the quality of mechanical recyclate (Schlossnikl, 2024).

Tackling additives is particularly important as it is a principle means of improving the environmental impact of plastics which will remain in future use, coincident with overall reduction in the use of plastics and phasing out single use items and certain plastic types. This is because the petrochemicals industry is dependent on fossil fuel use and is locked in to high greenhouse gas emissions: using renewable energy to fuel the plastic supply chain will not solve plastic's climate impacts, nor will maximising energy efficiency throughout the plastic supply safeguard the climate of the planet (Hamilton et al., 2019). As stated (ibid.):

Current emissions projections for the plastic lifecycle are inconsistent with meeting the 1.5°C temperature target. If the production, disposal, and incineration of plastic continue on their present growth trajectory, they will undermine global efforts to reduce emissions and keep warming below 1.5°C. By 2030, these emissions could reach 1.34 gigatons per year—equivalent to more than 296 five-hundred-megawatt coal plants.

Weaknesses in how the methodology was applied

For purposes of reproducibility, best practise would have been to provide the results for each scoring exercise with references, and from this show how the final score was obtained. But, this is not provided. It also seems like the methodology was sometimes shuffled between products and impacts. For instance, in the process of scoring "*water effects*" [according to Annex 4] this topic should be assessed against (*inter alia*), "*microplastics*", and "*oceans pollution*"; but for plastics however [Annex 5, Box 18] these two impacts are described under the "*biodiversity*" assessment, though they are not identified as aspects to consider for "*biodiversity*" according to Annex 4.

Water use is stated as being high during plastics production [185 tonne for every tonne of plastic produced – p.223] and the associated impact on the marine environment is listed. It is hard then to reason why this has been scored "*medium*". Similarly, the improvement potential includes "*Minimising the use of single-use plastics, designing plastics to reduce microplastics release and to facilitate their recycling*". Though these measures would be huge and transformative, the JRC's scores for both the impact and improvement potential of plastic is again given as only "*medium*".

Limits to literature sources and technical understanding

The quality of the plastics literature review is weaker than for that reported for other intermediate product groups. It is also disproportionately reliant on industry sources. The discrepancy in review quality between groups reflects perhaps the multi-authorship involved in the JRC study and a lack of satisfactory moderation of scores.

For example, other product groups such as *Detergents* and *Lubricants* each have over fifty references mostly from independent academic journals. In comparison, Plastics has fourteen. Of these, one is the 2007 POL BREF, Plastics Europe is listed twice (once as just a website url), Eunomia are listed but no reference is given, and there is an un-traceable reference: *UN Environment 2014*, while only two references are from academic journals.

Errors in the review

Some of the supporting evidence does not seem to align with the conclusions. This misalignment has then affected how the scores were allocated and hence the grading of "*Plastics and polymers*".

Under "*Life-cycle energy consumption*" for plastics [Annex 5, p.236], the JRC suggest that future improvements will come from "*decoupling plastic from fossil feedstock [such that] in future plastics from recycled oils or secondary plastics, biomass, or even* CO_2". The JRC study here cites a reference, which is a 2019 publication by CIEL and Break Free From Plastic titled Plastics and Climate: The Hidden Costs of a Plastic Planet. When cross-referenced, the paper indicates that the solutions being quoted by the JRC are actually "*false solutions*" (Hamilton et al., 2019). The graphic below is from page 95 of this report.

Recommended "high-impact interventions" include steps such as: stop production and use of single-use items, stop new and expanded petrochemical and plastic production infrastructure, and set and enforce meaningful emissions limits and monitoring requirements. Included on the list of "low-impact interventions" is the point to maximise energy efficiency throughout plastic supply chain. In any case, the "life-cycle energy consumption" section of the JRC study does not reflect current thinking.

Strategies	Greenhouse Gas Emissions Reduces greenhouse gases or limits emissions growth	Impact Lifecycle approach	Non-Climate Benefits Will it have +/- impacts on SDGs	Feasibility/ Deployability Feasibility/ Is it ready for implementation	Scalability & Affordability Can it be implemented cost-effectively at scale
False Solutions					
Biodegradable plastic	Low	Low	Moderate	Moderate	Low
Use bio-feedstocks in petrochemical and plastic manufacturing	Moderate	Low	Low	Moderate	Low
Plastic-eating organisms	Low	Low	Moderate	Moderate	Low
Ocean cleanup	Low	Low	Moderate	Low	Low
Use chemically recycled feedstocks in petrochemical and plastic manufacturing	Low	Low	Low	Moderate	Low
Further integrate petroleum refining, gas processing, petrochemical, and plastic manufacturing	Low	Low	Low	Moderate	Low
Waste-to-energy	Low	Low	Low	Moderate	Low

High / Moderate / Low

[Pg. 95, ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf]

Other false solutions from the same reference are chemical recycling, waste to energy, and greater integration of the petrochemicals to plastics production line. The reference highlights that **the most effective way to reduce GHG emissions from the plastic lifecycle is to produce less plastic and stop building plastic manufacturing infrastructure, but none of these options are given by the JRC as a potential improvement measure.**

Additionally, the JRC study does not represent an ambitious approach to recycling. While some recycling has merits, it is not the panacea not least because it is lower in the waste hierarchy than reduction and re-use. Consequently, the environmental benefits in differentiating between the less environmentally impactful plastic recycling methods of mechanical and to a lesser extent physical/dissolution recycling, versus the more unsound method of chemical recycling, are absent from the JRC study. Similarly, the JRC analysis of use of post-recycled content does not include limitations, and trade-offs with resource and energy use, rather describing it as [§2.3.3.3.4]:

> "A*n important measure that is directly linked to the decoupling of economic development from natural resource use and reduction of material dependencies*."

Text Box 3. The importance of differentiating between types of recycling

All recycling requires the use of resources and energy. The deeper the decomposition of used plastic via recycling step 1, the greater the amount of resources and energy that will be needed to re-construct it again in step 2.

Highly disadvantageous environmental trade-offs exist with chemical recycling: energy demand higher than virgin resin production, high GHG emissions, high volume of waste generated, low recycling yield, and petrochemical lock-in (Bell, 2023; Rollinson, 2023; Weber et al., 2023). But, these are not mentioned anywhere in the JRC text, and specifically not mentioned when potential trade-offs are listed [JRC study §2.3.2.4].

Whereas mechanical recycling puts the recyclate back into the plastic production line at the last stage (product shaping), chemical recycling puts the recyclate back many steps earlier, into the steam cracking stage (see also Text Box). Thus, chemical recycling therefore imposes the same processing energy and emissions as virgin plastic feedstock with the added emissions of depolymerisation on top. Chemical recycling does not reduce CO_2 emissions, it increases them.

Industry is particularly silent about how much of the pyrolysis oil is fit for use as a naphtha substitute: the value quoted by some industry sources is around 20% (Rollinson, 2023). During steam cracking only about 30% of this will become ethylene (Kusenberg et al., 2022b). Assuming a more lenient estimate of 50% pyrolysis oil is useable as a naphtha substitute, this gives an overall 15% yield of plastic being turned into new plastic. However, contaminants from plastic additives and off-specification hydrocarbon chemistry will mean that this is an overestimate (Rollinson, 2023). Types of mass balance accounting are then used to deceive the public over these figures. We are already advocating against this in consumer-facing products.

What the JRC Study Assumes about the POL BREF

Scope

The JRC study seeks to align with the scope of the POL BREF, evident through its scope descriptor for "plastics and polymers" [Annex 1]: "It usually contains polymers and additives that give additional properties to the mixture. The scope is plastic basic materials, synthetic rubbers and hydrocarbons containing oxygen".

"Basic plastic materials" is not defined and the term has no common definition. It cannot be assessed here which of the process stages are included or excluded, and where any intermediate product becomes a final or even a sub-intermediate product. The phrase is no longer in use by the EC and is taken from the introductory scope of the POL BREF.

The last sentence "hydrocarbons containing oxygen" is also from the POL BREF's scope. **However, neither the POL BREF nor the JRC study covers the range of "hydrocarbons containing oxygen."**

Notable also is the first sentence of **the JRC's definition of "plastics and polymers". Not only is the sentence vague as to whether additives are included, i.e. the use of the word "usually" and setting it apart from the last sentence where the scope is defined, but it is incorrect because not all additives give "additional properties to the mixture". Some are chemical residues that carry-over into the plastic (lubricants for example), along with fillers used to reduce cost.**

A clear and accurate definition would have influenced the JRC's methodology and findings, especially where boundaries among plastics, polymers and chemicals has not been clearly addressed (boundary unclear on how it assessed the integrated plastic production line, and hence derived its score).

The JRC Study, the POL BREF and "Improvement Potential"

The JRC study refers to the POL BREF repeatedly as a source of information for determining the "*improvement potential*" of plastics [Annex 5, Box 18]:

*"The improvement potential focuses on reducing the production of plastics in general, minimising the use of single-use plastics and designing plastics to reduce microplastics release and to facilitate their recycling, given the fact that the production process is under the polymer production BREF, in force since 2007, which establishes a set of general and specific measures to minimise the emission of pollutants into the **water** [*] and which are understood to be assumed by the sector."*

The above text is cut and pasted and assigned to all of: "*water effects*", "*air effects*", "*soil effects*", and "*biodiversity effects*", except that, as the asterisk denotes, one word - "*water*" - is interchanged with "*air*", "*soil*", or "*environment*" [for "*biodiversity*"] accordingly. Inexplicably, the JRC does not use this text or refer to the POL BREF at all for "*waste generation and management*" even though this parameter is covered by the POL BREF.

2. Does the POL BREF effectively minimise emissions of pollutants?

Though the greater limitations of the POL BREF are explored in Annex 2, for now, it is emphasised that the **POL BREF is limited in its reach. It is dominated by simple methods like stopping leaks and otherwise flaring/incineration of wastes with regard to minimisation of emissions. Despite this, the JRC cite it as best practice**. Another, more recent reference cited by the JRC clearly states the limitations of these methods (Hamilton et al., 2019):

On fixing leaks:
"Identifying and fixing leaking pipes and tanks in the plastic supply chain will not reduce plastic production or the emissions from waste and environmental plastic, but it could dramatically reduce upstream methane emissions that compound plastic's lifecycle greenhouse gas emissions."

On flaring:
"For existing fossil fuel and plastic infrastructure, mandating that gas from wells, pipelines, and facilities be captured rather than flared or vented can reduce an ancillary but important source of emissions."

Here the results are presented of an assessment to **determine whether the POL BREF adequately addresses emissions to air, water, soil, and biodiversity, as supposed by the JRC study.** A selection of extract examples are provided in tables specific to named plastic types, while some general matters are presented at the end. In text citations of page/section numbers, refer to the POL BREF unless stated otherwise.

Emissions to air

The focus of the POL BREF is volatile organic compound (VOC) air emissions. As stated in its text [p.23] "*In the context of the IPPC Directive, the focus is on the minimisation of the emissions of monomers at the industrial site*". These VOCs will be solvents and residual hydrocarbons. Although dust is sometimes referred to, this does not apply to all plastic types, and where mentioned it is seldom explained what the dust contains or its size range. There is no coverage of GHG emissions.

Other gaseous pollutants - NOx and SO_2 - are only listed for one plastic type (unsaturated polyester) and then they are data values with no discussion of BAT for mitigating emissions. Microplastics are not mentioned anywhere in the POL BREF, and apart from one sentence that directs care when burning halogenated molecules, the text is devoid of information on persistent organic pollutants.

Frequently emissions to air are mentioned that are not BAT, or the POL BREF describes observed effluent without any treatment. There is also an over-reliance on flaring/incineration as a default for treating hydrocarbon-laden gas streams. These issues will be further explored in Annex 2.

Table 1. Examples of where the POL BREF does not adequately address air emissions

Plastic	Text Comment	Page
HDPE	"*The air from the dryer, the air from the silos and the pneumatic conveying system are discharged directly to the air.*" This will likely contain residual VOCs and microplastics, so no abatement is shown for these flows.	46
LDPE	Table 3.9 (emissions and consumption data for LDPE plants) states "*dust includes all dust reported by the participants*", while no detail is given anywhere as to what the dust contains; noting that it derives from voluntary disclosure. Elsewhere, other plastics (ESPR) have no listing for dust emissions.	62
PVC	"*At the beginning of any polymerisation, the reactor is charged with water and some additives…this has to be vented to the air*". This unabated emission particularly concerning because it likely to contain halogenated organics, as there is only 85-95% efficiency in conversion of vinyl chloride monomer (VCM). The text then simply suggests putting a lid on the reactor: "*The need of venting can be reduced using certain technologies such as a closed lid*". Emissions will occur when the lid is removed to empty the reactor.	95
Viscose	"*Drying is carried out in serial drying drums with a counter flow of hot air. This air is not treated any further".* The drying air will likely contain viscose fibres and microplastics.	178

Emissions to Water

Some polymers require, during their production, the consumption of tremendous volumes of process water. This can be up to 160 times the mass of polymer produced [p.154]. Emissions data presents that in some cases this all ends up as wastewater [p.181/182], but it is not within the scope of the POL BREF to discuss to methods for reducing water consumption.

Too often in the POL BREF, much of this wastewater is unaccounted for, or the methods of mitigating pollutant emissions are unclear. Sometimes the POL BREF defers to the corresponding BREF for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector (CWWBREF)[6] but the two do not always align, possibly due to the age of the POL BREF. **Error! Reference source not found.** lists some examples:

Table 2. Examples of where the POL BREF does not adequately address water emissions

Plastic	Text	Comment	Page
PP	"*The catalyst residues were discharged from the process with the waste water streams*". No explanation is provided on what the catalyst is, nor how to recover it.		54
SPBR	There is no BAT section for this polymer [§12], while the summary of BAT [§13] has just four lines of text and two bullet points, stating "*BAT is to remove solvents by using one or both of the following or an equivalent: devolatisation extrusion, steam stripping*. However, this does not correspond with Figure 8 which shows "*water and hydrocarbon to drain*", along with another effluent flow for "*VOC*" going nowhere. Some of the "*water and hydrocarbons*" do not originate from "*stripping*", while the VOCs come from a separate "*Finishing*" stage that is not explained in the text.		131, 272
PVC	§12 contains no BAT for treating water emissions. §13 BAT just lists three options for general production: "*use a combination of: stripping, flocculation, biological wastewater treatment*". For the last, text refers to generic information in §12.1.18 which has catch-all statements: "*Various techniques exist to treat waste water...Depending on the waste water effluent and its composition, and the plant operation, the most appropriate techniques are selected*". VCM is toxic and has specific process management issues. Contradicting the POL BREF, the CWWBREF does not list vinyl chloride in its table of suitable effluent for stripping [p.270]. Instead it suggests: ultra-filtration [p.194], membrane reverse osmosis [p.237], membrane separation [p.339], bio-scrubbing [p.386] and bio-trickling [pp.390-391].		225-232
	In the introductory (non-BAT) section [§5.2.8] flocculation of wastewater is mentioned, followed by "*sedimentation*" or "*dissolved air flotation*". These methods are not discussed further. Text concludes with the unhelpful caveat "*sedimentation of fine particles can be more difficult*".		100

[6] Brinkmann, T., Santonja, G.G., Yükseler, H., Roudier, S., Sancho, L.D. 2016. Best available techniques (BAT) reference document for common waste water and waste gas treatment/management systems in the chemical sector.

PA	There is no BAT for waste water at all: There is no BAT §12 for any PA polymer, while text in §13 does not cover waste-water BAT. Huge amounts of water are consumed, the highest for any polymer – at 160 t/t, though no information is provided as to how much of this needs treatment. Text says that waste water is "*mainly recycled*", but does not say how. This is accompanied by unsatisfactory coverall statements: *"the quantity of contaminants depends on the process parameters, but also on the technology used and on the layout of the plant"*.		151 152
ESBR	Wastewater volume is high (3 ≤ m^3/t ≤ 5) though the highest and lowest values in the range have been inexplicably excluded. Three treatment options are named in §12 [p.237] – "*settling ponds, biological treatment, waste water strippers*", but these are not discussed, In contrast, "*Settling ponds*" for process effluent are not within the CWW BREF. Indeed, this method is not recommended as it results in VOC emissions (Hamilton et al., 2019). Biological Treatment methods are in the CWWBREF, but they are sensitive to contaminants and insufficient detail is provided by the POL BREF. "*Steam stripping*" is in the CWW BREF too [pp.268-270] where a selection of contaminants are listed, but again necessary detail is absent from the POL BREF.		126

Solid waste – emissions to soil

Control methods for minimising the release of microplastics and nurdles during plastic production, storage, and transportation are not discussed within the POL BREF. While emissions from storage are considered to be covered by another BREF (Emissions From Storage, EFS), that BREF does not specifically address or have considerations regarding polymers either. Notably absent also in the POL BREF is information on emissions and fate of pollution control media such as spent adsorbant.

Information is limited on BAT for air and water emissions, but even less is provided on BAT for solid waste. One section of BAT [p.195] is on dust, but only from a solitary process component "*pneumatically conveying pellets*". Otherwise BAT applicable to solid waste is basic housekeeping or managerial in nature. In summary, there are major data gaps, no consistency between the level of information provided for the different plastic production processes, and frequently no specific information provided at all.

Table 3. Examples of where the POL BREF does not adequately address solid emissions

Plastic	Text	Comment	Page
PET	There is no BAT Section 12 entry for this polymer, and in Section 13 [p.274] there is no mention of BAT for solid waste. Three categories of solid waste are listed in a table of "*emissions and consumption*", these being "*polymer*", "*hazardous*" and "*other*". The "*other*" category is 3 to 40 times greater than amount of "*polymer waste*" and over 10,000 times larger than "*hazardous waste*". But, no information is provided about what it contains, where it goes, or how to minimise its volume or impact.		170
Viscose	In a table of "*emissions and consumption*" the only entry is "*hazardous waste*" with no detail in the text as to what it contains, where it goes, how		181- 182

	to minimise its volume and emissions. Yet, for BAT §12 there is also no information on how to minimise or handle emissions of "*hazardous*" waste, but rather reference is made to incineration of (so far unmentioned) "*non-hazardous waste*".	
SPBR	The "*emissions and consumption*" table gives only the words "*rubber waste*" as a solid waste output. There is no description of what it contains. BAT [§13] refers only to "*hazardous waste*" and "*non-hazardous waste*", with the instruction offering little guidance: "*minimise the volume by good segregation/good management and send for off-site treatment/recycling*".	136, 270
PA	No BAT is provided for PA because there is no §12, while the brief entry for BAT in section 13 only applies to gaseous effluent. There is a single paragraph in the introductory section titled "*waste*" which says that "*scraps of polyamide 6 are usually recycled*", but it does not say how, only that "*a small quantity (dirty) goes to landfill*". Other solid wastes are named - "*hazardous wastes…(i.e solvents)*" and "*other wastes…*(*used resins, sludge*)" but no information is offered for their management either.	152

Biodiversity

Biodiversity impact mitigation is not part of the POL BREF, and it is not evident why the JRC cited it here. The POL BREF does not include BAT for additives in plastics or catalysts, and although there are other issues which may impact on biodiversity, such as the release of macro- and micro-plastics during production and transport, the POL BREF does not adequately cover these either.

General limitations

The benchmarking data on emissions, presented in tables in the introductory sections [§2 – 11] devoted to each plastic type, are incomplete. For the important polymer PP, there is no table of information at all, because data "*have not been reported*" [p.66].

There are many instances of unspecified effluent with no BAT offered. In these cases it is impossible to assess how to manage this effluent. In some cases the POL BREF fills in the blanks with black box options such as the unhelpful "*adequate treatment*".

Table 4. Examples of how the POL BREF does not adequately address emissions in general

Plastic	Text	Comment	Page
PET	Figure 10.10 shows "*effluent*" coming from a "*packbox*" into which is also fed "*steam*", "*gas*", and "*chemicals*". The text does not discuss a 'packbox', whether this effluent is gaseous, liquid or solid, what the chemicals are that are added, and what chemicals may be contained in the effluent. There is no §12 BAT for this polymer, and only very brief and generic information in section §13, insufficient to assess and manage these emissions.		169
PS	After a devolatisaton step "*a purge of undesirable components is carried out on this stream".* This lacks context, being unclear what stream this is referring to, but there is also there is no discussion of where the purge		78, 223

	goes, not least what it may contain which therefore influences how best to do it. The BAT [§12] for this plastic is just a single table on one page listing the costs and efficiencies of varying "*available techniques*" in terms of "*low, medium, and high*", with few other remarks.	
Viscose	The tables of "*emission and consumption data*" [pp.181-182], show effluent of absorbable organic halogen compounds, but there are no comments on these emissions. The POL BREF does not elaborate on what type of molecule these may be, though the group includes persistent organic pollutants. It also fails to explain where they originate, and does not provide any specific BAT in §12 or §13 for mitigating environmental impact from their release to air, water or soil.	181-182
PA	For discontinuous production: "*The smoke generated at this stage is sent to an adequate treatment plant*". The same text occurs for "*continuous*" production where the same text appears but the word "*adequate*" has been omitted. It is not explained what this smoke contains nor how to mitigate emissions. There is no BAT §12 for this polymer in the POL BREF, and only one line of text in §13	141

3. Need for a coherent plastic and polymers definition

Analysing the different studies, we realised that the POL BREF and JRC documents do not use the most up-to-date or accurate definitions for what defines 'polymers' or 'plastics'. To understand what might be within the scope of a potential delegated act under the ESPR, clear definitions must be established that align with European and international precedents.

This lack of clear definitions has implications in what it is in the scope of the two reports. Neither the POL BREF nor the JRC study adequately clarify what constitutes the boundary of a plastic and polymer production line. Both parameters are paramount when making an assessment to improve the environmental impact of a material. The ESPR text is however clear: parameters should apply across the "*full value chain*", defined as "*all activities and processes that are part of the life cycle of a product, as well as its possible remanufacturing*" [Article, 2, 11].

Proof points:
The ESPR provides the following, relevant, definitions [Article 2]:
(1) "*'product' means any physical goods that are placed on the market or put into service*";
(2) "*'component' means a product intended to be incorporated into another product*";
(3) "*'intermediate product' means a product that requires further manufacturing or transformation such as mixing, coating or assembling to make it suitable for customers*"
(36) "*'consumer product' means any product, excluding components and intermediate products, primarily intended for consumers".*

The JRC study uses different terminology than what is established in the ESPR in some cases. For example, the JRC uses the phrase "*end-use products*" and applied it in their study, this being defined as a material that is "*sold directly to consumers and ready for their intended use", thereby distinct from "intermediate products*" [p.6]. The ESPR refers to these products as "*consumer products*".

The JRC study uses the below phrasing to define the scope of the sector being addressed:

Plastic is a polymeric material that has the capability of being moulded or shaped, usually by the application of heat and pressure. It usually contains polymers and additives that give additional properties to the mixture. The scope is plastic basic materials, synthetic rubbers and hydrocarbons containing oxygen.

This scope does not quite align with what has been laid down by either European Union regulations or in international conventions. An EU definition of plastic comes from the Single Use Plastic Directive[7]: *'plastic' means a material consisting of a polymer as defined in point 5 of Article 3 of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which can function as a main structural component of final products, with the exception of natural polymers that have not been chemically modified[.]*

The definition of plastic as provided by the recently adopted Basel Convention technical guidelines on the environmentally sound management of plastic wastes (UNEP, 2023) emphasis an important point—that plastics are comprised of **both** polymer(s) **and** additives:
"*Plastic is a synthetic material or modified natural material, either a polymer or combination of polymers of high molecular mass modified or compounded with additives such as fillers, plasticisers, stabilisers, flame retardants and colourants*".

The two definitions differ in that the Basel Convention definition includes additives as an intrinsic part of plastic whereas the EU definition uses the phrase "may have been added" as regards to additives. This issue of additives is important because it is often the additives which pose the most hazards to environment, health, and circularity.

Text Box 4. Definitions of polymer, plastic and the plastic production line

A 'polymer' is a large molecule joined together by carbon atoms, along with other elements. Plastic contains one or more types of polymer and these are produced by chemical synthesis; though there are natural polymers that are not 'plastic', for example DNA. The first plastics were made from natural polymers (cellulose), but the vast majority are now made from petrochemicals.

In material science, the verb 'plastic' means a type of permanent deformation that can occur when a material is subjected to pressure and/or heat induced stress. In modern language, 'plastic', as a noun, identifies with a range of synthetic materials, some of which go through a plastic deformation stage (of moulding or shaping) during manufacture. However, some that do not deform plastically (*i.e.* elastomers such as styrene butadiene rubber) are still usually grouped among 'plastics'; while other materials, such as metals, can behave plastically but they are not.

The whole plastics production chain involves a wide range of processing activities, usually integrated on the same site with petroleum refining (Bauer and Nielsen, 2021). The output of these installations is a pelletised resin called a 'nurdle'. These pellets/nurdles are then transported to a different site for manufacturing into articles such as films, bottles, containers, etc.

5. Directive (EU) 2019/ of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (europa.eu)

4. Plastics and polymers as ESPR intermediate products

The parameters to be covered by the ESPR are comprehensive and offer a broad range of options for improving the performance of plastics. These include the product requirements [Article 1]: "*durability and reliability, reusability, upgradability, repairability, possibility of maintenance and refurbishment, presence of substances of concern, energy and resource efficiency, recycled content, product manufacturing and recycling, products' carbon and environmental footprints, products' expected generation of waste materials*." This list is expanded by Annex 1 with parameters such as "*microplastics release*" and "*avoidance of technical solutions detrimental to re-use, etc.*"

ESPR Article 1(2), directs that "*This regulation shall apply to any physical good that is placed on the market or put into service, including components and intermediate products"* (with some exceptions, none of which apply to plastics. The ESPR does not restrict to production activities in the European Union. However, Article 16 (1), (c) says that prioritisation should take into account "*the distribution of the environmental impacts, energy use and waste generation across the value chain, in particular whether they take place within the Union*". This is in order to achieve EU climate, environmental and energy efficiency objectives. So emphasis is placed on minimising impact within the EU.

While the ESPR gives a definition both of "*product*" and "*intermediate product*" [Article 2], there are many places in the main text where it is not clear that reference to "*product*" also means "*intermediate product*".

Derogations with substances of concern

"*Substances of concern*" is defined [Article 2, 27] as having certain hazardous characteristics, or by "*negatively affect [-ing] the re-use and recycling of materials in the product in which it is present*". Note, as stated earlier, that only "*product*" is referred to, and it is not clear that this also applies to "*intermediate products*"; nor is "*negatively*" defined. Without clear definitions, these terms can be left open to interpretation.

Some nuance is attached to these derogations with the related term of "*chemical safety*". As given by Article 6(3), the ESPR should not restrict the presence of substances based on chemical safety. However the same paragraph goes on to say that "*the setting of performance requirements shall also, where appropriate, reduce significant risks to human health or the environment."* When it comes to polymers and plastics, and additives used in plastics, there is evidence that these do pose significant risks.

Article 7 is robust as it requires that information shall be provided to "*...enable the tracking of all substances of concern throughout the life cycle of products*" (unless covered by other acts). It then goes on to list the type of detailed information to be disclosed. However, there are potential exemptions based upon concentration and "confidential business information".

These possible exemptions could pose risks to transparency and circularity. The exemption can only be applied where the "*substance of concern*" is present in concentrations above "*0.1% weight by weight*" [Art. 7, 5, (c)]. This is applicable to "*the product, its relevant components, or spare parts*" so some clarification is needed as to whether this also applies to intermediate products. Moreover, this threshold value is set too high. It provides a loophole with respect to the toxic impact and bioaccumulation potential of plastic additives in the environment because many are present below the proposed threshold of 0.1wt% (Turner and Filella, 2021).[8]

Practicalities of application to plastics

Recital 49 of the ESPR includes the following language:

"When prioritising intermediate products, the Commission should also take into account the consequences for final products that are made from such intermediate products." By addressing plastics and polymers as an intermediate product under the ESPR, the EU has the possibility to improve the sustainability performance of plastic products suitable to end users (e.g. packaging) in ways that are complementary to existing product regulation.

More information is needed as to how aspects of plastic products and intermediate products might be practically implemented by the ESPR. For example, the plastic/metal composite materials, commonly used as packaging combined with metal (e.g., metallised wrappers and sachets) or paper-based materials (e.g., in beverage cartons), are extremely difficult to recycle. These materials are not covered by the POL BREF. Would the plastic in the composite be a "*component*" and an "*intermediate product*"? Were these addressed by the JRC in their prioritisation, albeit that packaging was excluded from their methodology?

The EU Packaging and Packaging Waste Regulation (PPWR) introduces sustainability requirements for all packaging placed on the single market. By 2030 all packaging has to be designed for recycling. Technical specifications of "design for recycling" will be put down in delegated acts to be adopted before January 2028, including for plastic packaging. These technical specifications are to drive environmental improvements in the waste phase by addressing packaging-specific issues (e.g. composite materials and other hindrances for sorting and recycling).

The PPWR does not, however, make any requirements to address the sourcing of primary plastics in a way that would steer the plastic producing sector into becoming more sustainable. Packaging designers will not have to think about the environmental impact of buying plastics from one producer or another.

However, the PPWR does push packaging designers, to use recycled plastic in plastic packaging and will add requirements to source recycled plastics from sources that are well performing on environmental indicators. It will provide sustainability requirements for plastic recycling technologies ("The Commission shall adopt by 31 December 2026 delegated acts supplementing this Regulation with sustainability criteria for plastic recycling technologies" and "The Commission shall assess, in view of the available recycling technologies, their economic and environmental performance, including the quality of the output, the availability of the waste, the energy needed and greenhouse gas emissions and other relevant environmental impacts.")

Since these indicators are lacking for primary plastic used in packaging, the ESPR would be able to make significant improvements by addressing plastics as an intermediate material.

[8] It is also unsatisfactory if the EU seeks to recognise chemical recycling as a viable recycling option since many of the additives in plastic are steam cracker contaminants below 0.1 wt%, i.e. chlorine, fluorine, sodium, calcium, lead, silicon (Kusenberg et al., 2022a)

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Annex 1: Notes on the text

When referring to specific parts of the JRC, ESPR, or POL BREF, and less frequently to other 'best reference' documents, identifying sections, page or figure/table numbers are cited in square brackets, while extracted text is in italics. Independent references are used occasionally for supportive information, and these are cited in parenthesis, along with the source listed in full at the end of the document.

A number of acronyms, used for types of plastic, are expanded below:
ABS = acrlyonitrile butadiene styrene
ESBR = emulsion polymerised styrene butadiene rubber
HDPE = high density polyethylene
LDPE = low density polyethylene
PA = polyamine
PET = polyethylene terephthalate
PS = polystyrene
PU = polyurethane
PVC = polyvinyl chloride
SAN = styrene acrylonitrile
SPBR = solution polymerised rubber containing butadiene
VCM = vinyl chloride monomer

Annex 2: Reference document on best available techniques in the production of polymers

Summary

Published in 2007, the POL BREF draws from an "*information exchange*" between 2003 to 2005. Its coverage is the operation of European plastic production facilities only, and only some of them provided data. The POL BREF's stated aim is to "*provide reference information for the permitting authority to take into account when determining permit conditions*", and while perhaps the remit was focussed on permitting requirements at the time, this is not explicitly stated.
The POL BREF is a large document (over 300 pages) and much cross-referencing is required in the pursuit of pertinent information. This activity is hindered by the information being fragmentary, not always under the appropriate section heading, and with many data gaps.
Following two introductory sections, general issues in the production of eight different plastic types are presented in chapters 3 to 11. The BAT for <u>*some*</u> of these plastics are first introduced in the key section 12, while section 13 provides a BAT summary drawn largely from the content of its predecessor. A brief one and a half pages [§14] is given to one emerging technique for viscose fibres; and chapter 15 discusses limitations and recommendations for future work.

Missing polymers

Granted, there are many types of plastic and some constraints have to be applied; but those chosen for coverage by the POL BREF were selected in part based on production volume and potential environmental impact, but importantly also on "*the availability of data*". Two plastics are notable by their absence:

Polyurethane is missing, though it has a **7.5% share of European polymer demand, bigger than PET and PS which are within the POL BREF** (Chalmin, 2019). Globally, the production volume is estimated at 10%, again on a par with PET and PS (Hamilton et al., 2019). By excluding this, the POL BREF misses issues during PU manufacture that require special attention, such as the use of toxic substances phosgene (a chemical warfare agent) and formaldehyde (Karali et al., 2024).

The PS co-polymer Acrlyonitrile Butadiene Styrene (ABS) – famous for that durable plastic used in Lego bricks and now the main polymer for 3D printing - is not specifically covered by the POL BREF. Also missing is Styrene Acrylonitrile (SAN) which [according to Table 1.1 of the POL BREF] is produced in Europe in greater quantities than unsaturated polyester which *is* covered by the POL BREF.

Limitations in scope and data acquisition

Though having the title of "Polymers", the POL BREF is largely about a single narrow reaction step in the long chain of events necessary for plastic production. Importantly, it also does not mark out a clear boundary and there is no consistency across plastic types as to where the production starts or ends. This is even though the other stages usually occur integrated at one site in practise.

Reference has previously been made to scope text: "basic plastic materials, synthetic rubbers, and oxygen-containing hydrocarbons". This is taken from Annex 1 of the now defunct IPPC Directive[9], and is a subset of eleven categories under the heading of "Chemical Industry". The IED[10], which replaced the IPPC Directive, has dropped the word "basic" from "plastic materials". Inorganic chemicals are also used in plastic manufacture but are not covered by the POL BREF.

Old methods and old priorities

At the time of its publication, the average age of the exemplar production plants was twenty five years [p.61]. Thus, the information in the POL BREF derives from, on average, fifty year old designs.

In the subsequent twenty years, the landscape in plastics production has shifted, with greatest production now occurring in China, Russia, U.S.A, and Middle East, using shale gas or coal to methanol, the latter estimated to emit approximately ten times more CO_2 than shale gas cracking (Hamilton et al., 2019).

Environmental priorities have shifted too, onto topics which modern importance which are not covered by the POL BREF but which are important to the ESPR, such as: choosing alternative, more environmentally benign, reagents and catalysts (so called, green chemistry); environmentally sound treatment of catalyst waste, minimising catalyst carryover into products, and issues in catalyst regeneration; minimising spillage of microplastics/nurdles; GHG emissions (other than VOCs); potential for reducing substances of concern - additives and NIAS; issues with incorporation of recyclate into the process line (via chemical recycling), making plastics more easy to recycle, and the importance of recovery/regeneration of solvents and reagents rather than the default of -situ flaring.

Dominated by the input of industry associations

Data gathering relied heavily on industry provision, for which [p.279] "*confidentiality concerns represented a considerable obstacle*". The resultant limitations are broadly evident: Table cells are frequently empty of values, and parts of the key section on BAT [§12] are populated by the disclaimer

[9] European Commission, 1996. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control.
[10] European Commission, 2010. Directive 2010/75/EU of the European Parliament and of the Council of 24 November on industrial emissions (integrated pollution prevention and control) (recast) (Text with EEA relevance).

"*No further information/details submitted*". The largest omissions are perhaps that there is no §12 entry at all for PP (one of the most common plastic types) nor for PA. While for some plastics (PA), the other important BAT section [§13] contains only three lines of text. For others (SPRB) the authors state that "*no technical justification [for BAT] could be agreed on*" [p.280].

Three respondents provided emissions and consumption data for unsaturated polyester, despite there being 43 sites in Europe [pp.115-117]. Here information was supplemented by the chemicals industry (CEFIC) who gave, surprisingly, a value of "zero" hazardous solid waste to landfill, but 7kg per tonne hazardous waste for unspecified 'external treatment", and no values at all for good practice waste water effluent. The relevance of this is that many raw materials used in the production of this plastic are now identified as toxic and/or hazardous such as bisphenol A and tin-oxide, and though it is stated that "polycondensation will generate reaction water containing unreacted raw materials and impurities" [p.112], no information is provided about what quantities go into the waste.

Observed, rather than *best* practice

Site visits were used for data gathering [p.279]. The POL BREF too often describes what occurred twenty years ago, namely *operational* (in other words established) processing rather than *best* practice. For examples of this see the text extracts provided in Table 2, Table 5, and Table 6.

Missing polymer production steps

The POL BREF does not include most steps in the polymer production and plastic value chain. The red boundaries in Figure 1 show those covered by the POL BREF, with the dashed line indicating partial coverage. Note the relatively small amount of GHG emissions associated with the stage(s) covered by the POL BREF.

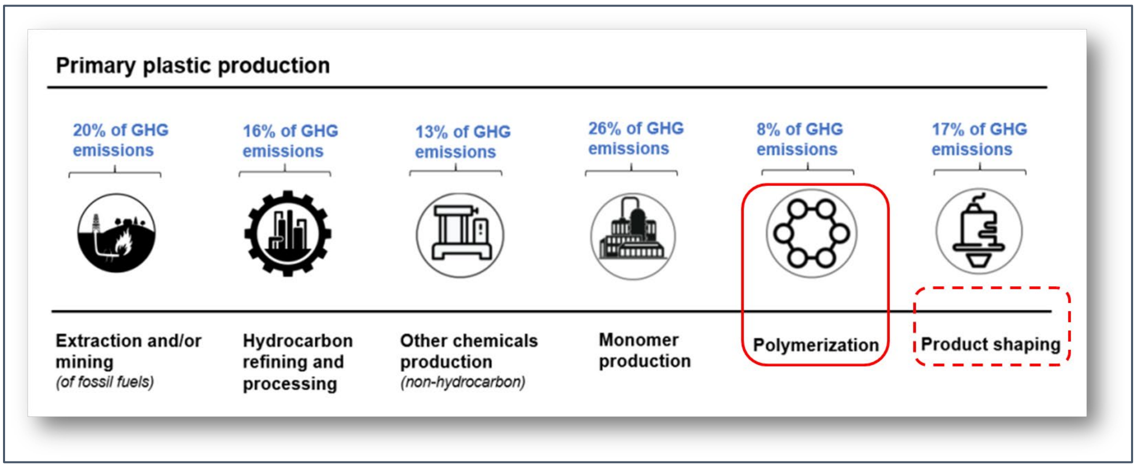

Figure 1. The entire processing line in the production of plastics. Drawn boundaries illustrate the stages covered (dashed line, in-part) by the POL BREF for some polymers. Adapted from Karali et al., 2024.

Steam cracking

Steam cracking is the method for producing ethylene and propylene along with other organic chemicals used in plastic manufacture. The process is central to the production line of almost all widely used plastics (Hamilton et al., 2019). The steam cracker stage is not covered by POL BREF, but reference is made to material coming from and being routed to it [p.38-39], as well as being on the same production site [p.47]. Steam cracking is covered by the more recent LVOC BREF.

Text Box 5. The impact of steam cracking to ESPR for plastics

Large modern steam cracker plants can emit between 2 and 4 tonnes of CO_2 for every tonne of ethylene produced (Hamilton et al., 2019). With European ethylene production in 2022 estimated at 23.5 million tonnes (Chemanalyst, 2023), this puts the combined emissions from such installations in Europe at between 47 and 94 million tonnes of CO_2 per year.

Steam cracking has a fixed operational window (LVOC BREF), and is very sensitive to the many additives in plastics at levels much lower than the limit proposed for industry disclosure by the ESPR (Kusenberg et al., 2022a). Purifying these additives from the oil will use more energy and generate more waste, which is also not covered by the POL BREF; or the pyrolysis oil will just be diluted with large quantities of petroleum naphtha (Rollinson, 2023).

Any chemically recycled plastic must pass through the steam cracking stage thus emitting the same amounts of CO_2 on top of which will be the emissions from the pyrolysis stage itself. While the petrochemicals industry is making heavy investment in more steam cracking infrastructure, the world needs to stop using steam crackers.

Another issue, not covered by either the POL BREF or the LVOC BREF is the increased de-coking necessary when using chemically recycled plastic pyrolysis oil, due to the lower proportion of long-chain paraffins (Rollinson, 2023). When coke forms, efficiency drops, and the plant is taken off-line for 18 to 48 hours for de-coking [LVOC BREF, p.134]. This also generates a dirty gas, and though some abatement is used, some plants directly vent to the atmosphere unabated [ibid].

Product shaping

This is the last stage in plastic production. Sometimes [*i.e.* p.71] the POL BREF refers to injection moulding, extrusion and thermoforming, but there is no BAT for these methods. They are specifically outside of scope [p.xxiii]. Still, one exception is a single paragraph on burning the off-gases from extruding PE [p.211]. Spinning into fibres is discussed for two plastics: viscose and PA; but for some reason no BAT is discussed for the spinning of other polymers which *are* covered by the POL BREF and which can *also* be made into fibres (*i.e.* PET and PVC).

Purification

Extremely pure raw materials are needed for polymer production, meaning that side products from monomer synthesis, impurities from storage containers, oxygen, degradation products or stabilisers added for transport, have to be removed before use to attain a purity level of in some cases 99.9999 % [p.21]. Though the POL BREF says that purification will be discussed where necessary, text is only provided for one polymer [§8.2.1 – SPRB], and this is just three small paragraphs. There is no generic BAT for purification in §12 or §13.

Inadequate on additives

References to some of the plastic additives mentioned in the POL BREF are:

- "…chain transfer agents or sometimes emulsifiers or colloidal stabilisers either become part of the product or are separated" [p.24];
- "lubricants (internally or externally) to help process the resin for end usage. The addition of antistatic agents, UV stabilisers, glass fibres, or colourants via compounding]…antioxidants are used for rubber stabilisation and flame-retardants are added for special PS applications" [p.70];
- "blowing agents" [p.71];
- "lubricants and mould release agents [p.74];

- "surfactants, emulsifiers and protective colloids used to prepare and stabilise the dispersion of the monomer" [p.94];
- "hardeners and accelerators, skinning agents, thixotropes, dyes, pigments, self-extinguishing agents, fillers" [p.108];
- "coupling agents, structure modifiers, extender oil, killing agents, and product stabilisers" [p.131];
- "antifoam agents, molecular weight regulators, lubricants, delustering agents, etc." [p.144];
- "polymer additives (for anti-pilling, antistatic, flame retardant, antibacterial, and heat resistance properties)" [p.161];
- "…emulsifiers, catalysts, modifiers, shortstops, antioxidants and extender oils, are also required" [p.119].

Despite these substances being ubiquitous in plastic production, they are all set outside of the POL BREF's scope with regard to BAT. Very rarely the chemicals are mentioned by name, e.g. inhibitor '*hindered phenol'* [p.100], but the POL BREF provides no discourse on safe management during storage and use. In all cases their ultimate fate is not recorded, so it is not known what fraction, if any, additives are contained in effluent burned or sent for disposal. Consequently, associated emissions to air, water, or soil, potential for human and environmental impact both within and outside the process, carryover into wastes, etc., cannot be ascertained because they are not discussed.

Notwithstanding their negative impact on the environment and recyclability of plastics, this absence should not be the case because the quantity of additives incorporated are not trivial. Some content values, on a weight basis, are: pigments ≤ 10%, fillers ≤ 50%, colourants ≤ 5%, flame retardants ≤ 25%, plasticisers ≤ 70%, and most others ≤ 3% (Hahladakis et al., 2018).

Certain additives are listed for PVC but the text is unhelpful [p.96]: "*emulsifier…initiator… copper and a reducing agent is often used*". The PVC section is however unique in that it offers guidance for environmental impact mitigation, but it merely says the following[p.97]: "*Lower levels of emulsifier can be advantageous, for example for applications coming into contact with food, where water absorption or clarity is important, and also for the environmental impact of the process.*"

Yet, one single glimpse of what a future POL BREF could cover appears on p.123. This explains that ten years ago the use of potentially carcinogenic chemicals (volatile nitrosamines) were present in concentrations of ppb and these were phased out. No other information of this type exists.

Flaring as default

Flaring is a type of incineration. Both words are used in the POL BREF, along with "*thermal oxidation*" and "*catalytic oxidation*" which are essentially the same thing – they burn and release GHGs and potentially other gaseous pollutants - the latter employing a catalyst. Flaring has been considered utilitarian for decades, for destroying waste streams that contain VOCs, usually in gaseous but potentially in liquid or solid form.

Flaring is practiced partly because of ease and cheapness relative to alternative forms of disposal or recovery, but also because many VOCs are harmful to the environment, so although burning them releases CO_2, it is a case of the lesser of two evils. Better methods are now required for moving as close as possible to circularity and mitigating climate change. Alternatives include reducing the use of solvents, recovery of the VOCs by condensation or adsoption to capture the VOCs, or possibly bio-filtration. These however will incur trade-offs, in terms of energy and waste generation, but this should be part of a broader discussion that is lacking in the POL BREF.

On too many occasions the POL BREF defers to flaring/incineration or other burning as the default, likely again reflecting 'operational' rather than 'best' practice, for treating waste. This is contrary to its own assertion that flaring is only BAT for discontinuous flows *"...if these emissions cannot be recycled back into the process or used as a fuel"* [p.iii]. A selection of examples are provided in Table 5.

There are ways to improve flaring to optimise complete combustion, but such operational parameters are also not discussed by the POL BREF. Similarly, catalytic oxidation can reduce fuel costs, but this is off-set by the expense of catalysts and their susceptibility to poisoning by elements such as sulphate, chlorine, lead, arsenic, phosphorous, all of which demands knowledge of the fuel and waste streams which is, again, inadequately explained.

Table 5. Some examples of the POL BREF text on flaring/incineration

Plastic	Text	Comment	Page
PVC	"*...vents leaving the recovery plant pass through a VCM chemical absorption or absorption unit, a molecular sieve, and incinerator or catalytic treatment unit*". This contradicts text elsewhere that says flaring is not suitable for chlorinated gas streams in PVC processing, although it does add simply that incineration must be designed to limit dioxin formation.		100, 201
HDPE	"*The small amount of hydrocarbons in the nitrogen rich purge gas can be recovered or the stream is sent to a flare*". No discussion is provided on how to recover the hydrocarbons. BAT §12 repeats that recovered monomers "*are sent to a thermal oxidiser or to a flaring system*". Even monomers in the vapour captured from storage silos are transferred to a "*thermal or catalytic oxidising unit*".		46, 210-212, 218
Viscose	"*The waste liquor from the dialysis process is disposed of by vaporisation and incineration*". BAT §12 does not mention dialysis. It only states that "*non-hazardous wastes are incinerated in a fluidised bed incinerator*".		176, 248
General	"*Separated monomers, mostly as gases, can be directly returned to the process, returned to the monomer unit to be prepared for purification, transmitted to a special purification unit, or flared off*". Purification is only discussed for one plastic type (SPBR).		22
HDPE	"*The remaining ethylene can be recovered and sent back to a nearby cracker for use as fuel gas".* This may be referring to a steam cracker or a Fluid Catalytic Cracking Unit (FCCU), but both are major emitters of GHGs.		44

Catalysts are not adequately covered

Reference to best practice in catalysis during polymer production is not part of the POL BREF, even though many forms of catalyst are widely used. The document refers to catalysts only infrequently, in passing, and inconsistently, invariably lacking detail. While types of catalyst are sometimes mentioned (titanium and chromium, cobalt chloride [p.43, p.176]) quantities, emissions and energy intensity of regeneration, handling and storage, downtime during regeneration, gases used, fuel used, how much loss of catalyst there is, how to protect catalyst from sintering and poisoning, minimising emissions to air, soil , and water are not discussed.

Ways to improve catalysis to minimise environmental impacts would be to discuss issues in catalyst carry-over into both waste and product streams.

Some that are mentioned by the POL BREF are now considered to be hazardous waste constituents by the UN Basel Convention Annex 1 (UNEP, 2019) or other legislated controls (e.g. antimony, copper, phthalates). Since many catalysts are rare and expensive they would also come under the remit of the ESPR for purposes of EU autonomy and resilience [ESPR, p.1]. Also, information could be provided by a future POL BREF on avoiding catalyst deactivation/poisoning by contaminants or high temperatures; while some deactivation may be repaired via regeneration but this incurs the use of reagents and energy which in turn creates emissions and waste and so should also be part of current BAT. Table 6 shows some examples of limitations with regard to catalysts in the current POL BREF.

Table 6. Some examples of the POL BREF text on catalysis in plastic production

Plastic	Text / Comment	Page
PET	"*...the reaction is enabled by a catalyst containing manganese [and] typically, antimony is added to catalyse the polycondensation reaction".* Other text says that catalysts containing manganese *"...ends up in the product*", but no information is given on the ultimate fate of antimony.	161
PP	There is a specific section on catalysts for polypropylene [§3.2.5.1] but this is absent in all other polymer chapters. Text says that "*catalyst residues and atactic PP had to be removed to get an acceptable final product"* but does not explain how. It also states that some catalysts needed "*de-ashing*" but provides no further information on BAT.	p p.52-57
PP	"*...with modern catalysts, neither the catalysts nor the atactic polymers have to be extracted*". Figure 3.13 also shows catalysts going in but not coming out, but contradictory accompanying text says that "*the catalyst residues were discharged from the process with the waste water stream*". Their fate is unknown.	54, 57.
PS	"*various catalysts are used at different temperatures depending on their rates of decomposition".* No further information is provided	72

Issues in storage and transportation

Storage and transportation is not given adequate emphasis by the POL BREF. This applies to raw materials, products and wastes and emissions therefrom. For example, PVC is the only plastic to have reference to vapour return systems, while floating roofs are only listed for BAT with PS and ESBR; despite both of these being general techniques that apply to all production methods. The information provided is sparse generally, but of this content most is devoted to minimising leaks of VOCs during storage and transportation. The least information is on solid emissions, with no discourse at all on BAT for curtailing spillage of microplastics and nurdles.

PVC

Asymmetric coverage is given to BAT during storage for PVC production, specifically with its precursor VCM. There are however the usual gaps and weaknesses. For example, p.225 explains that emissions are prevented by providing tanks with "*connection to the VCM recovery system or to appropriate vent treatment*", without stating what this treatment might be.

Section 5.2.2 [p.94] mentions limited good practice in VCM supply, storage and unloading, but does not explain that this monomer is multi-toxin, an established carcinogen, and both flammable and explosive with a wide concentration range in air; nor that the fumes are also toxic – phosgene, hydrochloric acid, and carbon monoxide (Beyond Plastics, 2024). Indeed, there has recently been a major incident where this substance was spilled during transportation (*ibid*.)

PA

Text [p.142] describes that during PA66 production "*water vapour leaving the concentrator is condensed and the condensate is collected into a tank*" which then goes to a [p.143] "*main wastewater collecting tank*" to join other liquid process effluent such as "*water vapour blown off from the autoclave during the polymerisation cycle*". But, the POL BREF provides no further information on the fate of these unspecified liquids. This is because there is no BAT §12 for this polymer, and §13 does not cover waste-water at all. The water is said to mainly carry hexamethylenediamine, from which a leak during transportation caused injury to 37 people at a nylon intermediates plant, coincidentally in the same year that the POL BREF was published (Industriall, 2007).

Unsaturated polyester

For this plastic, the POL BREF informs that [p.114] "storage times and conditions at the production factory, during transportation and at the customer warehouse have to be controlled to avoid unwanted curing". But, it does not explain how it is to be controlled and what might be the consequences.

The introductory entry for this plastic is unique in that it has a section titled "Process safety hazard issues" [p.109]. Although some hazardous chemicals are associated with its manufacture, this is also true of other plastics, which have no corresponding sections of information. In terms of the content of this section, information is still open-ended. For example, it lists "flammable mixtures in storage" [p.109], but not why this occurs or how to manage it.

PE

This plastic is unique in having a section called "*delivery of the product in its original particle shape*" [p.220]. There are just two sentences, one contains the information that there are "*industrial hygiene and safety concerns (dust explosions are possible)*", but no further discussion. Many of the fields are empty of information.

PP

There is no BAT §12 for this plastic, and nothing specific given in §13. But there is introductory information [p.56] that says: "*Residual moisture and volatile substances are removed with a flow of hot nitrogen before the polymer is conveyed to the storage tank and stabilised*". However, no explanation is give as to how it is stabilised and why. No storage parameters are offered.

PS

While there is also introductory information on the storage of PS, it is provided piecemeal and lacks detail. Tables [pp.77-89] have only words for storage parameters: "*temperature*" and "*level control*", "*nitrogen charged with VOCs*" and "*dust and packaging*", but the table's cells which should contain more detail only have the entry "*N/A*".

Elsewhere, text on p.73 explains that: "*The greatest concern during storage of styrene is the prevention of self-polymerisation which is a runaway reaction. The most important factors in maintaining a long shelf life for styrene are: low temperatures, adequate inhibitor levels, correct construction materials for storage and handling equipment, and good basic housekeeping*…." It is good that an inhibitor is listed (TBC 4-tert-butylcatechol) along with recommended concentration levels; and while in BAT §12 tables give five named options for techniques to minimise emissions during storage of PS, but there is no explanatory text.

ESBR

There is a specific section on BAT for storage during the production of this plastic [§12.6] which comprises a third of a page, along with entries in a table, with all information repeated in §13. All references are to the storage of gases. It is of note that ESBR is the only for plastic for which reference is given to the Storage BREF.

Potential loopholes

Lack of coverage of the full plastic production line in the POL BREF creates potential loopholes. Emissions across the full value chain and life cycle are separated though many occur at the same site in integrated process lines. The same applies to the omission of BAT with respect to catalysts, additives, and inorganic chemical reagents used in plastic production. One other example so far not mentioned is with treatment plants off-site and that are outside of the plastic production line, such as for waste-water. Transportation of chemicals, wastes and products between sites also is weakly resolved.