# Criticality Within Planetary Boundaries

**A Public Interest Approach to Critical Chemicals for Europe's Clean, Safe and Just Industrial Transition**

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# I. Chemical pollution crisis, insufficient response and our alternative.

### 1. The chemical industry as a driver of intersecting planetary crises

The chemicals we produce shape the quality of our environment and our health. The chemical industry is not merely an economic actor facing competitiveness challenges. It is a primary driver of multiple intersecting crises, pushing the "novel entities" and other six planetary boundaries - including climate change and biodiversity loss - beyond safe limits simultaneously.

Thousands of industrial chemicals are now widely dispersed across the planet, including in remote regions and human biological systems. The 2022 Human Biomonitoring Initiative (HBM4EU) detected a broad range of industrial chemicals (including PFAS, phthalates, flame retardants, and pesticides) in European populations, confirming alarmingly high exposures to substances associated with serious health impacts, including cancer, reproductive harm, and premature mortality.

In Europe, communities near chemical and petrochemical clusters face disproportionate exposure to industrial pollution, with persistent impacts on air, water, and soil quality. For instance, analysis submitted in legal proceedings concerning a planned petrochemical facility in Antwerp suggests air pollution impacts associated with hundreds of premature deaths, compared to approximately 300 permanent jobs created, illustrating the scale of local health risks.

These chemical pollution impacts cannot be understood in isolation from the climate and plastics crises. The chemicals sector is the largest industrial energy consumer in the EU[1] and the third-largest industrial CO2 emitter, accounting for around 5% of the bloc's greenhouse gas emissions, with around 99% of all synthetic chemicals and plastics derived from oil and gas. Petrochemical feedstock like ethane, LPG and naphtha are projected to drive 70% of global oil demand growth by 2026, while plastics production and incineration continue to increase greenhouse gas emissions (850 million tonnes of greenhouse gases in 2019, a figure set to rise to 1.34 gigatonnes annually by 2030 if current trends continue) and toxic burdens.

These are not separate crises but interconnected systemic failures requiring a coherent response.

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[1] Chemicals industry accounts for 21.5% of total final energy consumption in industry in 2023, the highest share of any industrial sector.

## 2. Existing pollution burdens and the rising cost of inaction

The pollution burden is already enormous and growing. PFAS contamination alone is estimated to generate remediation costs of up to €2 trillion over 20 years in Europe, or more than €100 billion annually if emissions continue. Cleanup costs for contaminated soil can reach 280,000 Euros per kilogram. Globally, PFAS remediation costs largely exceed global GDP of $106 trillion[2] .

The European Commission estimates that fully implementing EU environmental laws could save the EU economy around €180 billion every year in health costs and direct costs to the environment. Plastic pollution alone imposes far higher costs of inaction than prevention[3]. Air pollution from fine particles contributes trillions in global health costs annually.

These figures demonstrate that continued pollution and reliance on fossil-based chemical production is economically irrational and socially unsustainable.

## 3. **Structural roots of the European chemical industry's competitiveness crisis**

The EU chemicals sector's competitiveness challenges are rooted in its production model:

- linear production systems
- fossil-based feedstocks and value chains[4]
- high energy intensity
- hazardous chemical inputs and "toxic ignorance or indifference"[5]
- weak circularity
- supply-driven production

These structural characteristics make the sector vulnerable to energy price volatility, carbon pricing, and regulatory tightening. Rising energy costs, investment gaps, and slower deployment

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[2] For comparison, a 2022 study in Nature estimated losses due to recorded climate change impacts at an average US$143 billion per year between 2000 and 2019 (between 0.05% to 0.82% of global GDP annually over the study period).

[3] $113 billion for inaction against $65 billion for action per year.

[4] which may not align with future needs such as access to renewable energy, sustainable feedstocks or low-carbon sources of industrial heat.

[5] Toxic ignorance implies that the industry choose toxic inputs not because toxicity is unknown, but because under the current status quo they prioritise toxics' lower impact on industry's core concerns (e.g. carries fewer cost and creates fewer barrier to production), while deprioritising impact toxics have on people and nature.

of innovation are not solely external pressures; they are partly consequences of the industry's technological and material choices.

Importantly, environmental and health costs remain largely externalised, effectively socialising damage while privatising profit.

Competitiveness challenges are therefore not only external but structural. Transitioning toward safer, circular, less energy-intensive production is both a necessity and an industrial strategy.

### 4. EU policy response and risks of misdirection

The European Commission has launched an Action Plan for the chemical industry and established a Critical Chemicals Alliance (CCA) to define "criticality", map production, and guide investment[6].

The definition of "criticality" will shape the future trajectory of the sector. Unfortunately, the emerging CCA approaches risk prioritising industrial supply chain resilience over societal need, potentially locking in existing harmful production systems.

This approach risks reinforcing:

- fossil lock in dependence and associated false solutions[7].
- delayed innovation, substitution and stifling competition[8].
- increased pollution.
- misallocation of public funding[9].
- regulatory incoherence and uncertainties[10].

[6] This classification, in turn, would open a possibility to "benefit from enhanced trade monitoring and support, including under the Customs Surveillance Systems."

[7] False solutions include overreliance on end-of-pipe approaches such as carbon capture or chemical recycling.

[8] Stifling competition includes limiting investment into new solutions and market entrants (e.g. SMEs) that face structural barriers compared to incumbent actors.

[9] Such misallocations concern funding and institutional capacity, as decision-making is increasingly shaped by incumbent industry interests rather than a neutral, evidence-based assessment of societal need.

[10] Labeling substances as 'critical' that are simultaneously prioritised for phase-out or regulatory action under different EU legislations creates contradictory signals across the EU policy framework. This, in turn, undermines legal predictability for investors while complicating compliance.

### 5. Our proposal: A public interest definition of criticality

We propose a future-proof definition of "criticality" grounded in public interest, planetary boundaries, and EU sustainability objectives that would lead the chemicals industry out of the crisis. Criteria should be based on three pillars for the foundations of a modern, competitive industry:

1. **Clean production**: Low-carbon energy and processes[11], combined with state-of-the-art pollution prevention measures.
2. **Safe and more sustainable chemicals**: Replacement of hazardous substances (starting with the most hazardous), by developing intrinsically less hazardous ones.
3. **Circular systems**: Prevent waste and reduce resource use.

We will first give elements for defining 'criticality' in a forward-looking manner, before detailing the underlying methodology this definition would entail, finishing on the practical actions such approach to 'criticality' would presume across industry's multiple dimensions - from pollution prevention to production reduction.

# II. Defining 'Criticality' as essential for society, not industry's status quo.

The way "criticality" is defined will shape the trajectory of the chemical industry's transition. The European Commission's "essential-use" concept provides a solid foundation, because it takes a societal perspective, asking whether the use of chemicals, materials or processes is truly necessary to protect health and safety or to ensure the functioning of society, and whether acceptable alternatives exist. Its purpose is to accelerate the phase-out of non-essential uses of the most harmful substances while allowing time for substitution where essential uses remain.

However, the emerging approach within the CCA risks shifting the focus from societal need to industrial "vulnerability", understood as the exposure of existing production sites and value chains. This could result in substances being classified as "critical" because they are important to current industrial supply chains, even where their uses are not essential to society. In doing so, structural dependence on legacy production systems—including those that drive pollution,

[11] meaning energy and industrial processes with very low or near-zero greenhouse gas emissions (such as renewable electricity, electrified heat, and other non-fossil-based solutions)

fossil fuel dependence and overconsumption—risks being reframed as a strategic asset worthy of protection and public support.

We therefore argue that "criticality" should be defined in line with the European Commission's Essential Use Concept. Critical chemicals, materials and processes should be those that are necessary for health or safety or critical for the functioning of society, and for which no acceptable safer or more sustainable alternatives exist. Criticality should reflect societal necessity, not industrial dependency or market relevance.

In particular, criticality should not be conflated with:

- the strategic importance of existing not sustainable supply chains;
- the availability of affordable feedstocks that sustain overproduction or overconsumption; or
- the preservation of existing production assets and business models.

This approach recognises that the fundamental role of the chemical industry is to support essential societal functions, including (but not limited to) safe and clean food production, water services, biodiversity protection, pollution prevention and environmental remediation, while enabling the transition to a safe, sustainable and competitive European economy.

Moreover, criticality must be assessed in a holistic manner through:

- **A value chain lens, not molecule-by-molecule assessment.** Criticality cannot be assessed at the level of individual molecules in isolation. It must be evaluated across the full value chain and function context (including downstream products such as textiles and packaging characterised by overconsumption).
- **A cross-dimensional lens, not a siloed approach**. Criticality cannot be assessed from a one-dimensional perspective alone - be it pollution, climate or circular economy taken in isolation. It must cross its evaluation to make sure that advances in one dimension will not undermine another, in order to ensure that we are truly advancing towards a sustainable future in all of its multiple facets.

# III. Methodologies to concretise the definition of ‘Criticality’.

The CCA is currently developing a methodology for assessing “criticality”. However, methodology is not neutral: the design choices made today will determine which substances and processes receive public support, which production models are locked in, and which transition pathways are foreclosed.

A chemical produced in Europe without external dependency may be labelled “critical” because it contributes to supply resilience (i.e. addressing “vulnerability”). Yet resilience that merely preserves an unsustainable status quo is not in the public interest. In such cases, what is protected is not the functioning of society, but the continued operation of incumbent industrial structures.

This creates a risk that “criticality” becomes a proxy for maintaining existing production systems, rather than a tool to identify what is truly essential for society. Current methodological approaches under discussion therefore risk steering industrial policy away from the necessary transformation of the sector.

We therefore propose the following methodological principles as a precondition for a definition of criticality that serves people, the environment, and long-term European competitiveness.

**1. Core orientation: forward-looking and society-centred**

“Criticality” must be defined in a forward-looking manner, aligned with EU sustainability objectives and the Essential Use Concept. The starting point must be societal value, not industrial dependency or existing production capacity.

**2. Resilience: system-level, not molecule-level**

“Resilience” should not be assessed at the level of individual chemicals or production sites. Instead, it must be evaluated at the level of:

- feedstocks, and
- industrial sectors and value chains

This includes Europe’s dependency on fossil-based and future bio-based feedstocks, as well as systemic exposure to global supply chains.

A molecule-level approach risks misclassifying structurally unsustainable systems as "critical" simply because they are currently embedded in European production.

## 3. Three complementary lenses for assessing criticality

Criticality assessments must apply three interconnected analytical lenses:

### A. Value chain lens (not molecule-based assessment)

Criticality must be assessed in relation to societal functions and end uses, not individual substances in isolation. This includes evaluating downstream sectors such as textiles, packaging, construction, and other areas characterised by structural overproduction or overconsumption.

### B. Systems lens (not siloed assessment)

Criticality cannot be assessed from a single environmental or policy dimension. Climate, pollution, circularity, biodiversity, and resource use must be considered together to avoid burden-shifting between objectives.

### C. Transition lens (not status quo assessment)

Criticality must be assessed against Europe's long-term transition objectives, not existing production patterns. The fact that a substance is widely used today or economically important should not be sufficient to classify it as critical.

## 4. Production systems and infrastructure

Where production sites are considered, assessments must go beyond location-based or supply-risk indicators.

They must include:

- environmental performance indicators
- alignment with EU decarbonisation pathways
- emissions intensity benchmarks (e.g. ETS benchmarks)
- transition readiness of processes

Importantly, assessment must focus on **processes and production systems**, not only physical sites.

### 5. Societal necessity and alternatives

A central element of the methodology must be the question:

- Is the chemical use necessary for societal functions?
- Are there safer or more sustainable alternatives available?

Criticality cannot be defined without explicitly assessing:

- the function the chemical performs
- whether the function itself can be delivered differently
- whether substitution is feasible within a reasonable transition timeframe

### 6. Governance and value definition

The definition of societal value and long-term impacts must not be determined solely by industry actors.

It should be developed through inclusive and transparent processes involving:

- public authorities
- scientific expertise
- civil society organisations
- where relevant, social partners

This is essential to ensure legitimacy, avoid capture, and align the methodology with public interest objectives.

# IV. Putting 'Criticality' to action: practical consequences of 'criticality' defined sustainably.

Definitions and methodologies only matter insofar as they shape real-world decisions (from investment and innovation priorities to funding choices) that determine the direction of the chemical industry's transition.

The actions outlined below flow directly from the commitments already co-developed by the chemical industry under the EU Chemical Industry Transition Pathway, including moving away from fossil feedstocks, reducing toxicity, and increasing transparency. The Critical Chemicals Alliance process must therefore be consistent with these commitments, not a vehicle for weakening them.

This section translates the proposed definition and methodology of criticality into a coherent set of operational consequences across production systems, consumption patterns, and EU policy frameworks.

### 1. Pollution Prevention

#### 1.1 Upstream pollution prevention and industrial process control

Priority must be given to upstream interventions in production processes, rather than end-of-pipe remediation. This includes:

- upstream pollution prevention in production processes
- safer chemical substitution
- strict process emission standards
- integration of best available techniques into production systems

Industrial processes must be designed and assessed based on their capacity to prevent pollution at source, rather than control it after release.

#### 1.2. Chemical Safety

Criticality must prioritise chemicals that are both low-carbon and safe. This requires a decisive shift away from hazardous substances - including through the Restriction Roadmap, particularly the most persistent and toxic ones, including PFAS-related substances and PVC precursors.

Regrettable substitution must be avoided, including poorly assessed alternatives that shift rather than reduce harm[12].

Full traceability across value chains is essential to ensure that substances of concern are identified and controlled throughout production, use, and end-of-life phases.

### 1.3. Reduce production volumes

A managed reduction in production volumes is necessary to align the sector with environmental limits and demand realities.

This includes:

- chemical simplification and reduced material intensity
- addressing structural overcapacity in European production
- shifting away from volume-driven business models

### 1.4. Emissions reduction

Decarbonisation must be a core criterion of criticality.

The chemical sector is one of the EU's largest industrial emitters, with emissions arising across feedstocks, production, and end-of-life treatment. A large share of its footprint is linked to fossil-based inputs and downstream combustion or incineration.

Criticality assessments should therefore prioritise:

- low-emission chemical pathways
- lifecycle emissions reduction potential
- alignment with EU decarbonisation trajectories
- avoidance of lock-in into fossil-based infrastructure

Chemicals that enable emissions reductions in other sectors (e.g. energy, buildings, mobility) should be prioritised, while those reinforcing high-emission systems should be phased out.

### 1.5. Circular and Resource-Efficient Production Systems

[12] EEA provides a concrete example of regrettable substitution with HCFCs being replaced by HFCs, which subsequently proved to be extremely potent greenhouse gases

A future-proof chemical industry must be based on reduced resource use and circular material flows.

Key priorities include:

- phase-out of fossil feedstocks (starting with naphtha)
- prioritisation of secondary over virgin materials
- strict recycling hierarchy: mechanical → physical → chemical (last resort)
- limits on chemical recycling, which must demonstrate clear environmental benefits

Chemical recycling should only be supported where verifiable environmental benefits can be demonstrated, and processes such as pyrolysis and gasification should not substitute upstream reduction, reuse, and mechanical recycling.

### 1.6. Biomass and alternative feedstocks

Biomass is a limited resource and cannot substitute fossil feedstocks at scale within planetary boundaries. Its use must therefore be strictly prioritised based on highest societal value.

Bio-based and recycled feedstocks are not inherently sustainable. Their use must be conditional on demonstrated reductions in climate, environmental, and health impacts across the full lifecycle.

## 2. Reduce consumption and demand

Criticality cannot be addressed on the supply side alone.

Policies must actively reduce demand for unnecessary chemical use through:

- sufficiency strategies
- reduction of overconsumption in downstream sectors
- redesign of high-impact value chains such as textiles and packaging
- promotion of alternative business models

Many sectors do not require additional chemical inputs but rather systemic redesign of production and consumption patterns.

## 3. Transform production

Innovation must support structural transformation of the chemical sector, not reinforce existing high-volume, fossil-based production models.

Public and private R&D funding should prioritise:

- high-value, specialised and safe chemical functions
- substitution of hazardous substances
- development of non-toxic and low-carbon production pathways
- scale-up of safe and sustainable alternatives

Innovation support should extend across the full chain (from research to commercialisation) but must be subject to strict environmental and social conditions. Public funding should de-risk transition technologies, not prolong unsustainable bulk production.

## 4. Deliver on Just Transition

This transition must be accompanied by a **just transition framework**, including:

- job-to-job transitions
- reskilling and regional support
- social partner involvement
- protection of workers' health, as they are directly exposed to hazardous substances

The transition is both a health imperative and an industrial opportunity.

## 5. Enforce social and environmental conditionalities

The sector has already received substantial historical public support, with the Clean Industrial Deal committing €100 billion in state aid to energy-intensive industries with no enforceable conditions attached. The case of ArcelorMittal[13], as well as the fact that major petrochemical companies directed over 75% of profits to shareholder payouts rather than transition investment, illustrates precisely why conditionality must be enforceable, not merely stated. We cannot afford another ArcelorMittal.

[13] ArcelorMittal received substantial pledged support under the Clean Industrial Deal yet announced redundancies and job relocations abroad.

Public support must be:

- conditional
- enforceable
- aligned with environmental and health objectives

Without strict conditionality, subsidies risk reinforcing fossil-based and high-emission production systems.

## 6. Ensure full coherence with the Green Deal

A sustainable criticality framework must be fully aligned with EU policy objectives, including the Green Deal, Clean Industrial Deal, Circular Economy Action Plan, Chemicals Strategy for Sustainability, and zero pollution ambition.

Substances, processes, or sites identified for phase-out under EU law cannot simultaneously be classified as “critical” for public support without creating incoherence. For example, defining PFAS precursors, highly toxic benzene, PVC or steam crackers as “critical” would directly contradict chemicals, product, and waste legislation, as these are substances and sites of concern for which phase-out is the priority.