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SOS-ZEROPOL2030

D2.2 Overview of the existing **governance landscape** and the constraints and best practices of current governance efforts to achieve zero pollution for the selected priority pollutants

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Executive Summary

Aim and Scope

The European Union's (EU) Zero Pollution Action Plan, adopted in May 2021, aims to drastically reduce pollution in air, water and soil. It in particular "sets out an integrated vision for 2050: a world where pollution is reduced to levels that are no longer harmful to human health and natural ecosystems, as well as the steps to get there". This report focuses on land-based sources of marine pollution. It explores policy developments across the entire value chain of contaminants (e.g., production, usage, end-of-life, and end-of-pipe) to achieve EU's zero pollution objective. The aim of this report is to:

Identify the best practices and constraints of current EU governance efforts to achieve zero pollution for four selected priority pollutant groups, namely underwater noise, chemicals, nutrients and microplastics.

To achieve the aim, the scope of the report is the in-depth study of the upstream governance arrangements that relate to two case contaminants of Tyre Wear Particles (TWPs) and Per- and Polyfluoroalkyl Substances (PFAS). The Zero Pollution Action Plan objective for microplastics, and thus also TWPs, is to reduce the release of microplastics into the environment by 30%. For PFAS, the Chemical Strategy for Sustainability outlines the EU's zero pollution objective, which is to phase out their use in the EU, unless deemed essential. The report focuses on land-based sources of emissions to the aquatic and marine environment, taking into account the production and use of PFAS and tyres.

Research Questions

This report uses the notion of governance arrangement to provide an overview of how the Zero Pollution Action Plan sets in motion policy changes within the governance of land-based emission sources of marine contaminants. A governance arrangement is defined as "the temporary stabilization of the content and organization of a particular policy domain at a certain policy level or over several policy levels" (Leroy & Arts, 2006, p. 13). The overview includes the identification of organizational elements of key actors, rules of the game and available power resources, and the content (discourses) within identified governance arrangements. Research questions answered in this report are:

1. Which governance arrangements exist or are emerging that – as a response to the Zero Pollution Action Plan – (will) govern TWP and PFAS generation and releases into EU waterways that ultimately reach the marine environment?
2. What are the best practices and constraints within existing and emerging governance arrangements for developing EU regulation to achieve the zero pollution objectives for TWPs and PFAS in EU's waterways and marine environment?

Overview of governance arrangements and their policy developments to achieve EU's zero pollution objectives for TWPs and PFAS

The following governance arrangements are emerging that govern the way in which tyres are produced, used and treated during their End-of-Life, as well as how TWPs and PFAS emissions are prevented from reaching EU waterways. For tyres and TWPs, these are 1) Production of Tyres, 2) Use and Abrasion of Tyres, 3) End-of-Life of Tyres, and 4) End-of-Pipe TWPs emissions (see chapters 4 and 5 for an overview). Within these four governance

arrangements, five policy developments are taking place that will change the EU governance landscape for zero pollution from TWPs (see chapter 6):

1. Euro 7 proposal to ban the most environmental harmful tyres
2. Eco-design for tyres to reduce TWP abrasion
3. Labelling of tyres to include a TWP abrasion rate
4. Infill ban to reduce secondary TWPs
5. Improved wastewater treatment to capture TWPs

For PFAS, one emerging governance arrangement was identified around the most prominent policy development of the REACH restriction proposal for PFAS, which addresses PFAS emissions from upstream sources (see chapters 7 to 9 for an overview):

6. REACH restriction proposal for PFAS

Best practices and constraints for achieving EU's zero pollution objectives

Based on the overview of the five governance arrangements, the report discusses best practices and constraints for further developing and implementing the six identified policy developments in chapters 6 and 9. Based on these best practices and constraints, chapter 10 concludes that the following best practices and constraints exist for achieving the zero pollution objectives for underwater noise, chemicals, nutrients and microplastics.

- **Best practice 1 Life cycle perspective to address contaminant emissions**: the Zero Pollution Action Plan is contributing to the development of a life cycle perspective to address all life cycle stages of products that contribute to generating marine pollution emissions.
- **Best practice 2 Source-based approach to achieve zero pollution**: by targeting production and use as sources of contaminants, pollution is prevented, rather than mitigated.

Constraints to achieve the zero pollution objective for marine pollution are:

- **Constraint 1 Increasing power of producing industry**: by targeting pollution at source, the role and power of the chemical industry and product manufacturers is increasing as they are lobbying and influencing the development of various preventive regulations through which they will be regulated.
- **Constraint 2 Dependencies between policies within different governance arrangements**: policy developments focusing on land-based sources of emissions take place in largely autonomous governance arrangements with the risk of contradictions or conflicts to emerge between EU regulations that addresses particular contaminants and product life cycle stages.
- **Constraint 3 Continued and legacy pollution**: the combination of continuation of pollution on the short term and legacy of pollution from the past, means that a source-based approach will only be a partial solution to the prevention of emissions. This means that the end-of-pipe and end-of-life governance arrangements will remain important to achieve further reduction of (legacy) pollution in the future.
- **Constraint 4 Policy-making based on lack of data:** for some contaminants, there is a lack of data and methodologies to determine emission sources, pathways and their associated levels of pollution and environmental impacts. In these cases, legislators rely on data that comes from the industry.

1 Introduction

1.1 EU ambition for zero pollution of European Seas

The European Union's (EU) comprehensive and ambitious policy and legislative framework governing the environmental protection of European seas[1] is acknowledged as one of the most advanced in the world, especially when it comes to reaching zero pollution (EEA report NO25/2018).

The Marine Strategy Framework Directive (Directive 2008/56/EC) and the Water Framework Directive (WFD, Directive 2000/60/EC) set European targets to protect transitional and coastal waters. Under both directives, Member States develop national strategies that are reviewed every six years to assess both the environmental status of waters and progress towards achieving a variety of targets, including for noise, microplastics, chemicals and nutrients.

Meanwhile, the **European Green Deal** is the EU's overarching strategy adopted in December 2019 which aims to make the EU the first climate-neutral continent. It is a sustainable growth strategy that covers all sectors of the economy. This stems from a response to the climate and environmental emergencies that humanity faces today and is therefore meant to facilitate the transition of the EU towards a climate-neutral continent and a modern, resource-efficient, and competitive economy by 2050.

The ongoing 2023 review of the Marine Strategy Framework Directive, combined with the European Green Deal and its focus on a zero environmental pollution agenda, provides an opportunity to address marine pollution in Europe in a holistic manner. Implementation of the Green Deal is done through a set of strategies and action plans, one of which is the Zero Pollution Action Plan. The **Zero Pollution Action Plan**, adopted in May 2021, aims to drastically reduce pollution in air, water and soil. It in particular "sets out an integrated vision for 2050: a world where pollution is reduced to levels that are no longer harmful to human health and natural ecosystems, as well as the steps to get there".

1.2 From Source to Seas –the SOS-ZEROPOL2030 Project

The overall aim of the Source to Seas - Zero Pollution 2030 (SOS-ZEROPOL2030) project is to develop a holistic zero-pollution framework that will guide the EU towards achieving zero pollution in European seas by 2030. Marine contamination and pollution[2] occur as a direct result of human activities on land and at sea. Despite existing regulations, marine pollution is still increasing. To address this increase in pollution, a transition is needed in the way in which the EU addresses and manages marine pollution; a transition that needs to address change in multiple dimensions (legal, social, economic, industrial, and environmental) and with all stakeholders (e.g., decision-makers, scientists, citizens, industry). In this context, SOS-ZEROPOL2030 aims to develop a holistic zero-pollution

[1] An overview of the relevant policy documents and strategies regarding environmental pollution of the EU's marine environment is presented in D2.1 'EU Zero Pollution Ambition' (Devriese et al., 2023)

[2] Not all contamination is pollution. In this report, we refer to pollution as emission of contaminants that are potentially harmful to human health and/or natural ecosystems. The EU ambition is thus to reduce the level of emissions of contanimants to levels that are no longer harmful to human health and natural ecosystem. It is an ambition for zero-pollution, not zero-contamination.

framework that will guide the EU towards achieving zero pollution in European seas by 2030. The project focuses on four priority pollutant groups: underwater noise, chemicals, nutrients and microplastics and two specific case study contaminants, i.e. Tyre Wear Particles (TWPs) and Per- and Polyfluoroalkyl Substances (PFAS[3]).

This report and Task 2.2 sit within WP2: *Building Blocks for Zero Pollution Governance,* which will provide an EU pollution governance analysis and survey of social perceptions in several EU countries. Work Package 2, including this report, in particular contributes to specific project objectives:

- To better understand the barriers that compromise successful marine pollution management and stakeholder participation in Europe to identify appropriate intervention points, measures and actions that can support a blue-green transition with a focus on human behaviour, socio-economics and governance.
- To capitalise upon best practices concerning the implementation of sustainable and effective measures that address marine pollution for priority pollution types in European Seas.

Within WP2, D2.1 describes in detail the environmental policy and stepping stones to accelerate environmental policy for the projects four different types of pollution and evaluates current European environmental targets (Devriese et al., 2023). D2.3 focuses on the development, delivery, and analysis of a standardised, quantitative survey tool to investigate public and stakeholder perceptions of the projects four different types of pollution, priorities and barriers.

D2.2 in this context is starting to link the two case study contaminants (PFAS & TWPs) to the project's priority pollutant groups. Our approach mirrors the projects' structure and utilises the case study contaminants to allow for further in-depth analyses of the contaminant life cycle with a focus on land-based sources of marine pollution.

This Deliverable reports on Task 2.2 with the aim to:

Identify the best practices and constraints of current EU governance efforts to achieve zero pollution for the project's four selected priority pollutants groups of underwater noise, chemicals, nutrients and microplastics.

D2.2 compliments the activities in D2.1 and D2.3 and specifically contributes to the following objectives of Work Package 2:

- To develop a robust assessment of the zero pollution topics and trajectories on the EU level, based on the current implementation of EU policies and legislation.
- To identify opportunities and best practices for improving the implementation of EU policies and legislation through a stocktaking assessment and stakeholder consultations

1.3 Policy changes in governing diffused source–to–sea pollution

The Green Deal and the Zero Pollution Action Plan mean that the governance landscape (e.g., the set of actors and institutions that regulate society) for marine pollution is changing. A particularly noticeable trend is how the EU is developing a parallel track of 1)

[3] In this report we use the acronym PFAS as a plural term ('PFA substances'), in line with the European Chemicals Agency's language. We thereby avoid the use of the double plural 'PFASs'.

updating and incorporating emerging[4] marine pollutants in existing environmental regulation for the EU's marine regions, and 2) efforts to reduce emissions from sources on land. While Task 2.1 and D2.1 focused on the first track, Task 2.2 and this report focuses on the second.

The parallel track of not only updating existing governance arrangements that govern the marine environment but also land-based sources of marine pollution has increased the complexity of the governance landscape of these contaminants. While targets to reduce pollution from contaminants in the marine environment are set, the relationship with land-based sources of contaminants makes it challenging to develop effective and preventive regulatory approaches to reduce marine pollution, as these require going upstream and therefore affect other policies and regulations. Regulatory approaches that govern marine pollution rarely stand on their own, but are interdependent with other policy domains, creating a polycentric governance landscape that consists of multiple interdependent governance arrangements that each focus on a particular issue area relevant to the reduction of marine pollution (Mahon & Fanning, 2019; Raakjaer et al., 2014).

This interdependency is reinforced by the adoption of the Green Deal, its underlying Zero Pollution Action Plan and associated efforts to develop new and update existing EU laws and regulations. Recent developments such as the proposal for a PFAS restriction, the microplastic initiative and the labelling requirements for tyre abrasion point to the fact that governance arrangements that govern marine contaminants are indeed expanding and changing. They include both environmental regulation and a focus on the life cycle of products and preventive banning of contaminants generated by land-based sources.

This report assesses how the European Green Deal and its focus on marine pollution is changing the governance landscape of addressing marine contaminants. It uses the policy arrangement approach that offers a framework to study the institutionalization of governance arrangements, i.e. the process leading to the formation, deformation and reformation of governance arrangements (Van Tatenhove et al., 2000). A key concept used within this approach is that of the governance arrangement, which refers to the temporary stabilisation of the organisation and substance of a policy domain within which actors take and implement decisions (Van Leeuwen, 2010). While a governance arrangement is temporarily stable, it can also be subject to change as a response to developments outside of existing governance arrangements or from changing interactions within a governance arrangement (Arts, Leroy, & Van Tatenhove, 2006; Van Leeuwen, 2010). This approach is further introduced in chapter 2 of this report.

1.4 Scope of the report

In order to achieve the aim of Task 2.2 we adopted a two-step approach towards defining the scope of the report to be the EU governance of land-based sources of TWPs and PFAS emissions to the aquatic and marine environment. First, given the extensive nature of the EU governance landscape for zero marine pollution, we focus on the project case study contaminants of Tyre Wear Particles (TWPs) and Per- and Polyfluoroalkyl Substances (PFAS - a group of chemicals widely used in industrial and consumer applications). Demarcating

[4] Sometimes also referred to as Pollutants of Emerging Concern (PEC), to reflect the pollution itself may not be new, but evidence of ecotoxicity has been underdeveloped and is not yet reflected in regulation (Sauvé & Desrosiers, 2014)

the scope of contaminants allows to explore in more detail how the Zero Pollution Action Plan, in combination with other strategies and action plans, is forming new and reforming existing governance arrangements for land-based sources of marine pollution. Second, for each case study contaminant of TWPs and PFAS, we in particular focused on sources of emissions to the aquatic and marine environment. We also focused on current policy developments that link to reducing emissions from land-based sources, taking into account the production and use of PFAS and tyres.

The starting point for identifying these policy developments is the EU strategy to tackle microplastics, including those from tyres, through its Plastics Strategy and Zero Pollution Action Plan[5]. The **EU Plastics Strategy**, launched in January 2018, outlines a set of actions and goals to transform the way plastics are produced, used, and disposed of within the EU. Key elements of the strategy as it relates to TWPs are an examination of policy options and information requirements for reducing unintentional release of TWPs from tyres, and methods to assess microplastic losses from tyres.

The **Zero Pollution Action Plan**, adopted in May 2021 aligns with the EU Plastics Strategy. It aims to drastically reduce pollution in air, water and soil. The 2030 target that relates to microplastics and TWPs is to improve water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%). In terms of microplastics, it particularly mentions sources such as tyre wear, synthetic textiles, and the breakdown of larger plastic items.

The EU Plastics Strategy and the Zero Pollution Action Plan are interconnected, with both aiming to improve the sustainability of plastics and mitigate their negative impacts. By incorporating measures to prevent the release of microplastics and promote circular economy principles, these initiatives work together to address the multifaceted challenges posed by microplastic pollution. To move away from the linear economy, known as; 'take, make, use, dispose', the EU has made enormous efforts to keep resources flowing within its economy through the EU's **Circular Economy Action Plan**, where the focus is on 'reuse, share, repair, and recycle' to create a closed-loop system. The new circular model would minimize the continuous use of resources and the creation of waste, pollution, and carbon emissions. Initial efforts have among others focused on setting standards for waste recovery and recycling, among others also for tyres. According to the European Tyre and Rubber Manufacturers Association (ETRMA) the Circular Economy begins at the design phase to ensure optimal performance and longevity of tyres.

To address the use of PFAS and the contamination that they cause to the environment and human health, the European Commission has outlined a set of actions, targets, and measures[6]. In addition to the Zero Pollution Action Plan, the **Chemical Strategy for Sustainability** sets the tone of actions on PFAS. The strategy was published in 2020 and aims to phase out the most harmful chemicals. For PFAS this has been translated in the more specific objective of phasing out the use of PFAS in the EU, unless their use is essential. The strategy together with its action plan highlights measures such as a ban of PFAS as a group from fire-fighting foams, allowing only the use of PFAS where they are proven to be essential for society. The strategy proposes addressing PFAS in relevant regulation in areas of water, sustainable products, food, industrial emissions and waste,

[5] Further information is available in D2.1. The Zero Pollution Ambition (Devriese et al., 2023).

[6] Further information is available in D2.1. The Zero Pollution Ambition (Devriese et al., 2023).

and includes a review of the annexes of the Environmental Quality Standards Directive and Groundwater Directive to include PFAS as a group (where possible). Other actions include financial support towards identifying methodologies to remediate PFAS contamination and funding for research on PFAS substitutes.

In order to identify relevant governance arrangements that address land-based emissions from TWPs and PFAS at source, the report focuses on the whole contaminant, not the chemical components separately. TWPs are generated as a result of mechanical abrasion during the interaction between tyres and road surfaces, resulting in the generation of small plastic particles. For the TWP case, road wear particles, as well as particulate matter are excluded from the scope. Furthermore, the TWP case study focuses on aquatic pollution, which includes EU waterways and the marine environment, see ***Figure 1***. Air and soil pollution are excluded, as the assumption is that TWPs enter the marine environment mainly via waterways. Other life cycle stages, such as pre-production, the use of raw materials, and the export of tyres (as waste) outside of the EU have also been excluded.

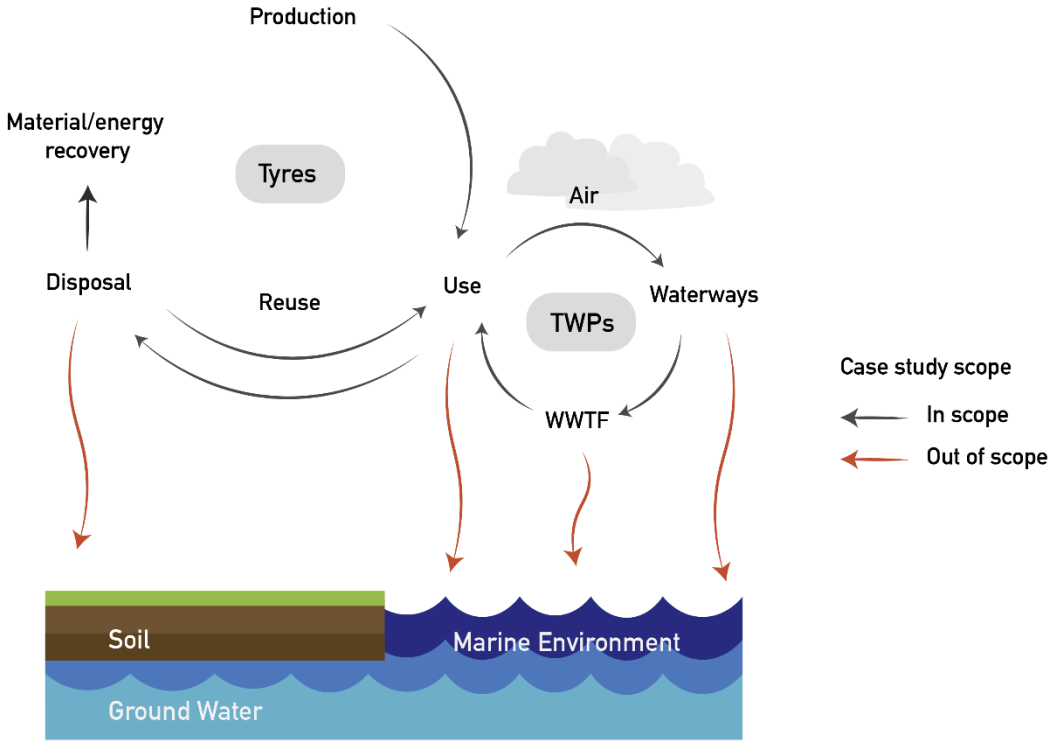

Figure 1 Life cycle stages of tyres and TWPs, showing scope of TWP case study

PFAS are a group of chemicals composed of fully (per) or partly (poly) fluorinated carbon chain connected to different functional groups (OECD, 2022). The governance landscape of PFAS in the EU is a complex patchwork of complementary policies, directives and regulations, covering different parts of the life cycle. We have chosen to focus on the most ambitious policy development, which is the universal restriction proposal on the manufacture, placing on the market and use of PFAS under EU regulation on the registration, evaluation, authorisation and restriction of chemicals (REACH). This would address PFAS pollution at the production stage while considering exceptions for certain applications. We exclude from our scope the ban on PFAS used in firefighting foam, as well as developments happening in other directives that address other life cycle stages (see Figure 2).

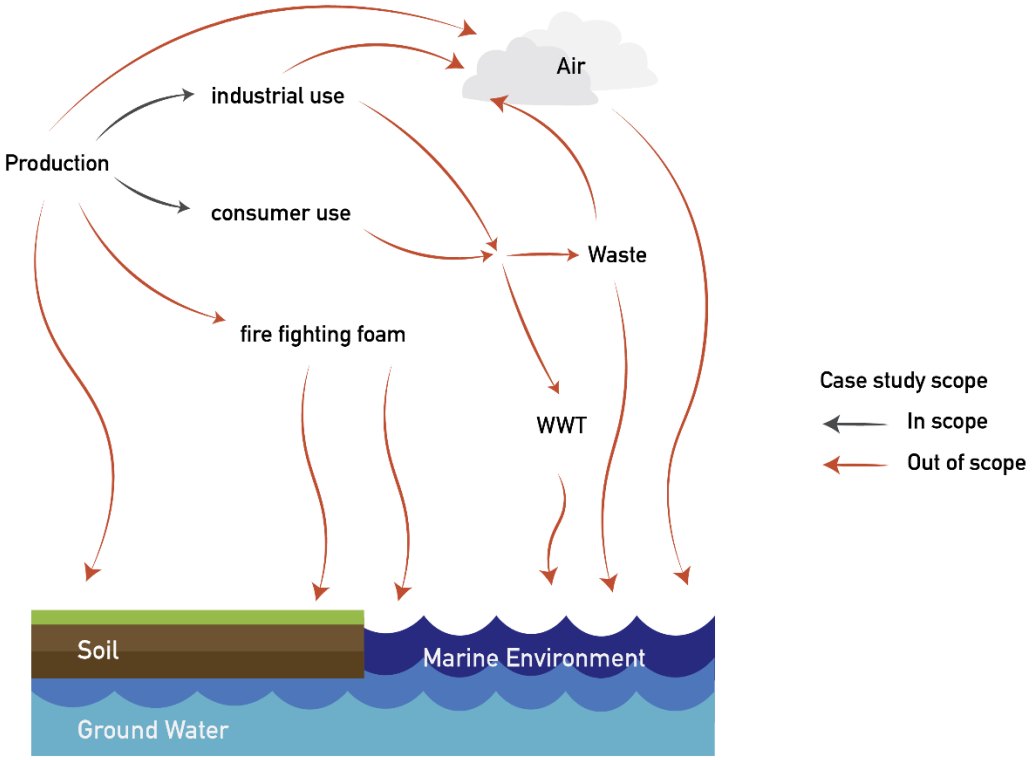

Figure 2 Life cycle stages of PFAS, showing scope of PFAS case study

1.5 Aim, research questions and outline

Within Work Package 2, Task 2.1 and D2.1 focused on environmental pollution governance, without delving into the measures across the entire life cycle of contaminants. Task 2.2 and this report (D2.2) focus on land-based sources of marine pollution. The aim of Task 2.2 is to:

Identify the best practices and constraints of current EU governance efforts to achieve zero pollution for the project's four selected priority pollutants groups of underwater noise, chemicals, nutrients and microplastics.

To achieve this aim, Task 2.2 examines how the Green Deal, in particular the Zero Pollution Action Plan, sets in motion policy changes to govern the emission sources of TWPs and PFAS. It will, in part 1 and 2, use the policy arrangement approach to identify the governance arrangements through which current initiatives to reduce TWPs and PFAS respectively are formulated, decided upon, and implemented. The analysis includes the identification of key actors and discourses within the EU policy making process, as well as power resources and relations within each governance arrangement. It also examines how governance arrangements are linked to each other, something that is especially relevant for the TWP case, where efforts focus on changing different stages of the life cycle of tyres, i.e., the production, use and end-of-life, to reduce TWP emissions. Part 1 and 2 end with exploring how recent policy developments to reduce TWP and PFAS emissions within these governance arrangements represent best practices as well as are bound by constraints in achieveing the EU zero pollution ambition for TWPs and PFAS. The following two research questions are answered in Part 1 and 2 of this report:

1. *Which governance arrangements exist or are emerging that – as a response to the Zero Pollution Action Plan – (will) govern TWP and PFAS generation and releases into EU waterways that ultimately reach the marine environment?*
2. *What are the best practices and constraints within existing and emerging governance arrangements for developing EU regulation to achieve the zero pollution* objectives *for TWPs and PFAS in EU's waterways and marine environment?*

Based on the answers to these research questions presented in Part 1 for TWPs and Part 2 for PFAS, the final concluding chapter (chapter 10) identifies best practices and constraints of current governance efforts at the EU level to achieve zero pollution for the project's four selected priority pollutants groups of underwater noise, chemicals, nutrients and microplastics.

Before Part 1, however, chapter 2 will introduce the policy arrangement approach which offers an analytical framework to identify governance arrangements, the interdependency between them as well as processes of policy and/or institutional change. Chapter 3 explains the methodology used to collect and analyse the data for the two case studies of TWPs and PFAS.

2 Theoretical Approach: Polycentric governance and institutional change

The growing fragmentation of institutions and policy initiatives in (global) environmental governance has been extensively explored (Biermann et al., 2009; Visseren-Hamakers, 2015; Zelli & van Asselt, 2013). According to Ostrom (2010), global governance is characterized by multiple interdependent centres of authority that are formally independent of each other. The term polycentric refers to multiple centres of decision-making or governance arrangements, which are formally independent of each other, but function in a coherent manner and with consistent and predictable patterns of interacting behaviour.

Indeed, the sustainability governance of European seas is hampered by a patchwork of conflicting, sectoral policies and a diversity of governing institutions with their own rules and policies (Soma et al., 2015; Van Hoof et al., 2012; Van Leeuwen et al., 2014). This for example also goes for plastic pollution, which is increasingly regulated through a variety of governance arrangements at various levels of governance (Van Leeuwen et al., 2022; Vince & Hardesty, 2018). In order to understand how the European Green Deal might improve regulatory responses to pollution, one needs to be able to identify how the European Green Deal affects different governance arrangements individually and collectively.

2.1 Policy arrangement approach

Continuity and change in environmental and marine governance both result partly from strategic innovations and partly from more comprehensive social transformation processes (Arts, Leroy, & Van Tatenhove, 2006). The policy arrangements approach was developed to assist in understanding the dynamic between stability and change in environmental governance (Van Tatenhove et al., 2000). The policy arrangement approach is, therefore, a theory of institutionalization: “institutions, no matter how stable they appear at first sight, are subject to continual change and adjustment, deconstruction, and reconstruction (Arts, Leroy, & van Tatenhove, 2006, p. 96). The main aim of the policy arrangement approach is to understand and analyse the on-going institutionalisation of governance arrangements, which is the result of the interplay between the interactions of actors participating in putting policy into practice daily on the one hand, and processes of social and political change (political modernisation) on the other hand (Arts, Leroy, & van Tatenhove, 2006). Institutionalization leads to the formation, deformation and reformation of governance arrangements (Van Tatenhove et al., 2000).

A governance arrangement is defined as “the temporary stabilization of the content and organization of a particular policy domain at a certain policy level or over several policy levels” (Leroy & Arts, 2006, p. 13). The organization and content of a governance arrangement determine how actors develop and implement policies and regulations to govern a certain policy domain. A policy domain refers to the issue area for which a group of actors interact in a relatively stable institutional setting to develop and implement policies and regulations. Stability in the organization and substance of a governance arrangement is based on the actors involved, rules-of-the-game that guide actors' behaviour and expectations, power resources and relations between actors, and discourses that specify the different interpretation schemes that frame actors' preferences (Arts et al., 2000; Van Hoof et al., 2012; Van Leeuwen, 2010; Van Tatenhove, 2022). How

these dimensions are defined is presented in Table 1. Table 1 also shows a more detailed set of potential power asymmetries and manifestations that we have used to assess the power of different actors. The more of these resources and manifestations of power an actor uses, the more powerful its position is vis-à-vis other actors in a governance arrangement.

Table 1 Definitions of the dimensions of a governance arrangement

Arrangement dimensions	Definition
Policy Domain	An issue area for which a configuration of actors interact to develop and implement policies and regulation
Rules of the Game	The institutional setting of policy making and implementation; those norms and rules that define the expectation of behaviour during policy making and implementation
Actors	Any organization involved in or affected by policy-making and implementation
Discourses	Expressed ideas about the issue area's problem definition, its causes and possible solutions
Power & Resources	Resource asymmetries and manifestation of power through: Formal positions in decision making and implementation processes (as defined by the rules of the game) Lobbying and access to actors in formal positions in decision making and implementation processes Knowledge asymmetry between actors Financial resources asymmetry between actors Ability to enter into litigation of actors Being included in multiple governance arrangements that span linked issue areas at the same time

2.2 Institutional change and integration of governance arrangements

A change to a governance arrangement can be unintended or a deliberate intervention, either from an actor within a governance arrangement or from external changes of other (actors within) governance arrangements. Changes in governance arrangements can begin in any of the dimensions, for example, the appearance of new actors or a change in the composition of coalitions, the discourses that actors express, the rules of the game or availability of power resources (Arts, Leroy, & van Tatenhove, 2006; Liefferink, 2006; Van Leeuwen, 2010). Such a change in one dimension can trigger a chain of reactions in the other dimensions, leading to the renewal of the governance arrangement. This report is particularly interested in how the EU Green Deal's Zero Pollution Action Plan sets in motion policy developments that will lead to new governance arrangements or change existing ones.

Polycentric (or nested) governance more specifically emerges through a process of integration between dimensions of various governance arrangements. In a fragmented setting, governance arrangements will co-exist side by side (Soma et al., 2015). In such cases, sectoral polices and goals are being developed separately from developments in other policy domains (e.g., shipping versus fisheries). Moreover, stakeholder representation is sectoral organised instead of representation to reflect also those policy domains that are indirectly affected by a governance arrangement. In such cases, no integration between governance arrangements exists.

Integration is frequently understood in terms of connection and coordination of activities and policies, as well as organization and stakeholders (Lockwood et al., 2010 cited in Soma et al., 2015). Institutional integration might result from overlap due to shared or competing substantive problems or from deliberate actions of actors to align and create overlap between governance arrangements (Raakjaer et al., 2014; Young, 2002). In particular, shared or contested knowledge, discourses, commitments, and expected changes in behaviour and (environmental) objectives cause such interplay between governance arrangements to emerge (Gehring & Oberthür, 2009; Raakjaer et al., 2014; Van Leeuwen & Kern, 2013).

Integration of governance arrangements means that policies and objectives of different policy domains become interlinked. For example, to meet the objectives of sustainable development and Ecosystem-Based Management, economic, social and ecological objectives of different sectoral marine policy domains are becoming more coordinated (Raakjaer et al., 2014). Stakeholder representation could also become organised around integrated objectives and measures, which would mean overlap in the actor and power dimension would exist. This could in turn imply that discourses overlap and become shared across multiple governance arrangements.

3 Methodology

3.1 Case study research design

A case study approach was chosen as the most suitable research design for Task 2.2. Two cases are analysed more in-depth in this report: the governance of land-based sources of TWP and PFAS emissions. The selected cases on TWPs and PFAS allow for an in-depth analysis of a real-life phenomenon and give insights into why and how governance practices change, or governance arrangements shift and interact. As such, this case study is exploratory in nature (Yin, 2009).

3.2 Data collection methods

Two data collection methods were used in our explorative case study: document analysis and literature review, and semi-structured interviews.

Document analysis and literature review

For the TWP case, four governance arrangements around the life cycle of a tyre and associated emissions of TWPs were identified: (1) production, (2) use (abrasion), (3) end-of-life (tyre as waste), (4) end-of-pipe (TWPs in water). For the PFAS case, a single governance arrangement was considered, i.e. the proposal of a universal restriction on the manufacture, placing on the market and use of PFAS under the EU REACH regulation.

As a basis to identify the governance arrangements, relevant EU policies and governance issues related to TWPs and PFAS were identified based on a literature review and life cycle approach.

A desktop study was performed to identify relevant documents for further analysis around EU governance arrangements for TWPs and PFAS. The documents consist of legal and policy documents (EU directives, action plans, strategies), peer-reviewed articles, media coverage, blog posts, EU websites, public consultations, studies, assessments and reports between 2018 and 2023. For EU legislation, the main data source was EUR-Lex, as well as the websites of relevant European institutions.

In-depth semi-structured interviews

The semi-structured interviews were conducted based on a topic list (Annex 12.3) that was developed around the four dimensions of the identified governance arrangements including rules of the game, actors, discourses and power relations (Fereday & Muir-Cochrane, 2006).

For the TWP case, the interviewees were selected based on their expertise in one or more of the identified governance arrangements and life cycle stages. As such, nine representants from the tyre and recycling industry, environmental non-governmental organisations (NGOs) and European Commission Directorate-Generals were interviewed covering the whole life cycle of TWPs (Annex 12.2).

For PFAS, nine interviewees were selected based on their knowledge of the universal restriction process under REACH and the underlying challenges for chemical regulation. Representatives of the chemicals and plastics industry, EU policy makers, dossier submitters, NGOs and investigative journalists have been interviewed (Annex 12.2).

3.3 Data analysis

Qualitative data analysis methods were applied, including manual coding to identify key concepts, their interrelationships, and themes (Fereday & Muir-Cochrane, 2006). The audio-recorded and transcribed interviews were manually coded in a spreadsheet. The codes were developed based on the topic list and dimensions of the identified governance arrangements. This allows for comparison between the responses from the different interviewees on the same governance arrangement and life cycle stage. In an additional step, a thematic analysis based on the codes was applied to identify emerging themes, best practices and constraints, as well as linkages. The data analysis was a team effort, in which various researchers reflected and discussed preliminary findings, the coding process and the relevant steps in the analysis.

For both case study contaminants, TWPs and PFAS, during the analysis, different research strategies can be distinguished:

The analysis started with a focus on the existing governance landscape that relates to the reduction and prevention of pollution from the case study contaminants. A key objective was to determine the main policy domains and how emissions and pathways of the contaminants are governed. Policy domains were determined based on identifying the rules of the game, actors, discourses, and power manifestations involved in governing contaminants during different life cycle stages.

The different life cycle stages were followed by an analysis of the identified and selected governance arrangements, defining how actors interact within identified governance arrangements. The selection was based on the life cycle perspective and the anticipated relevance for achieving zero marine pollution. For each case, governance arrangements were analysed along the dimensions of rules of the game, actors, discourses, and power relations.

Thereafter it became possible to focus on the best practices and constraints for achieving zero marine pollution. This included policy developments that should be considered when further developing measures and adapting governance arrangements to achieve zero pollution from TWPs and PFAS. These were identified by analysing how the dynamics between the arrangement's dimenions enabled and constrained achieving zero marine pollution both on the level of the individual governance arrangements and among their interaction, revealing gaps, dominant power dynamics or discourses.

During the analysis an iterative approach was taken including a literature review, semi-structured interviews and data analysis processes, which have been reflected and discussed among a research team from different institutes and with varying disciplinary backgrounds to guide the research and ensure methodological triangulation. The combination of analysing literature, documents and interviews filled in the gaps in terms of life cycle stages and governance arrangements. Weekly (online) meetings and a two-day team workshop (May 2022 in Wageningen) formed the basis for identifying and analysing the life cycle themes, the scope and the gap analysis. A consortium workshop (October 2022 in Potsdam) has been extremely helpful in confirming identified best practices and constraints.

3.4 Ethics

Ethical approval for the research was provided and approved by the Norwegian Agency for Shared Services in Education and Research (SIKT). During task 2.2, each research activity was carried out by an experienced team of researchers from different institutions. The expert interviews were conducted in pairs and the scope of the project was made explicit to the interviewees. The autonomy of the interviewees in the project has been respected. This includes: 1) providing interviewees with sufficient information to make an informed decision as to whether to take part in the SOS-ZEROPOL2030 project (informed consent); 2) ensuring that interviewees are not subject to coercion to take part in SOS-ZEROPOL2030; 3) ensuring that interviewees are aware that they are free to withdraw from being interviewed at any time without giving reason; 4) protecting and respecting personal data provided by interviewees through appropriate procedures for confidentially and anonymity. Furthermore, the guidelines provided by the Economic and Social Research Council Framework for Research Ethics were followed throughout the course of the deliverable.

PART 1 Best practices and constraints in polycentric governance of Tyre Wear Particles

To navigate the complex governance landscape of TWPs in part 1, we explore EU governance arrangements as they relate to the various life cycle stages of tyres. By utilizing and narrowing the life cycle into four distinct stages we aim to better understand the complexities of policies, actors and TWP governance. After an overview of the life cycle stages provided in chapter 4, we begin the governance arrangements overview in chapter 5 at the production phase where tyres are designed and manufactured. We then move to the governance arrangement for use and abrasion delving into the dynamics of road transportation and the implications it may have. Finally, we examine both the end-of-life (disposal and reuse) as well as end-of-pipe (mitigation of TWPs) governance arrangements. The analysis of the four governance arrangements will lead to identifying best practices and constraints to achieve the zero pollution objective for TWPs in chapter 6, where five policy developments are assessed that will implement the Zero Pollution Action Plan and that will change the governance landscape for TWPs in the future.

4 Life cycle stages relating to TWPs

Within the theoretical backdrop of this report, a targeted analysis of the life cycle is relevant. A life cycle consists of the various stages of a product from raw material extraction to end-of-life disposal and aims to provide insights on potential environmental implications and potential prevention and mitigation strategies along the way. Pollution from tyre emissions (TWPs) are affected by several stages of the tyre life cycle. TWPs therefore require a deeper analysis of policy and governance domains including mitigation measures at each stage of a tyre's life cycle. The following four stages are detailed further in this chapter Production, Use, End-of-Life and End-of-Pipe (see Figure 3).

The **production** stage entails the design and manufacturing of tyres using complex chemical substances and an energy-intensive industrial process. This stage contributes to greenhouse gas emissions, energy consumption, and water usage. Additionally, the release of plastic particles during the production process can directly contribute to the microplastic distribution in the environment.

In 2020, 4,2 million tonnes of tyres were produced, 16 per cent less than in 2019 (ETRMA, 2021b). More than 200 raw materials can be used for tyre production, among which natural and synthetic rubber are the main raw materials (Trudsø et al., 2022). In addition, a tyre consists of chemicals, such as trace metals, oils, fillers, sulphur, resins, anti-aging agents and vulcanization accelerators, as well as textiles, such as viscose, nylon, aramid and polyester fibres (ibid.; Katarzyna et al., 2020).

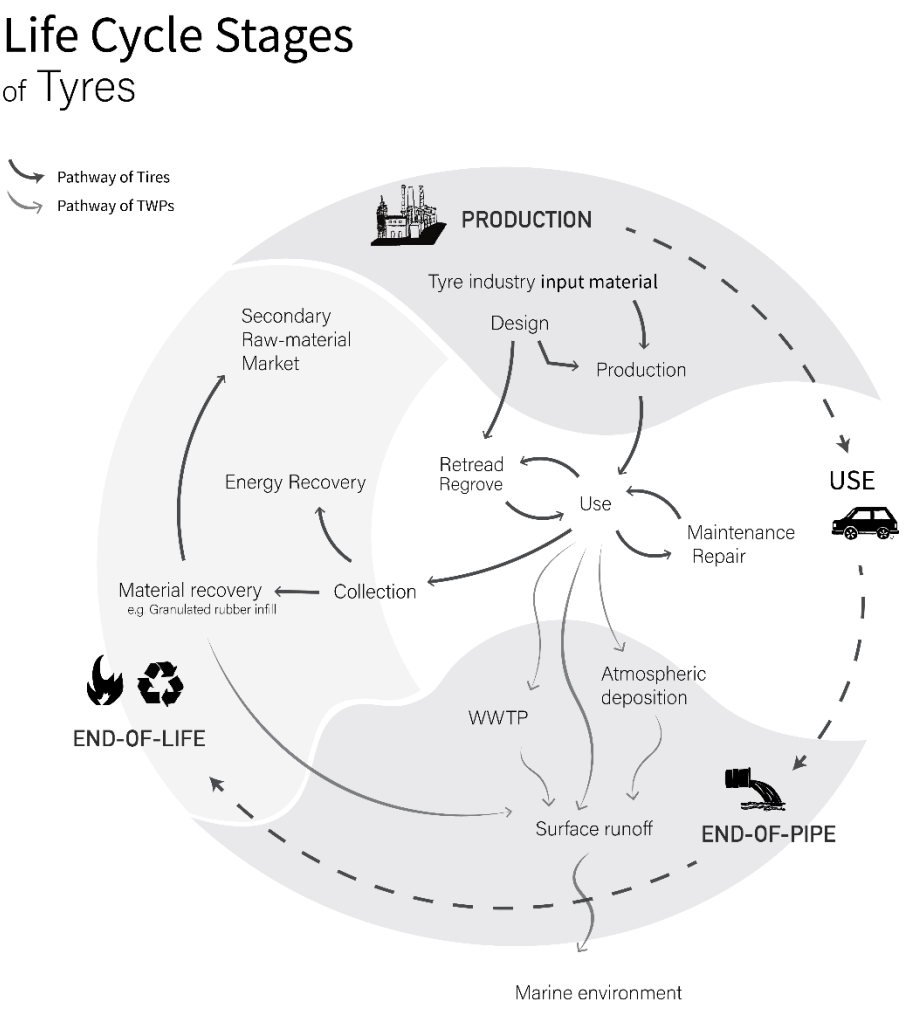

Figure 3 Life cycle stages for tyres and TWP emission sources

The **use/abrasion** stage involves the interaction between tyres and road surfaces, resulting in the generation of plastic TWPs through mechanical abrasion. Tyres break down into particles that are primarily deposited on roads or paths (Knight et al., 2020). These particles are subsequently released into the environment, affecting air and water quality and even enter the food chain (Halsband et al., 2020). TWPs in the environment are estimated to be one of the most abundant types of microplastic, with global emissions estimated to be 6.15×10^6 tons based on a population of 7.59 billion people (Luo et al., 2021). With the increased use of electric vehicles, TWP emissions could further increase in the future as electric vehicles are heavier and are able to accelerate to higher speed quicker than conventional fuel cars (Timmers & Achten, 2016). The fate of TWPs released during abrasion on road surfaces can follow many paths, ultimately leading to microplastic contamination in the terrestrial or marine environment (Baensch-Baltruschat et al., 2020).

The **end-of-life** stage involves the collection of disposed tyres, and their material recycling or energy recovery (see Figure 3). Improper disposal practices such as landfilling can lead to the dispersion of plastic particles into the environment, perpetuating the microplastic pollution problem. Following the prohibition of end-of-life tyre (ELT) landfilling, it is estimated that 95% of all ELTs are now collected, the remaining 5% is unknown or kept in stocks. ETRMA, representing nearly 4.400 companies in the EU, estimates that 40% of ELT are used in energy recovery, mainly in coal plants and cement kilns, while 52% of ELT are used in recycling. Within the recycling category, 70% consists of infill of granulated rubber, and 25% consists of inorganic content use for cement manufacturing. The remaining 5% consists of pyrolysis and steel recycling (ETRMA, 2021a). The granulated rubber infill in synthetic sports pitches and playgrounds are an important secondary source of microplastic and chemical pollution, which is why it is being phased out under REACH regulations on intentionally added microplastics. Sustainable material recycling methods are essential to minimize negative impacts on human health and the environment in the end-of-life stage of the life cycle of tyres.

Finally, the **end-of-pipe** stage includes wastewater, stormwater, and road runoff management and treatment, to retain the emitted microplastics before these reach water bodies (OECD, 2021). Abrased TWPs are washed away from the road surfaces through rain or flood events, which can flow into urban wastewater facilities, or directly into streams, rivers, and lakes (Knight et al., 2020). Alternatively, TWPs flow from the roads and infiltrate the soil, thus entering the groundwater systems (Gieré & Dietze, 2023). Depending on the region, the majority of TWPs that are washed from road surfaces within municipal regions will be treated in wastewater treatment facilities, where most microplastic particles will be removed before the effluent is released into the environment (Dey et al., 2021; Luo et al., 2021). This will occur through physical or chemical treatment, where the majority of microplastics will become trapped in sewage sludge (Tang & Hadibarata, 2021).

Sewage sludge can then be used for agricultural purposes, incinerated, or sent to landfill (Cydzik-Kwiatkowska et al., 2022). In the case of sewage sludge being used for agricultural purposes, there are concerns that this could lead to the leaching of microplastics into soil, water, and food crops, and may also contribute to the build-up of microplastics in the environment (Gieré & Dietze, 2023). When sewage sludge is sent to landfill or incinerated, it may enter the environment through bottom ash or leachates (Silva et al., 2021). Lastly, TWPs deposited on roads can enter the atmosphere through air or wind turbulence, which can impact air quality within a region or across borders, finally depositing in the ocean or many miles from its original location (Sommer et al., 2018). Ultimately, TWPs take multiple paths once released into the environment. However, the focus in this report will be on preventing the release of microplastics from entering the marine environment through waterway infrastructure, such as through road runoff or wastewater treatment facilities, and will therefore only indirectly include considerations about regulation associated with TWPs entering groundwater, sewage sludge or the air.

5 Polycentric EU governance arrangements addressing TWPs

Existing EU governance arrangements for the life cycle stages of production, use, end-of-life and end-of-pipe are shaped by power relations, between multiple governance actors, and discourses in relation to the prevention and reduction of TWPs. The emission of TWPs is closely linked to the production, use, end-of-life, and end-of-pipe stages along the tyre life cycle, as TWPs are emitted during vehicle use through the friction occurring between tyres and the road surface (OECD, 2021; Tonegawa & Sasaki, 2021).

In this chapter, the main objectives and measures (rule of the game), actors, discourses and power dynamics of the governance arrangements for production, use, end-of-life, and end-of-pipe stages of tyres and TWPs are analysed. This chapter therefore answers the first research question: **Which governance arrangements exist or are emerging that – as response to the Zero Pollution Action Plan - (will) govern TWP generation and release into EU waterways that ultimately reach the marine environment?** Before diving into the analysis of the four governance arrangements, the key highlights of TWP governance across these governance arrangements are presented.

5.1 Key TWP governance highlights

The analysis of the EU governance arrangements along the four life cycle stages of TWP demonstrate how the rules of the game, actor networks, discourses and power relations are rapidly changing. The dynamics regarding the rules of the game are summarised in Figure 4, covering the main ongoing EU policy developments on the governance of TWP emissions. These are further explored in chapter 6 with regards to constraining and best practices for their development and implementation.

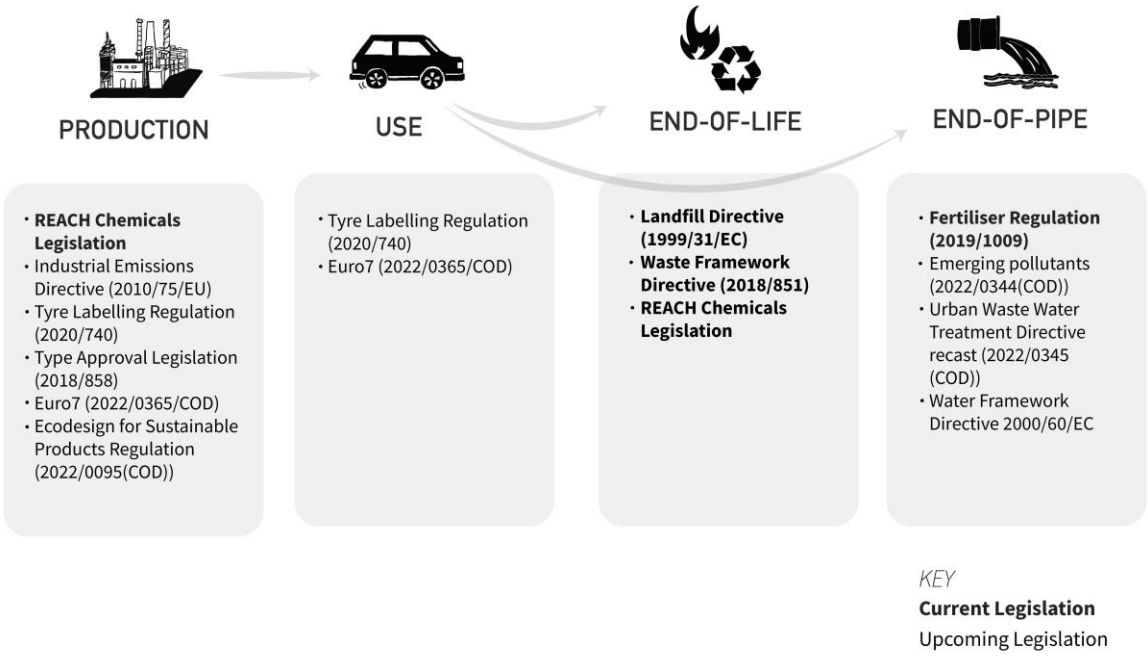

Figure 4 Current and upcoming EU legislation for tyres and TWPs

The discourse analysis influencing policy developments across the life cycle stages is summarised in Figure 5. It shows how the Tyre Labelling Regulation is a shared interest between regulators and the tyre and rubber industry, but the extent of the potential gains from this regulation is being questioned by NGOs. There is a common discourse around eco-design, which is particularly favoured by the NGOs, the recycling industry and high-level EU ambitions, but this discourse is challenged by the tyre producer industry. Producers argue for an approach in which other factors beyond tyre design such as road design are considered and highlight the trade-offs in e.g. safety from changing tyre design to reduce particle emissions. The intricate link between TWPs and toxic chemicals is similarly brought forward by the end-of-life actors and NGOs, but largely avoided by regulators and the tyre and rubber producers.

The actors shaping and influencing the governance of TWPs in the EU vary across the life cycle stages of tyres. We compared the power and influence of actors across the life cycle stages in relation to the identified policy developments for the emerging governance arrangements of TWPs (Table 2). These are based on the extent to which a stakeholder has a formal position in the regulatory processes; access to decision-makers through lobbying; access to knowledge and monitoring resources; financial resources; and presence in multiple governance arrangements. This qualitative, comparative assessment is visualised in the colouring (darker colour means higher power), with the more powerful actors listed at the top of the table.

Table 2 Power of actors involved in governing TWPs

Actor (power hierarchy)	Formal position in regulatory processes	Lobby and access to decision-makers	Knowledge and monitoring resources	Financial resources	Involvement in multiple Gov. Arrangements
Rubber, Tyre and Car producing industry					
EU institutions		n/a			
Member State institutions		n/a			
ENGOs/civil society					
Recycling industry					
Research institutions and startups					
Wastewater treatment facilities					

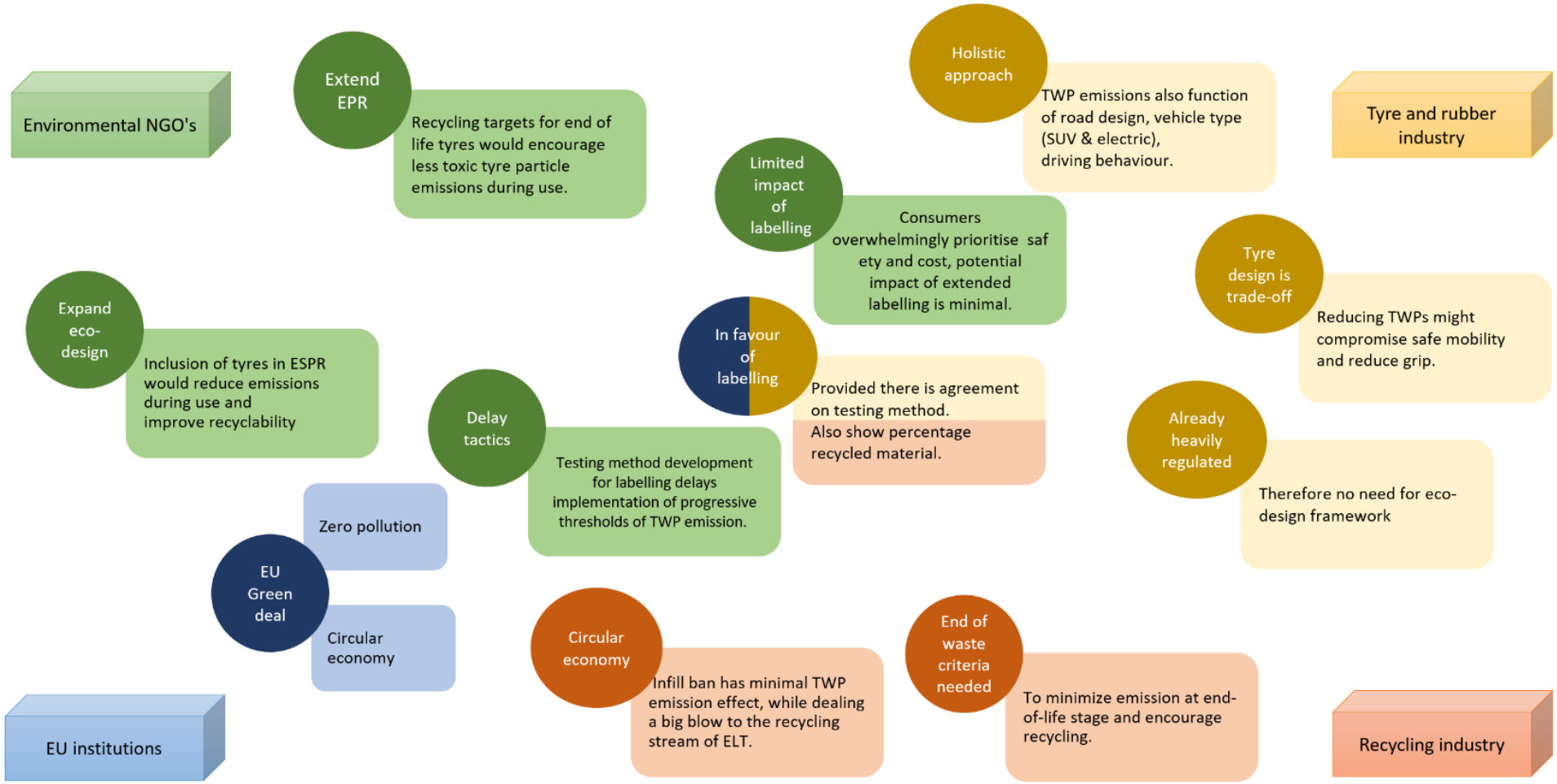

Figure 5 Summary of discourses around the governance of tyres and TWPs

5.2 Stage I: EU governance arrangements for tyre production

Although TWPs are emitted during tyre use, the design, composition and manufacturing of tyres have relevant implications for the abrasion rate during the use stage (OECD, 2021). For example, the design of a wider tread could reduce the generation of TWPs due to less abrasion (Klüppel, 2014; Pohrt, 2019). Policy interventions at source therefore also include sustainable design and manufacturing process of tyres to prevent or reduce TWP emissions resulting from abrasion (OECD, 2021). Table 3 provides a summary of the four dimensions (rules of the game, actors, discourses and power) of the governance arrangement for tyre production.

Table 3 Production stage - Summary of governance Arrangement dimensions

Production	
Rules of the game	Currently no specific regulation on TWP emissions exists
	Industrial Emission Directive and REACH apply to tyre composition, manufacturing and design which are inherently linked to TWP emissions
	Tyre Labelling Regulation, Type Approval Legislation and 2018 Plastic Strategy indirectly affect tyre design and as such TWPs
	Upcoming Microplastic Initiative and Euro 7 regulation cover TWPs
	Standards from standardization Organisations (UNECE, ETRTO, ISO)
Actors	The European Commission (DG Energy, DG ENV, DG MOVE)
	The tyre (ETRMA, ETRTO) and automotive industry (ACEA, EUCAR)
	Environmental NGOs and civil society organisations
Discourses	Different approaches on the role of tyre design, eco design and other policy interventions along the life cycle stages
	Chemical composition of the tyre and tyre design need to be improved in order to meet the future mileage and abrasion rates
	Each change in design has implications for other characteristics, such as driving safety that have to be considered in the tyre design
	Scope of the new Eco-design for Sustainable Products Regulation based on the eco-design directive to include tyres in the future is debated
	The Tyre Labelling Regulation and education of the consumer are essential to ensure a better product on the market
Power relations	The tyre and automotive industry are very involved and influential at EU level processes related to TWPs, in particular through tyre composition and design
	Environmental NGOs and civil society organisations are actively engaged in the consultation processes of the European Commission, such as the Microplastic Initiative and exchange with the industry
	EU Commission and Member states hold important tools and resources for incentivising the use of energy-efficient and safe tyres

5.2.1 Rules of the game

Currently, no regulation at the EU level specifically applies to TWPs or limits TWP emissions. However, different policies and regulations directly or indirectly apply to the relevant aspects of the production stage around TWPs. This includes, as further outlined below, the raw materials used, the composition, and design and labelling of tyres.

For tyre composition, the Industrial Emission Directive (European Commission, 2010) establishes rules on emissions from industrial activities to prevent or reduce pollution from industrial installations. This includes the production of synthetic rubber, listed in Annex I of the Industrial Emission Directive (ibid; Trudsø et al., 2022). As such, the Industrial Emission Directive is of relevance to the tyre composition, since a tyre consists of mostly natural rubber, petroleum-based synthetic rubber, carbon black, fillers, and other materials, such as accelerators (Alsaleh & Sattler, 2014; Katarzyna et al., 2020).

In relation to tyre manufacturing, the European Chemical Regulation REACH establishes obligations to provide information and register substances used in the tyre manufacturing processes (Art. 10 European Commission, 2006). REACH applies to substances used in tyres, as well as to the tyre product itself (ibid.). This is of relevance to tyre manufacturers and suppliers, as they must register the product and provide information, including physicochemical, ecological and toxicological data, as well as information on the product use, potential exposure to human health or the environment, classification, labelling, and safe use for each application (Art. 10a European Commission, 2006; Trudsø et al., 2022).

As per the 2018 Plastics Strategy, Member States must create incentives for the use of energy-efficient and safe tyres (European Commission, 2018). It must be noted that these policies apply to polymer particles, not polycyclic aromatic hydrocarbons (PAHs), which are subject to Directive 2005/69/EC on marketing and use of PAHs in extender oils and the production of tyres, as well as Directive 2004/107/EC on air emissions including PAHs to not exceed the amount of PAHs in ambient air. As such, these regulations apply to a different group of chemicals and are thus outside the scope of this research, which is focused on TWPs.

Different regulations indirectly addressing TWPs through tyre design exist. For instance, the Type Approval Legislation (European Commission, 2022f; UNECE, 2008a, 2008b) sets minimum requirements for tyres to be placed on the market (ibid.; Interview DG Energy, June 2023). These requirements are set by the United Nations Economic Commission for Europe (UNECE) Working Group and once approved, the European Commission endorses the same regulations to be applied in all Member States (Interview DG Environment, June 2023). This is in line with the overarching 2018 Plastic Strategy, which lists the introduction of minimum requirements for tyre design through an EU-wide tyre standard as a policy option to prevent or reduce tyre abrasion (European Commission, 2018).

Regarding the Type Approval Legislation, a novel development at EU level concerns the upcoming Euro 7 regulation, which will be the first regulation directly addressing non-exhaust emissions from brakes and tyres on the road (European Commission, 2022f). The in November 2022 presented Commission proposal includes requirements to regulate emissions from brakes and tyres and will be the first worldwide emissions standard to set limits on microplastic emissions for all vehicles, including electric vehicles (European Commission, 2022e). As such, the regulation will be an important instrument for the reduction of TWPs under the objective of introducing an emission standard by 2025, excluding the worst performing tyres from the market (Interview Michelin, June 2023).

The 2020 Tyre Labelling Regulation (European Commission, 2020c), repealing Regulation (EC) No 1222/2009, requires the labelling of tyres based on the following parameters: rolling resistance, wet grip, external rolling noise, as well as snow and ice grip (European Commission, 2020c). The labelling of tyres based on these parameters allows consumers to make an informed decision upon purchase. It also introduces thresholds for these parameters (Interview Michelin, June 2023). As such, different characteristics must be considered in the development phase of the tyre, as well as a certain compromise between abrasion, noise behaviour, driving performance and driving safety (Interview Audi AG, June 2023). The Tyre Labelling Regulation also establishes provisions for retailers to guide customers upon purchase based on the labelling scheme. Furthermore, the European Commission is planning to develop an environmental indicator, including tyre abrasion and mileage for a new tyre label, once reliable testing and measuring methods are available (Interview DG Energy, June 2023; European Commission, 2020b). This is also reflected at the international level in United Nations Regulation 117 and for brake particles in Global Technical Regulation 24, which might provide guidance (Interview Audi AG, June 2023). Furthermore, the labelling of tyres is presented as a policy option to provide more information for consumers on the tyre product in the 2018 Plastic Strategy (European Commission, 2022d).

All of these policy developments are included in the upcoming microplastics initiative, which focuses on the unintentional release of microplastics, such as from tyres, and seeks to develop an integrated approach for TWPs, including eco-design requirements, labelling and standardisation measures, as well as methods for measuring the release of microplastics from tyres. The initiative will be developed in coordination with the development of the EU strategy for sustainable textile design and manufacturing and the Sustainable Product Initiative. This will also be followed by a range of measures to include research and development of new materials for tyres and understanding the sources and pathways of microplastic in the environment.

5.2.2 Actors

At the EU level, the European Commission is tasked with developing measures to tackle the unintentional release of microplastics, such as from tyres, based on the 2018 Plastics Strategy (European Commission, 2018, 2019). More specifically, DG Energy is tasked with the labelling of tyres, Directorate-General for the Environment (DG ENV) with the Microplastic Initiative and Directorate-General for Mobility and Transport (DG MOVE) with policies on sustainable mobility and transport (see also Devriese et al., 2023).

The tyre industry is primarily represented by ETRMA and the European Tyre and Rim Technical Organization at the EU level. TRMA represents different tyre manufacturers, suppliers, and distributors. The interests of international tyre manufacturers are represented at the EU level through the Imported Tyre and Rubber Manufacturers Association. The automotive industry is primarily represented by the European Automobile Manufacturers' Association (ACEA) and the European Council for Automotive R&D (EUCAR). Tyre and car manufacturers work closely together on tests of tyres to ensure their quality. In 2018, ETRMA initiated the European Tyre Road Wear Particles Platform, which is facilitated by the European Business Network for Corporate Sustainability and Responsibility and applies a multi-stakeholder approach. The platform brings together stakeholders from civil society, such as the International Union for Conservation of Nature and Natural Resources, the Plastic Soup Foundation, the Global Nature Fund, national authorities (such as the Evidence Policy Action Network, the German Federal Environment

Agency), the road sector (such as the European Asphalt Pavement Association, the European Concrete Paving Association), as well as actors focusing on the driving behaviour (such as the Allgemeiner Deutscher Automobil Club (ADAC), Fédération Internationale de l'automobile) and chemical suppliers (such as the European Chemical Industry Council (CEFIC)).

Actors focusing on the development of a tyre abrasion standard testing and indicating tyre performance, thus affecting tyre design, include actors from the industry, such as tyre manufacturers as well as independent test laboratories, such as the ADAC. The latter, for instance, supports Original Equipment Manufacturers with tyre testing or during the development phase of the tyre (Interview Audi AG, June 2023). Furthermore, consumer interests are represented by the European Consumer Voice in Standardization, which promotes and defends the collective European consumer interest in relation to tyre labelling.

Concerning setting criteria and standards for chemicals and additives, the plastic and chemical industry (e.g. chemical suppliers like CEFIC), as well as public entities (such as the Organisation for Economic Co-operation and Development (OECD), European Centre for Ecotoxicology and Toxicology of Chemicals, the European Chemicals Agency (ECHA)), EU Member States and the European Commission, are important actors. Furthermore, market surveillance authorities, influencing which products enter the EU or European Economic Area market present another relevant set of actors. The non-profit organisation Product Safety Forum of Europe represents market surveillance authorities at the EU level. Co-competition between manufacturers, for example in finding substitute material or collaborating on recovering carbon black from tyres, is a new technique that allows to secure more funding for research (Interview Michelin, June 2023). However, exchange between companies remains challenging due to antitrust regulations (Interview Audi AG, June 2023), emphasising the importance of umbrella associations, such as European Tyre and Rim Technical Organization (ETRTO), ETRMA, ACEA and EUCAR at the EU level. Actors engaging with relevant aspects of tyre composition, also include collaborations between tyre manufacturers, Original Equipment Manufacturers and stakeholders, such as start-ups, for example on the enzymatic recycling of plastics, as well as engineering companies (Interviews Audi AG and Michelin, June 2023).

5.2.3 Discourses

One of the aspects discussed with TWPs revolves around the question of where to tackle the problem. For instance, the tyre industry highlights the need to focus on the effect rather than the source of the issue through regulation or systems that reduce the amount of particle emissions, such as water retention systems that capture rainwater and provide a short-term solution to address the quantity of the problem (Interview Audi AG, June 2023). This results from a life cycle perspective, revealing the usage when the tyre is on the road as the key life cycle stage that needs to be addressed (Interview Audi AG, June 2023). In parallel, manufacturers continue working on using more sustainable material, improving the longevity of the tread and energy efficiency (and therefore fuel consumption) of the tyre, while acknowledging the complexity of finding a balance between those tyre characteristics (Interview Michelin, June 2023).

The European Commission, in a public consultation from 22 February – 17 May 2022, collected 411 views on measures to reduce the impact of microplastic pollution on the environment from a wide range of different stakeholders, including business organisations

and associations, environmental and consumer NGOs, academic and research institutions, as well as public authorities and EU citizens (European Commission, 2023b). All respondents agreed or somewhat agreed to improve tyre design to reduce tyre abrasion (European Commission, 2023b). In part, the discussion includes expanding the scope of the Ecodesign for Sustainable Products Regulation based on the European Ecodesign Directive, covering energy-related products including tyres (Interview DG Energy, June 2023). While this option was discussed during the consultation and could be considered in the future, the European Commission's approach prioritises areas without existing measures. In the case of tyres, multiple regulations are already in effect, covering aspects from greenhouse gas emissions to the Tyre Labelling Regulation and the End-of-Life Vehicles Directive (Interview DG Energy, June 2023). As such, there is a risk of overlapping and contrasting measures, as well as double regulation (*ibid.*).

In relation to tyre design and labelling, the introduction of a testing method to measure tyre resistance to wear and tear has resulted in the expression of different views from a diverse set of stakeholders. Civil society organisations advocate for an EU regulation banning tyres, which have the highest rate of tread abrasion, from sale (Hann et al., 2018), while the tyre industry tends to focus on the trade-off between the reduction of friction and safety (Carroll, 2022). However, by focussing on improving one characteristic, implications for the other characteristics will have to be considered, which will have to be tested as well (Interview Audi AG, June 2023). For instance, an adjustment of the wear rate or the operation weight of the tyre might cause a negative impact on the rolling resistance or noise behaviour (Interview Audi AG, June 2023). In addition, the car industry highlights the role of individual driving behaviour, and road characteristics, such as the road design and traffic flow, as relevant factors affecting the release of TWPs besides to the tyre design (Interview Audi AG, June 2023; Carroll, 2021, 2022; European TRWP Platform, 2019; Jekel, 2019; Tonegawa & Sasaki, 2021).

One challenge in relation to tyre labelling highlighted by industry representatives is the limited awareness on the environmental impact and sustainability aspects of tyres upon purchase (Interview Michelin, June 2023). Based on a study conducted by the European Commission, the relevant parameters for consumer choice are safety (particularly grip on wet), fuel efficiency, purchase cost, and mileage (Interview DG Energy, June 2023). Abrasion is not considered a parameter for choice and as such will be reflected under the same indicator as mileage (Interview DG Energy, June 2023). Therefore, a testing method will consider both, measuring abrasion and the tread consumption as a proxy of a potential mileage. However, it must be noted that there is no correlation between abrasion and mileage (Interview DG Energy, June 2023). Since consumers prioritize the longevity of the tyre, regulation and education of the consumer are essential to ensure a better product on the market, for which tyre manufacturers use their network of dealers and prescribers to ADAC, Autobild, among others. However, the European Commission sees an increase in awareness of the tyre label among drivers (Interview DG Energy, June 2023).

5.2.4 Power

Within the governance arrangement for tyre production, the most promiment power relations and resources relate to the tyre industry, environmental NGOs, the European commission and Member States. The tyre industry has an important and powerful role, as it accounts for the design and manufacturing processes of tyres and can influence the composition as well as the sustainability of the product, affecting tyre abrasion and the emission of TWPs. Tyre and car manufacturers collaborate with universities and research

institutes to draw from their knowledge, for instance on toxicity, which is outside the tyre manufacturers' expertise (Interview Michelin, June 2023). Instead of developing the competencies needed internally at the company level, manufacturers build partnerships with academia to develop the science, technologies, and chemicals needed (Interview Michelin, June 2023). Furthermore, tyre and car manufacturers collaborate on testing tyres, as the responsibility to ensure the tyre quality relies on them (Interviews Audi AG and Michelin, June 2023). As such, they hold a very decisive position and are supported and represented by strong and powerful associations, namely ETRTO in terms of technical questions and ETRMA for economic aspects (Interview Audi AG, June 2023). Furthermore, industry actors are well represented in different fora, such as the UNECE task force or the International Organisation for Standardisation (ISO) working groups on tyre abrasion, where industry representatives participate as experts in the name of the respective company (Interview Michelin, June 2023) and thus have the capacity to provide input through these platforms. In the discussions related to the Euro 7 regulation, tyre manufacturers successfully argued to include non-exhaust emissions under the upcoming regulation, extending the scope, as it initially only applied to cars (Interview Michelin, June 2023).

Due to this powerful position, environmental NGOs have called on the European Commission to regulate tyre design, such as through a legal threshold for tyre wear to effectively prevent TWPs (Carroll, 2022). In a different approach, the World Business Council for Sustainable Development and the Global Platform for Sustainable Natural Rubber, established by the Tire Industry Project (TIP), promote the use of natural rubber in tyre production. A study carried out by ADAC, testing tyres from 15 different tyre manufacturers, revealed that the trade-off between low abrasion and safety can be resolved by tyre technology and that some tyre manufacturers have recognized the need for low abrasion rates (ADAC, 2022). Despite some individual efforts by tyre manufacturers to design a sustainable tyre, there is currently no incentive for the commercialisation of this idea or for manufacturers to produce a more sustainable tyre. Moreover, the testing of tyre characteristics and performance is time-consuming, due to testing methods, validation, iteration loops and confirmation of the same aspects on the road (Interview Michelin, June 2023). As a result, even if a prototype that fulfils all the requirements is available, a tyre that can be produced in higher volumes is needed, so customers can be sure to have a premium product (Interview Michelin, June 2023). In addition, the exact composition of the tyre is something only tyre manufacturers know due to market competition.

The EU Commission and Member states are powerful actors in the production stage, as they set the agenda for new policies and regulations. The commission's proposal for the Ecodesign for Sustainable Products Regulation will significantly influence the rules of the games for the production of tyres. Moreover, Member States hold important tools and resources for incentivising the use of energy-efficient and safe tyres (European Commission 2018a).

5.3 Stage II: EU governance arrangement for tyre use and abrasion

The wear and tear of tyres generated through road transportation (referred to as abrasion) generates TWPs due to the friction between the tyres and the road surface (Rogge et al., 1993). Currently, this is an unavoidable feature of tyre design that occurs during the regular use of a tyre. These particles contaminate not only the road surfaces and nearby

soil but also adjacent water bodies (Kole et al., 2017) (see also section 5.4). Furthermore, a portion of these particles falls within the fine particulate matter size range and may play a role in contributing to air pollution (Panko et al., 2019), a concern that is important in determining the full range of pollution but will not be covered in this report. The following section will focus on the governance arrangement around the use and thus abrasion of tyres during use. Table 4 below provides a summary of the four dimensions (rules of the game, actors, discourses and power) of the governance arrangement for tyre use.

Table 4 Abrasion/use stage - Summary of governance Arrangement dimensions

Abrasion/use	
Rules of the game	The Microplastics Initiative sets the basis to explore the potential use of re-treated tyres, as well as to develop a standard for tyre abrasion
	The Tyre Labelling Regulation tasks the European Commission to create a test to measure the abrasion of tyre treads
Actors	European Commission (DG Energy, DG ENV, DG MOVE) and standardisation organisations (ISO, UNECE Task Force on Tyre Abrasion, European Tyre and Rim Technical Organisation)
	ETRMA as trade organisation for tyre and rubber producers
	Automotive industry, the Global Automotive Stakeholders Group, the VDA German Association of the Automotive Industry)
	Actors focused on transport and road (European Asphalt Pavement Association)
	NGOs (Transport & Environment)
Discourses	Development of a method to measure tyre abrasion
	Setting minimum requirements for tyre abrasion
	Providing information on tyre abrasion through labelling
	Driving behaviour and vehicle maintenaince
	Vehicle characteristics – e.g., weight of vehicles, electric vehicles
	Road surface characteristics and infrastructure
	Lack of up-to-date data on TWP emissions
Power relations	The European tyre industry has knowledge resources to develop testing methods, and financial capital
	European Commission uses its right to develop new regulation to address abrasion of tyres
	NGOs actively engage in consultation processes of the European Commission, such as the Microplastic Initiative and exchange with the industry to provide feedback on proposed directions

5.3.1 Rules of the game

There are currently no regulatory measures in place at the national, regional, or EU level that specifically address tyre abrasion and use. However, several EU initiatives aimed at addressing microplastics from various sources are currently being developed.

In May 2020, Tyre Labelling Regulation (EU) 2020/740, as outlined in Article 14, entrusted the European Commission with the responsibility of creating a test to measure the abrasion of tyre treads (European Commission, 2020c). The goal is to incorporate information about tyre abrasion into this regulation. This inclusion will be contingent on two specific conditions being fulfilled. First, the Commission must conduct an impact assessment based on relevant criteria and data and second, it must engage in consultations with relevant stakeholders as defined by applicable regulations and guidelines. Additionally, for this to be included, a standardised test method must be established to quantify and set limits on tyre abrasion. The Commission will adopt requirements for re-treaded tyres once a suitable testing method is available as part of the Tyre Labelling Regulation.

Efforts are underway within Europe to quantify the material lost from tyre treads over a specific distance travelled on the road (OECD, 2020). This process, however, also involves a thorough assessment of the method's practicality and consistency by tyre manufacturers to ensure that it is both feasible and reproducible (European Commission, 2020c). More recently, the Microplastics Initiative sets the basis to further explore the potential use of re-treated tyres, as well as to develop a standard for tyre abrasion (European Commission, 2022g). The objective to measure the unintentional release of microplastics from tyres, through a harmonised method at the European level has been expressed in the Circular Economy Action Plan (Carroll, 2021; European Commission, 2020a).

In relation to developing a tyre abrasion test method, different actors have proposed ways for the measurement of TWPs. The European Tyre and Rim Technical Organisation in cooperation with ETRMA, have proposed a tyre abrasion rate measurement vehicle method in 2022 with an analysis and final results to be available in summer 2023 (Interview ERMA, July 2023; ETRTO, 2022). ISO is currently developing international standards (ISO/AWI 18511-1 & ISO/CD 18511-2) for tyre abrasion rate measurement methods and the UNECE Task Force on Tyre Abrasion aims to propose a new United Nations (UN) regulation or a new requirement to UN regulation No. 117 under the 1958 Agreement for the type approval of tyres by September 2023 (UNECE, 2021).

Another significant effort within the EU to reduce TWPs is through Euro 7. The Euro 7 proposal addresses emissions from braking systems and tyres, and plays a role in meeting the Commission's recently proposed, more stringent air quality standards announced on October 26, 2022 (Interview Transport and Environment, June 2023; European Commission, 2022e, p. 7).

Finally, the EU's 'Sustainable and Smart Mobility Strategy' sets out to achieve a reduction of at least 90% transport-related greenhouse gas emissions by 2050 when compared to the levels recorded in 1990 (European Commission, 2020b). The strategy plans to reduce transport (e.g., improved public transport systems) and improve transport infrastructure and technology (e.g., smart mobility solutions to optimize transportation systems, reduce congestion, and improve fuel efficiency) (European Commission, 2020b). While these measures can reduce emissions, they are not specifically related to tyre wear but would have rather an indirect impact on their release into the environment.

5.3.2 Actors

The European Tyre and Rim Technical Organisation and ETRMA are key actors within the governance arrangement for tyre abrasion during use. Furthermore, concerning the use of tyres, the automotive industry is an important actor and includes the ACEA vehicle manufacturer trade association, the Global Automotive Stakeholders Group or at the national level, the VDA German Association of the Automotive Industry, among others. Actors focused on transport and road include the European Concrete Paving Association, as well as non-state actors, such as the NGO Transport & Environment.

The Rubber Tyres Case study, a project under the European Research and Innovation program Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing 13, was developed to support the governance of risks associated with the use of tyres (Broekhuizen, 2022). The European Tyre industry also created a Task Force on Tyre Abrasion Test Feasibility to develop a standard on tyre abrasion, however, no new information is available on this task force, and research is still ongoing.

Emissions Analytics EQUA Tyre is a UK-based testing and data analysis company that measures emissions from vehicles and engines. The company has developed a database that profiles the organic compounds found in tyres and contains test results and raw data from over 40 tyre manufacturers and hundreds of different tyre models. This database provides consumers, regulators, and tyre manufacturers with information about tyre emissions that could help develop policies and regulations around their emissions.

The road construction industry is also seen as an actor that has a role in the release of TWPs because the rate of particle abrasion is influenced by road characteristics, and because most TWPs are a mixture of both tyre and road particles (Interview Michelin, June 2023; Interview ETRMA, July 2023; Baensch-Baltruschat et al., 2020). As such, road design and construction actors could be considered relevant in addressing or mitigating TWPs.

NGOs (such as Environment and Transport) play a significant role in communicating scientific knowledge about the environmental impacts of TWPs to the EU. Their work includes the development of policy recommendations, and they actively advocate for more stringent legislative measures on the EU level, such as the through the recently proposed Euro 7 standards (Interview Transport and Environment, June 2023).

5.3.3 Discourses

Discourses about tyre use focus on different aspects related to tyre abrasion. This includes the development of a method to measure tyre abrasion, as well as setting minimum requirements for tyre abrasion and providing information on tyre abrasion through labelling (Interview DG Energy, June 2023). The latter is expressed in the 2022 public consultation under the framework of the Microplastics initiative, through which most stakeholders expressed in favour of labelling tyre abrasion (European Commission, 2023b). The labelling of tyres in relation to tyre abrasion and mileage would allow consumers to purchase more sustainable tyres based on the provided information about the classification of tyres. To reduce trade-offs between rolling resistance, safety, durability and environmental considerations in tyre technology, some stakeholders advocate for a life cycle impact assessment and for stakeholder involvement, such as through the application of a multi-criteria analysis (Kole et al., 2017).

The discourse on labelling has also introduced the question of setting minimum standards for tyres regarding abrasion to ban products from the market that do not meet those standards (Interview DG Energy, June 2023; Carroll, 2021). There is growing concern from actors, such as the International Union for Conservation of Nature and Eunomia, a sustainability consultancy, regarding the estimated time mentioned by the tyre industry concerning creating a test for tyre abrasion (EURACTIV, 2020). This is also expressed in the 2022 public consultation of the Microplastics initiative, which received responses from business organisations, NGOs and EU citizens, in favour of introducing legal limits on tyre abrasion (European Commission, 2023b). Moreover, the public consultation has revealed that business organisations and associations, NGOs, public authorities, and EU citizens are in favour of applying higher fees in extended producer responsibility for less-performing tyres (European Commission, 2023b).

At the same time, ETRMA argues that reducing tyre friction in the design will reduce road safety (Interview ETRMA, July 2023). Instead, ETRMA focusses on developing an abrasion testing method together with the EU Commission (Carroll, 2021). This method, in combination with tyre labelling, should then provide information to end users (consumers and businesses) to make a more informed choice. The European Tyre and Technical Organisation was created to support the creation of this method, which means that definitions and methods around the abrasion test are created within the industry itself and can exert considerable power.

The European Tyre and Road Wear Particles (TRWP) Platform, initiated in 2018, is a collaborative network, facilitated by European Business Network for Corporate Sustainability and Responsibility and developed by ETRMA. The platform focuses on the relationship between road surface characteristics and TRWP emissions in order to advance mitigation strategies to reduce their impact on the environment. The platform seeks to achieve this by bringing together government entities, academic institutions, NGOs, and industry, whereby they hope to foster shared comprehension of the issue and a better understanding of the role that different organisations can take. The industry-proposed approach thus extends the producer's responsibility to other sectors, i.e., the road sector and consumer behaviour. This sentiment is also reflected in the EU regulation on tyre labelling ((EU) 2020/740): “abrasion of tyres during use in combination with multiple factors including tread pattern and structure, road condition and driving behaviour.”

Discussions related to tyre use also include the need to optimise vehicle usage and maintenance. This includes adopting eco-driving practices, such as maintaining constant speeds and practising gradual acceleration and deceleration, as well as adhering to best practices for tyre maintenance, such as proper inflation, which can help reduce tyre wear. Concerns have also emphasized that since tyre wear depends on vehicle weight and mileage, reversing the current trends toward heavier vehicles and increased road traffic could reduce TWP release (Amato, 2018). In this regard, current discourses also explore the impact of the growing number of electric vehicles on TWP generation, considering factors like increased vehicle weight and torque (Interview ETRMA, July 2023; Zhang et al., 2023).

Consideration of influencing factors, like road characteristics, is also an area of discussion (Amato, 2018). Improving the composition and maintenance of road surfaces can significantly impact wear and tear (Liu et al., 2022). Although replacing existing infrastructure can be costly, there may be opportunities to factor in tyre wear concerns

during routine road renewal or the planning of new roads (OECD, 2021). Additionally, proper road surface maintenance is essential to minimize both tyre and road wear (Steyn & Haw, 2005). In this capacity, discourses around street cleanliness have also highlighted the potential role it can play in preventing TWP runoff into stormwater and surface water systems (OECD, 2021).

The Tyre Collective has developed a device that harnesses the airflow generated by the rotating wheel to capture tyre dust as it is produced (Snowden, 2020). The device can gather particles, which can then be repurposed into a form of rubber suitable for a wide range of applications. Such devices are relatively easy to attach to vehicles and do not require energy, yet scaling up this technology and implementation has not yet been studied.

One area of significant discussion centres around the lack of up-to-date information surrounding TWP emission estimates. A review on TWPs published in July 2022 highlighted the fact that most country-based estimates were based on other, mostly outdated, studies, and additionally, not based on studies conducted within the country (Fussell et al., 2022). NGO experts confirmed that all data on TWPs used by their institution also relied on information provided through outside organisations that are not based within the NGO country (Interview Transport and Environment, June 2023). Another study by Baensch-Baltruschat et al. (2020) noted that real-world conditions are rarely considered in degradation and ecotoxicological studies of TWPs, and that environmental monitoring of these particles still faces analytical challenges (Baensch-Baltruschat et al., 2020).

5.3.4 Power

Power relations in the governance arrangements for tyre use and abrasion exist between the European tyre industry, environmental NGOs, Members of European Parliament and the European Commision. The European tyre industry possesses relevant knowledge resources relevant to the development of testing methods to measure TWPs, as well as human and financial capacity, which informs the European Commission and standardisation organisations, such as the European Committee for Standardization, UNECE and the ISO. For example, TIP members contributed to the development of ISO standards on the physical and chemical characterization as well as the determination of Tyre and Road Wear Particles in the environment in the past. Together with the ETRMA, TIP members contributed to the OECD 2020 workshop on “Microplastics from Tyre Wear: Knowledge, Mitigation Measures, and Policy Options” and the 2021 OECD report (OECD, 2021). Furthermore, the tyre industry leads and sponsors scientific research on the potential human health and environmental impacts or tyres throughout their life cycle (Tire Industry Project, n.d.; Unice et al., 2019).

Due to these powerful resources of the tyre industry, there is growing concern from NGOs and Members of the European Parliament about delaying the introduction of a method for the measurement of tyre abrasion (Carroll, 2022). NGO’s, in turn, utilise their resources and access to decision-makers to raise awareness on the environmental and health impacts of TWPs. The European Commission and Members of the European Parliament use their rights to develop new regulation to address abrasion of tyres by developing revisions of existing regulation and by setting out strategic policy directions, such as the zero pollution action plan.

5.4 Stage III EU governance arrangements for end-of-life of tyres

The management of end-of-life tyres is of great importance for the zero pollution objective for TWPs, since ELT is currently among the largest sources of waste globally. In this section, we explore the EU governance involving the end-of-life for tyres, which changed significantly since the Landfill Directive (1999/31/EC) made the disposal of tyres in landfills illegal in the European Union from 2006 onwards. From the perspective of marine pollution in EU regional seas, we exclude exports of ELT outside the EU and focus on governance of EU regulated end-of-life streams, as implemented by EU Member States. Table 5 below provides a summary of the four dimensions (rules of the game, actors, discourses and power) of the governance arrangement for end-of-life tyres.

Table 5 End-of-life stage - Summary of governance Arrangement dimensions

End-of-Life	
Rules of the game	EU framework directive banning landfilling end-of-life tyres (ELT) results in average EU ELT recovery rates of >95%
	ELT recovery is implemented at Member State level, primarily through extended producer responsibility (65%) and free market system (~35%)
	The recent EU ban on intentionally added microplastics has consequences for ELT-derived granulated sport fields infill, with a transition period of eight years. This currently constitutes more than half of the recycling stream
	REACH regulation sets thresholds on safe maximum PAH content for infill material from ELT
	There are currently no EU material recovery targets for ELT
Actors	Established material recycling Industry: granulation
	Emerging material recycling industry: chemical recovery
	Engineering and research (pyrolysis, rubberised asphalt)
	Cement industry for energy recovery
	Environmental NGO's
	European Commission and Member States
Discourses	The recycling industry highlights and prioritises the circular economy objectives over the zero-pollution objective. They want to minimise energy recovery and exports and encourage investment into the recycling of ELT
	The recycling industry perceives that the lack of end-of-wsate criteria and eco-design makes recycling challenging
	Market for ELT-derived rubber is underdeveloped, leading to economically attractive options of incineration and export. This includes recycled content in Tyre production
	Tyre labelling of percentage recycled material, could facilitate material recovery

Power relations	Tyre and rubber industry decides on tyre design and composition
	Due to EU circular economy agenda, formal role and power of recycling industry is growing, but still lower compared to tyre and rubber producers
	European Commission and Member States have power of taking initiative on proposing new policies and regulations

5.4.1 Rules of the game

The most prominent EU policy in managing end-of-life tyres is the Waste Framework Directive (2008/98/EC). The WFD sets out definitions and concepts related to waste management and introduces principles such as the waste hierarchy, extended producer responsibility (EPR) and end-of-waste criteria for recycling.

In Directive 2018/851 amending the WFD (2008/98/EC), the European Commission calls for the creation of a "uniform measurement of the overall progress in the implementation of waste prevention measures" and so "common indicators and targets should be established". Data on waste statistics is collected under Regulation (2150/2002/EC), which is translated into waste management indicators in the form of recycling-, landfilling- and recovery rates. However, no statistics are collected for rubber coming from tyres, so quantitative targets are currently lacking.

Waste prevention is prioritized according to the waste hierarchy in the WFD, yet most strategies developed by the industry focus on re-use, recycling and recovery of whole tyres (Carroll, 2021). For instance, natural rubber is listed as a critical raw material but only half of ELT enters the recycling stream (ETRMA, 2021a).

For ELT-derived materials to be used in new products it needs to comply with end-of-waste criteria as articulated in the WFD. One of these criteria is "the absence of adverse impact on human health and the environment due to the use of a substance". This is relevant for the recycling potential of ELT with existing concerns around the release of microplastics and chemicals from ELT granulates. While Member States may develop end-of-waste criteria based on these conditions, the lack of European-wide end-of-waste criteria for ELT-derived rubber or rubber granulate is seen by the recycling industry as a challenge for recycling (Interview EuRIC, June 2023). The introduction of EU-wide criteria would potentially have implications for tyre and rubber production with indirect impacts on the environmental impact of TWPs during use.

The concept of EPR builds on the polluter-pays-principle, and is introduced in the WFD as a financial and operational instrument aiming to decrease the environmental impact of a product by making the manufacturer responsible for the entire life cycle of the product (Campbell-Johnston et al., 2020). The regulation requires that "Member States may take legislative or non-legislative measures to ensure that any natural or legal person who professionally develops, manufactures, processes, treats, sells or imports products has extended producer responsibility" (Article 8, Directive 2008/98/EC). When it comes to tyres, most EU countries (65%) are operating under EPR schemes, while some countries (35%) work under a free market system where local regulations implement ELT collection and treatment. As a result, producers are motivated to collect end-of-life tyres, thereby preventing (illegal) stockpiling or disposal within Europe (Winternitz et al., 2019).

By shifting responsibilities away from municipalities and towards producers, EPR is used as a means to incentivize producers to include environmental considerations in the design

of tyres (OECD, 2021). Producers should then be triggered to improve their product's design to last longer and facilitate material recovery (Article 3(12) and 9 of WFD). While the EPR schemes ensure that >95% of tyres are collected, no evidence has been found that EPR schemes lead to either waste reduction or eco-design improvements.

Microplastic emission occurs primarily during use. At the end-of-life, most microplastics come from rubber granulate infill in sports pitches and playgrounds. In April 2023, a revised REACH restriction proposal on intentionally added microplastics was approved, which will come into effect after an 8-year transition period. This includes a ban on rubber infill in synthetic sports pitches to reduce leakage of microplastics into the environment. While this contributes to the zero pollution action plan objective of the EU, it does pose a significant challenge to the recycling industry and the EU's objective of a circular economy. Since rubber infill represents the major recycling stream of ELT, the recycling industry is worried that microplastic pollution is being exported outside of the EU and calls for policy to encourage EU based recycling.

ELTs feature in a range of other (upcoming) policies, most notably the Eco-design framework legislation that is currently being finalized. Tyres will likely feature in the first or second round of products to be included in this framework (OECD, 2021). If they are, it would steer producers to make toxic-free tyres with a simpler composition to allow for wider recycling, with implications for the pollution-effect of TWP emissions during use. The end-of-Life Vehicle Directive (2000/53/EC) sets a framework for the reuse and recycling of car materials but does not currently cover end-of-life tyres. The 2023 proposal for a revision of this directive also excludes tyres from its scope, since tyres are already considered in separate legislation.

5.4.2 Actors

The most significant actor in the governance of end-of-life tyres is the European Commission, which set the EU agenda for a circular economy and zero pollution under the Green Deal. The policy developments around ELT flow from this agenda, most notably the REACH restriction on intentionally added microplastics with its associated implications for the recycling stream of ELT.

The ETRMA is an important actor with more than 4400 companies as members. It is the primary actor for production, but the association and their members have a long-term interest in marketing their products as sustainable and through EPR they are a stakeholder in ELT management.

The European Tyre Recycling Association (ETRA) is a significant actor, counting more than 250 recycling organisations to its members covering 43 countries. The European Recycling Industries' Confederation (EuRIC) also represents the European recycling industries with a vision of enabling the circular economy. ETRA and EuRIC act as a partner between the recycling value chain actors and policymakers.

There are mediating actors in the ELT value chain, such as organisations involved in the trading of ELT: The Rubber Trade Association of Europe, European Tyre Distribution, and Used Tyres Europe. Other industry actors have a role in the metal separation, granulation, and pulverization of ELT.

Regarding energy recovery, the primary stakeholder are the cement sector, which have make use of ELT as supplementary fuel. Also Eurofer, the European Steel Association’s

members are important actor for energy recovery, as they benefit from the uptake of tyres in the waste stream (Interview EuRIC, June 2023).

Engineering and technological research organisations are important actors in developing new economically viable ELT recycling pathways. These include technologically challenging thermal treatment technologies, i.e. pyrolysis, thermolysis and gasification. There are currently a few plants in operation, with only a limited market for the resulting products. The scaling of rubberised asphalt is another area of research that is being pursued. Linked to the need to advance research is the EU's Horizon Europe program which funds several research projects on the recycling of tyres.

5.4.3 Discourses

The tension between circularity and environmental impacts is an important debate around ELT (Lonca et al., 2018). EU policy appears to be in a transition from regarding ELT as waste going into landfills or exports, to encouraging energy recovery, material recovery and closed loop recycling of ELT as part of a circular economy. This last transition is still out of reach due to a lack of a market for ELT-derived materials, as well as the high level of technical innovation needed to remove toxic chemicals such as PAHs, that are formed during the production of tyres.

For example, the recycling industry is highlighting ELT derived granulated rubber as a vital component of material recycling as part of the circular economy ambitions of the European Green Deal. They argue that the potential environmental impact is acceptable in light of the energy and material conservation resulting from the material recovery of ELT. The benefits of material recycling, they argue, outweigh the localised infill release in sports fields. They also claim that a ban on rubber infill would only lead to more exports of ELT and associated environmental pollution. Also, the European Mechanical Tyre Recycling Branch of EuRIC and the ETRMA argue for EU-wide end-of-waste criteria to include rubber granulates from end-of-life tyres. This would make it more attractive to various actors in the value chain to use ELT-derived products (ETRMA, 2023; EuRIC, 2023).

In addition, the economic rationale behind EPR should trigger producers to improve their product's design to last longer and to facilitate material recovery (Article 3(12) and 9 of WFD). Environmental NGOs and members of the EU Parliament therefore advocate for changes in tyre design: for example, a Member of the European Parliament from the European People's Party states that the tyre labelling Directive ((EU) 2020/740) should be part of a larger policy response and measures that target tyre design and abrasion requirements (Carroll, 2021). These measures would gradually see poorly performing and polluting tyres being replaced by less abrasive and less polluting tyres on the market, also facilitating recycling of tyres.

Finally, ETRA (2023) argues that policy should focus on the much more substantial release of microplastics during the use stage of the life cycle, including agricultural tyre wear that enters agricultural land as bio-available particle sizes, as this is a larger source of environmental pollution.

5.4.4 Power

Power relations within the governance arrangement for the End-of-Life of Tyres is changing, because the transition to a circular economy in the EU is increasing the power of the recycling industry. The sector, represented in Brussels by ETRA, is expecting spectacular growth in the coming decade and is advancing the interests of the recycling industry, for

example by lobbying against the ban on the REACH restriction to include rubber infill materials in sports fields (ETRA, 2023). The power of the recycling industry is evident in the eight year transition period in the proposed infill ban, which according to environmental NGOs is longer than warranted by the evidence of the environmental impact (Interview EuRIC, June 2023). The recycling industry is also lobbying in favour of legislation of eco-design to favour mechanical recycling, and harmonising EU-wide end-of-waste criteria (EuRIC, 2023).

Currently, tyre and rubber manufacturers are under no obligation to disclose the chemical composition of their product, while the recycling industry on the other hand, has to do a full analysis of chemical composition of both input and output resources. This is seen as a power imbalance (Interview EuRIC, June 2023). It can be argued that the common EPR policy extends the decision-making power of producers by legitimizing their role in finding solutions for the handling of tyres as waste (Massarutto, 2014), potentially at the cost of the recycling industry. This might help explain why the mechanism of EPR has not led to significantly improved environmental design in practice (Winternitz et al., 2019).

Tyre and rubber producers also have the power to influence new regulations. While some of ETRMA's constituent members are in principle supportive of environmental legislation, others try to prevent changes in the regulatory landscape. The lobby of the tyre and rubber producers aims at aligning EU regulations with UN standards, have significant transition periods for new policies and highlight trade-offs between sustainable design, recleability, and for example the safety of tyres (Interview ETRMA, July 2023).

Both the tyre and rubber producing industry and the recycling industry allocate monetary resources to research with the aim of informing and influencing policy. They also have knowledge resources because of their access to industry production figures.

The European Commission in turn has the power and resources to establish criteria on the end-of-waste status that can determine the fate of tyres, and TWPs, towards the waste or into the recycling stream. The Commission, as well as Member States have significant power through policy making and setting out new regulations, as shown in the inclusion of the granulated rubber infill in the ban on intentionally added microplastics, despite lobbying pressure against it.

5.5 Stage IV: EU governance arrangements for end-of-pipe of TWPs emissions

Considering the diverse routes through which TWPs enter the environment, upstream interventions alone will not completely mitigate the potential for microplastic contamination within the water cycle. Consequently, the implementation of upstream strategies will need to be complemented by the adoption of end-of-pipe solutions. In fact, the majority of TWPs entering the aquatic environment depends largely on the treatment and collection of road run-off, which varies significantly between Member States (Skumlien Furuseth & Støhle Rødland, 2020). Table 6 provides a summary of the four dimensions (rules of the game, actors, discourses, and power) of the governance arrangement for end-of-pipe TWPs.

Table 6 End-of-pipe stage - Summary of governance arrangement dimensions

End-of-pipe	
Rules of the game	Urban Wastewater Treatment Directive: Proposed revision will identify microplastics as emerging pollutants and introduces monitoring obligations for microplastics in WWTF outlets and sewage sludge
	Water Framework Directive: guides monitoring and managing of surface water quality and defines environmental quality standards
	Proposed revision on priority substances amending the WFD and its two daughter directives (October 2022), acknowledges microplastics
	Sewage Sludge Directive (86/278/EEC): regulates the quality and use of sewage sludge produced from urban wastewater treatment. Currently does not specifically address microplastics or TWPs
	Fertilizer Regulation (2019/1009): currently the only legislation that specifies the amount and size of microplastic particle requirements in compost. Limits compost to contain no more than 3g/kg dry matter of macroscopic impurities above 2mm
Actors	The European Environmental Agency – monitoring agency
	Member States and their water authorities
	Wastewater treatment facilities
	EurEau
	Joint Research Centre of the European Commission and other research institutions
Discourses	TWPs release is caused by stormwater runoff or wastewater discharges from roads and other paved surfaces, environmental impacts uncertain
	Adapting or building WWTF infrastructure to effectively capture microplastics requires significant funding
	Wastewater operators are generally supportive of EPR schemes as effective way to involve industries in the discussion of water quality
	Use of sewage sludge – sewage sludge contains valuable organic compounds such as nitrogen and phosphorus, making it beneficial as both a fertiliser and soil enhancer. However, the sludge also contains varying levels of microplastics that have been removed during wastewater treatment processes
Power relations	Member States can set stricter standards for wastewater facilities on the treatment and quality of water released from their facilities
	EurEau – lobby organisation of wastewater operators in the EU, involved directly in developing the proposal for the recast of the UWWTD
	Joint Research Centre is responsible for developing models on water quality and quantity in the EU, and their models have been adapted to the policy updates of the UWWTD

5.5.1 Rules of the game

The most relevant EU legislation for TWPs entering the marine environment through waterways is the Urban Wastewater Treatment Directive (UWWTD) (European Commission, 2014) and the Water Framework Directive (European Commission, 2000). The UWWTD was adopted in 1991 and aims to regulate the discharge of urban wastewater into the environment. Although the original UWWTD does not specifically address microplastics, the proposed recast of the Directive identified microplastics as emerging pollutants and an 'increasingly important issue' (European Commission, 2022d). The impact assessment accompanying the proposal found that most microplastics in domestic wastewater stem from the use of textiles and the degradation of tyres on the roads when wastewater is mixed with rainwater (European Commission, 2022a). Following these findings, the proposal introduces new monitoring obligations (Article 12, former Article 15) for microplastics in outlets of urban wastewater treatment plants and in sewage sludge. Additionally, Article 9 now requires producers to contribute to quaternary treatment in cases where their products at the end-of-life contribute to pollution in the wastewater (European Commission, 2022d). However, this EPR application is limited to pharmaceutical and personal care products and does not include tyres or the unintended release of microplastics.

Member States have a duty to establish an environmentally friendly water management system to safeguard water resources, as specified in Article 13 of the WFD (European Commission, 2000). The WFD sets standards for water quality in surface waters and groundwaters, through two daughter Directives on the (1) quantity and quality of groundwater (2006/118/EC) and the (2) quality of surface water (2008/105/EC). The Groundwater Directive provides a framework for the monitoring and management of groundwater to protect and improve its quality, while the Surface Water Directive lays down environmental quality standards for priority substances. While the directives also set measures to prevent pollution sources and establish monitoring programs, they do not specifically address microplastics or TWPs. However, the proposal for an update on priority substances amending the WFD and its two daughter directives, published in October 2022, also acknowledges microplastics. However, this would not be targeted immediately but "after a methodology for monitoring has been developed" (European Commission, 2022c).

One pathway for removed microplastics and TWPs to re-enter the environment is through the disposal of sewage sludge (Iyare et al., 2020), which is the residual material after the treatment of urban wastewater and is regulated by the Sewage Sludge Directive (86/278/EEC) (European Commission, 2022b). The Directive sets out requirements for the quality of sewage sludge and its use in agriculture, land reclamation, and other applications. Although microplastic particles are present in sewage sludge due to their presence in wastewater, the directive does not specifically mention microplastics or TWPs. In fact, the Fertilizer Regulation (2019/1009) is currently the only legislation that specifies the amount and size of microplastic particle requirements in compost (European Commission, 2023c). The regulation sets a limit to compost to contain no more than 3g/kg dry matter of macroscopic impurities above 2mm in the form of glass, metal, or plastics (European Commission, 2023c).

5.5.2 Actors

The requirement that Member States must formulate water management plans promotes participation from wastewater authorities and the broader public. This means that wastewater authorities are tasked with actively developing plans to manage water resources in alignment with the WFD. Oversight of the implementation and monitoring of these water management initiatives is conducted by the European Environmental Agency.

The European Federation of National Associations of Water Services (EurEau) represents Europe's water services sector and contributes significantly to decisions regarding the management of wastewater within Europe. National water board associations within EurEau (e.g., German Technical and Scientific Association for Gas and Water, Federation les Enterprise de l'Eau (France)), also contribute to water quality management within individual Member States.

Innovation and research institutes are also important actors in developing technology to measure TWPs after they enter the environment. For example, the EU's Joint Research Centre is currently working on developing standardised methods for sampling, extraction, and analysis of microplastics in the environment (European Commission et al., 2021). Additionally, within the Horizon Europe program, one of the missions is to "Restore our Oceans and Waters". In alignment with this, the European Investment Bank, in collaboration with the European Commission, is financing operations to reduce the discharge of chemicals, nutrients, plastic waste, and microplastics into the ocean (European Commission, 2022f). Their support extends to enhancing waste, wastewater, and stormwater management, offering expertise in project preparation, implementation, and financing.

5.5.3 Discourses

There is growing concern about pollution from TWPs entering the environment through stormwater runoff or wastewater discharges from roads and other paved surfaces (Ding et al., 2023; Iyare et al., 2020). A working paper released by the Nordic Council reported that the main source of TWPs in the environment is likely untreated runoff from major roads where the drainage system is discharged directly into the marine environment (Skumlien Furuseth & Støhle Rødland, 2020). Given the environmental impact of TWP pollution, there is a need to develop effective methods for capturing these particles, for example in wastewater treatment facilities (WWTF) (Interview DG Energy, June 2023). However, as both road infrastructure and treatment facilities are built for long-term use, adapting them according to every emerging pollutant is not always a feasible solution (Interview EurEau, June 2023).

The discussions surrounding microplastic capture in WWTF are usually focused on finding the most effective and efficient methods for capturing these particles while minimizing potential negative impacts (Tang & Hadibarata, 2021). Some experts suggest that WWTF could play a role in controlling microplastic release by incorporating advanced treatment technologies or by implementing source control measures to prevent particles from entering the wastewater stream (Kay et al., 2018). Kay et al. found WWTF to be a key source of microplastics in river catchments. However, others argue that wastewater facilities may not be effective at removing these particles (Reddy & Nair, 2022) and that additional research is needed to better understand the environmental impacts of TWPs and potential mitigation strategies (Acarer, 2023). This is partly because wastewater treatment plants also receive industrial wastewater, which can contain contaminants not

covered by the UWWTD, such as microplastics and other chemicals. In most cases, there is limited understanding and knowledge of these types of contaminants, which could hinder the treatment process and contribute to the pollution of the water bodies where effluent is released, as well as prevent the reuse of treated wastewater and the recovery of sludge (European Commission, 2022d).

The use of sewage sludge is also an important area of discussion in relation to the presence of TWPs in the environment. This is because some Member States use sludge as agricultural fertiliser, an application that is supported and encouraged by the EU (European Commission, 2022b). Sewage sludge contains valuable organic compounds such as nitrogen and phosphorus, making it beneficial as both a fertiliser and soil enhancer. However, sludge also contains TWPs, which are filtered out in the wastewater treatment process (Iyare et al., 2020). Therefore, discussions around the use and monitoring of this application are on the agenda of the EU through an evaluation of the Sewage Sludge Directive. The evaluation confirmed the relevance of the Directive but recommended a review of the contaminants it regulates (i.e., organic compounds, pathogens, pharmaceuticals, and microplastics) (European Commission, 2023a). It emphasised the cost-effectiveness of agricultural sludge use over incineration, highlighting its importance in the context of zero pollution and climate change (European Commission, 2023a). Additionally, the evaluation brought attention to the lack of data on sludge use in agriculture and ongoing research in this area.

Wastewater operators are generally very supportive of EPR schemes and consider them an effective way to involve industries in the discussion of water quality. They emphasize the importance of shared responsibility in dealing with emerging pollutants as treatment plants cannot be solely responsible for treating all substances present in the influent (Interview EurEau, June 2023). As an example, they highlight that the presence of the pharmaceutical industry in discussions around water quality occurred only after EPR schemes were on the table (ibid.).

Advancements in the treatment of wastewater have also been made, with some discussion around the use of constructed wetlands and bioretention basins for capturing microplastics from stormwater runoff. These types of infrastructure can remove contaminants from stormwater before it enters waterways and have been effective in capturing microplastics (Chen et al., 2021).

The Tire Industry Project, a body representing 10 tyre manufacturers including Goodyear, Michelin and Pirelli, has commissioned multiple studies over the last decade, concluding that TRWP (tyre and road wear particles) present no environmental and health risks (Brock & Geddie, 2020). This was confirmed by expert interviews from the tyre manufacturing sector, who claimed that there was no evidence that TWPs posed a serious risk to the environment, with the exception of 6PPD causing mass mortality in coho salmon (McVeigh, 2022; Interview Michelin, June 2023).

5.5.4 Power

Within the governance arrangement for End-of-Pipe capturing of TWPs, Member States and the waste water sector have a particularly powerful position. Member States can set stricter standards for wastewater facilities on the treatment and quality of effluent being released from their facilities. For example, some Member States (i.e. Germany) have implemented their own regulations to address microplastics in sewage sludge. Germany has set limits for microplastics in sewage sludge used in agriculture and has implemented

monitoring programs to track the levels of microplastics in sewage sludge (Henseler et al., 2022). Given that many wastewater operators in the EU are public companies, owned by public authorities, they operate within a 'captive market' framework. This means that individuals cannot freely choose which wastewater operator they use. Consequently, the industry is primarily reactive to legal requirements rather than being driven by market forces (European Commission, 2022d). Additionally, in some Member States, as noted by wastewater operators, "Water authorities are guided by elected officials, and their priorities may shift based on political directions" (Interview EurEau, June 2023).

According to an expert in the wastewater sector, "The most important area for the governance of TWPs in wastewater facilities is the recognition of microplastics as an emerging pollutant (article 18 in the recast of the UWWTD)" (Interview EurEau, June 2023). Without this substance on the list, end-of-pipe operations such as WWTF do not need to consider them in the treatment of water entering their facilities, according to EU regulations. However, Member States or municipalities within Member States may decide to set stricter standards on water quality within end-of-pipe operations. This decision is often dependent on political factors, and as wastewater operations often function as democratic organisations (such as in the Netherlands), the boards are chosen through elections every four years (Interview EurEau, June 2023). Therefore, any decisions made regarding wastewater standards must also consider the economic burden and costs for the electorate (ibid.).

A significant authority on wastewater operations is EurEau, as they are a federation of National Associations of Water Services in Europe. Their members represent drinking and wastewater providers from 30 European countries, from both private and public sectors, and many of them are also on national boards for water services within EU Member States. Additionally, some of their members are also participating and advising EU legislative working groups concerning water quality. Notably, this includes both the proposal for an update on priority substances amending the WFD and the recast of the UWWTD, making this group highly influential in setting standards surrounding water quality and emerging pollutants (Interview EurEau, June 2023).

Finally, research institutes also hold power in communicating the environmental and health hazards surrounding TWP release, which can inform policy, establish appropriate standards, and advise public discourse. Specifically, the EU's Joint Research Centre is responsible for developing models on water quality and quantity in the EU, and their models have been adapted to the policy updates of the UWWTD (European Commission, 2022d). Additionally, DG ENV works closely with the Joint Research Centre to consult with experts when addressing specific policy concerns (European Commission, 2022d).

6 Best practices and constraints for current policy developments to achieve the EU zero pollution objective for TWPs

The governance landscape for preventing and mitigating TWP emissions to waterways within the EU is in flux, with various policy developments targeting different parts of the life cycle of tyres ongoing simultaneously. In this chapter, we will answer the second research question for the case of TWPs: **What are the best practices and constraints within existing and emerging governance arrangements for developing EU regulation to achieve the zero pollution objective for TWPs in EU's waterways and marine environment?** We answer this question by discussing five policy developments and presenting the main best practices and constraints that emerge from our governance arrangement analysis in relation to the zero pollution objective of reducing release of TWPs in EU's waterways and marine environment by 30%. An overview is given in Table 7.

Table 7 Overview of best practices and constraints for current policy developments to achieve the EU zero pollution objective for TWPs

Policy developments	Best practices	Constraints
Euro 7	Preventing the most environmentally harmful tyres from entering market	Determining emission threshold Power of industry in setting emission standard Economic consequences for industry (and potentially consumers)
Eco-design	Linking use- and end-of-life concerns with design and production to prevent abrasion Encouraging tyre circularity	Disagreements regarding the trade-off between TWP emissions and safety
Labelling	First step in encouraging eco-design Allows consumers to make an informed purchase decision	Limited industry incentives to produce tyres with lower abrasion rates Challenges associated with developing abrasion standards based on multiple parameters and pace of development could be determined by industry Limited consumer awareness
Infill ban	Reducing end-of-life microplastic emissions Encouraging alternative material recovery solutions	Uncertainty whether the ban enhances circularity of tyres Lack of alternative recycling markets
Waste Water Treatment	Defining microplastics as a priority substance will create urgency for a wide range of actors	Technological and financial implications for infrastructure needs Use of sludge on agricultural lands, may leach microplastics

6.1 Euro 7 proposal to ban the most environmentally harmful tyres

Under the upcoming Euro7 regulation, non-exhaust emissions will be addressed. It will be the first regulation directly addressing tyre wear particles through an emission standard for tyre wear planned for 2025. The introduction of emission standards will set minimum requirements for tyres to be placed on the market. This will impact the tyre supply, as the worst performing tyres that do not meet the necessary requirements will be excluded from sale on the market. This makes Euro 7 a best practice in terms of preventing tyres with high rates of tyre abrasion from being produced, sold and used.

Constraints for the Euro7 regulation lie with the implications it has for tyre manufacturers, who are responsible for integrating sustainability in their tyre design. The scale of the (economic) impact will depend on the emission standards developed and the amount of tyres being prevented from entering the market. Since the tyre industry is involved in developing these standards, constraints can emerge in terms of watering down of emissions standards.

6.2 Eco-design for tyres to reduce TWP abrasion

An expansion of the scope of the Ecodesign for Sustainable Products Regulation to include tyres is a possibility that is currently under consideration and is part of the consultation on new products. This offers an opportunity to set eco design requirements applicable to tyres. Eco-design is a best practice in terms of it being a source-based approach towards TWPs emission by using design to reduce levels of abrasion during the use of the tyre. Moreover, the tyre industry does not object to setting eco-design requirements and as such seems to share similar interests as the recycling industry which also calls for eco-design measures. In terms of eco-design, a life cycle analysis can give insights into key elements that are relevant in relation to TWP emissions. These elements include energy efficiency, primarily linked to reducing greenhouse gas emissions, and the longevity of the tread and the usage of tyre on the road (increase mileage). In particular, the longevity of the tread can be influenced through tyre design to create a tyre that is lighter, with less material but that can deliver the same performance. Thus, a life cycle approach holds the opportunity to consider design features that could reduce the need for further measures at the use, end-of-life and end-of-pipe stages.

It should also be taken into account that the existing EPR scheme for tyres, which puts responsibility to collect end-of-life tyres onto manufacturers, has not led to a push for eco-design requirements. This is in part due to the fact that under the waste framework directive, policy implementation is left up to individual countries. While EPR schemes ensure a high level of tyre recovery, they have not led to advances in eco-design. The infill ban under REACH, however, is an opportunity to create a link between the production and end-of-life stage, which could then push for eco-design requirements for the end-of-life in the near future. Using eco-design as a way to find an alternative for the use of tyres for infill and work towards developing a closed loop system of tyres and tyre materials would strengthen the potential of eco-design in becoming a best practice for advancing circularity. In addition, setting recycling targets for tyres or developing universal end-of-waste criteria could promote ELT treatment by the recycling industry to allow for closed loop material recycling of tyres. A constraint here is the 8-year transition period that is included in the infill ban, which reduces the pressure to work towards circular tyres.

One of the key constraints, however, is that while both recyclers and tyre manufacturers advocate eco-design requirements, they disagree on what these requirements should be. For example, recyclers point to the need to improve the recyclability of tyres by having a more uniform and predictable composition of tyres, with fewer 'difficult' chemicals being added. This would mean that TWPs emitted during abrasion become less hazardous too. While producers (ETRMA) recognise this, they highlight 'safety' and other dimensions of tyre design to argue for the necessity of making tyres that abrade and release microplastics and harmful chemicals. A trade off thus exists between environmental impact, recyclability and safety when developing eco-design requirements for tyres. This includes the potential for pushing tyre manufacturers to use so-called ‘regrettable substitution’ of materials used for producing a tyre, i.e. substituting environmentally unfriendly materials for other environmentally unfriendly materials. Moreover, eco-design might help reduce abrasion during use, but the increased use of heavier electric vehicles could in future might nullify these TWP emission reductions.

6.3 Labelling of tyres to reduce TWP abrasion

The Tyre Labelling Regulation serves two purposes: it guides consumers in making an informed purchase decision and sets parameters that have to be considered in tyre design. As such, it is of relevance to tyre manufacturers and the automotive industry to ensure the quality and performance of the product, classified and depicted through the tyre label. The current policy development to include a parameter on tyre abrasion and mileage to the tyre label will thus have relevant implications for the tyre design, making it a best practice in terms of the potential to use labelling to have the desired effect of strengthening eco-design and preventing TWPs generation during tyre use.

A constraint for ensuring labelling promotes both the eco-design of tyres and consumers buying sustainable tyres relates to the abrasion process as an essential component of ensuring a safe product and safe mobility. Bringing emissions down to zero is thus impossible by definition. Furthermore, improving the sustainability of the tyre through tyre design requires consideration of all parameters set out in the tyre labelling regulation, so as not to compromise on tyre safety. Two constraints further impede the way in which the tyre labelling regulation can promote eco-design. First, more time and research are needed to advance towards developing a more sustainable tyre. Second, since the tyre and automotive industry holds the knowledge and resources to invest and improve the design and composition of tyres, progress under the tyre labelling regulation may very much depend on these industry actors.

Another constraint is that there is currently limited awareness among consumers in relation to emission-related aspects of tyres. In a study conducted by the European Commission tyre abrasion was not considered a parameter for choice. The tyre label will include both mileage and abrasion under a single environmental indicator depicted on the new tyre label. This requires the development of a testing method for tyre abrasion that also measures the tread consumption as a proxy of potential mileage. This leads to a fourth constraint, which is that the two parameters, mileage, and abrasion, might not correlate, meaning that the single environmental indicator does not create enough transparency. In the future, a certain mileage of the tyre or a certain abrasion rate must be met by the industry and if this cannot be fulfilled then the tyre has to be improved, which will in turn impact the tyre design (Interview DG Energy, June 2023).

Despite these challenges, the tyre labelling offers opportunities to reduce TWPs by affecting consumer choices upon tyre purchase and increase awareness among end-users through the tyre label. As a result, consumers have the power to incentivize the tyre industry through the purchase of tyres with lower abrasion rates. Moreover, the increased activities around tyre labelling and the development of suitable testing methods for the respective parameters through the work and expertise of standardization organizations also means that tyre abrasion has become inextricably linked to tyre production, including its design.

6.4 Infill ban to reduce secondary TWPs

The ban on infill (as part of the ban for intentionally added microplastics) has consequences for the recycling market for tyres in the EU. The market for ELT is already limited. With the infill ban, the largest recycling avenue of tyres into sports field and playground infill is being phased out. While this limits the leakage of TWPs and chemicals into groundwater, a major constraint is that the ban could lead to lower rates of material recovery (a temporary step back in the circular economy) and increased exports outside the EU with associated export of pollution as there is no immediate alternative market for the material recovery of tyres. A further constraint exists around the lack of interaction between recyclers and producers and the long transition period does not provide immediate incentive to collaborate to developing recyclable tyres. This means that reusing tyres in producing new tyres is not yet pursued, even though as noted in section 6.2 the infill ban and eco-design regulation together form a potential best practice to develop a system for the close loop recycling of tyres.

6.5 Improved wastewater treatment to capture TWPs

The addition of microplastics (and/or TWPs) to the list of priority substances concerning water quality is expected to lead to improved wastewater treatment in EU Member States. The list concerns the WFD, its two daughter Directives (quality of groundwater and quality of surface water), and various other relevant water legislations, such as the UWWTD and Bathing Water Directive. Adding microplastics to the list of priority substances, in terms of it being a best practice, lies with the fact that all organisations whose activities are influenced by these Directives would need to comply with the standards and take measures to limit microplastic release. This would include those responsible for wastewater treatment facilities. The potential decrease of TWPs entering the environment would be significant. However, the main constraint for improving wastewater treatment infrastructure is that these are constructed for long-term use, and updating them can be costly. The technologies for improved treatment that is effective in removing TWPs from wastewaters are readily available, but implementing them is constrained by such costs.

Another constraint is the subsequent use of wastewater treatment sludge for agricultural purposes, a practice that is done in some Member States. While this may be beneficial for the soil and the transition to a circular economy, considerations must be made to limit the release of harmful contaminants back into the environment, especially when more TWPs are captured by wastewater treatment facilities.

PART 2 Best practices and constraints in the governance of PFAS

In this part, we explore the governance of Per- and polyfluoroalkyl substances or PFAS in the EU, specifically around the proposed universal PFAS restriction under REACH. Chapter 7 provides the necessary definitions and policy context to understand the ongoing debates around the PFAS restriction. Chapter 8 gives the governance arrangement analysis which explores the main rules of the game, actors, discourses and power relations. This leads to identification of best practices and constraints in relation to the EU's zero pollution objective of phasing out PFAS, except for essential uses discussed in Chapter 9.

7 PFAS restriction proposal in context

While our governance analysis will zoom in on the universal restriction proposal under REACH, this section provides a broader background of PFAS categories and uses, and context of the very dynamic global and EU-level PFAS governance landscape. We clarify the role of the intended revision of REACH in relation to the universal PFAS restriction proposal, to better understand the debate around the essential use concept. Finally, we summarise the content and rationale of the PFAS restriction proposal.

7.1 PFAS and its uses

PFAS are a group of chemicals composed of fully (per) or partly (poly) fluorinated carbon chain connected to different functional groups (OECD, 2022). This class comprises a diverse range of compounds that share the common feature of the 'per'-fluorinated carbon chain (Cousins, De Witt, Glüge, Goldenman, Herzke, Lohmann, Miller, et al., 2020). The strong bond between the carbon and fluorine gives PFAS properties which makes them very suitable for various industrial applications (SWD (2020) 249). Their properties are exceptional resistance to high temperatures, oil and water repellence, ability to act as surfactants, as well as fire and stain resistance, which make them useful for various industrial applications (UNEP, 2023; SWD (2020) 249).

These chemical properties of PFAS also cause their persistence in the environment, which is why PFAS are labelled as 'Forever Chemicals'. Their persistence results in long-term exposure associated risks such as bioaccumulation potential, mobility, long-rate transport potential, and more (Cousins, De Witt, Glüge, Goldenman, Herzke, Lohmann, Ng, et al., 2020; Glüge et al., 2020; UNEP, 2023); SDW (2020) 249). PFAS have gathered significant global concern regarding their impact (Brennan et al., 2021; Cousins et al., 2022). While some of the big molecules will partially degrade, these will often form small PFAS which are very persistent in the environment (SDW (2020) 249). Although a vast majority of PFAS have not undergone a toxicological characterisation (Sonne et al., 2023; Spyrakis & Dragani, 2023), most of the well-studied PFAS are considered toxic (SWD (2020) 249, (Cai et al., 2021; Chen et al., 2021; Fenton et al., 2021; Rudin et al., 2023).

In Europe, the main source of PFAS is their manufacture and use in industrial and professional installations (SWD (2020) 249). An extensive study compiled the information on their usage, reporting that PFAS are prevalent in almost all industrial branches (Glüge et al., 2020). A total of 531 PFAS registrations under REACH were counted by Rudin et al. (2023), from which 12 PFAS are listed on the candidate list of substances of very high

concern, with some registered as individually and others as part of a group, including the most recent addition 'GenX' (ECHA, 2023b).

The PFAS restriction proposal under REACH, further introduced in section 7.5, brings together information from literature and two consultation rounds with stakeholders to arrive at estimates of tonnages associated with PFAS production and use. The restriction proposal classifies PFAS in three main subgroups and divides them based on their main uses as illustrated in Figure 6 (European Environmental Bureau, 2023).

Group 1 – Classic PFAS: Includes PFAAs and PFAA precursors (including SCFPs)[7], ranging from ultra-short to very long chains. This group effectively focusses on the shorter-chain PFAS given the existing regulation exists to phase out the long-chain PFAS. This group targets for first time the C4 family and individual substances as GenX, ADONA, Cc6O4.

Group 2 - F-gasses: encompass the PFAS that are gasses or very low-boiling liquids. Within this group there are HFCSs, PFCs and HFOs, mostly small molecules under C6.

Group 3 – Polymers: also regarded as 'plastic PFAS', they are composed of a small number of linked monomers but do not fulfil the criteria of the polymer definition in REACH regulation. They are long molecules that repeat the same sequence of 2-5 carbons over and over. Generally, these are are hard or rubbery solids.

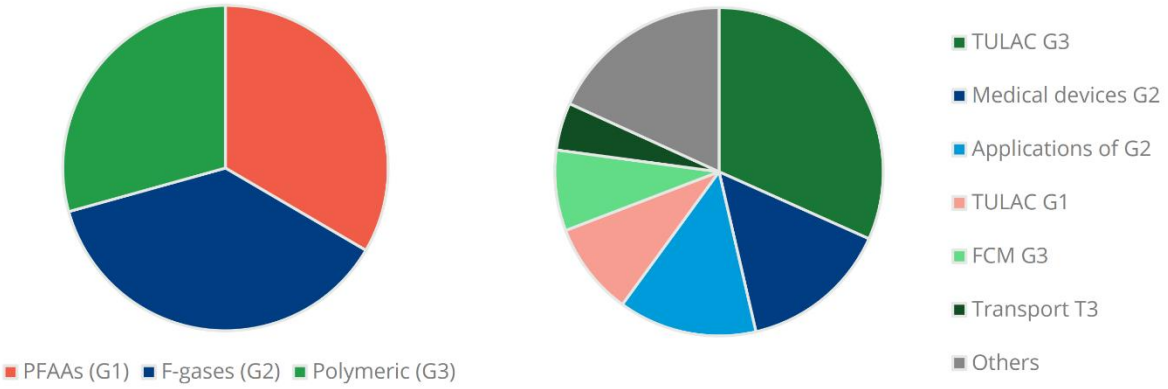

Figure 6 Tonnage of three PFAS sub-groups, and six main PFAS uses (Source: EEB, 2023)

There are many ways to categorise PFAS uses and applications. Based on the information in the Restriction proposal (Annex XV), the European Environmental Bureau concluded that six groups of applications make up more than 80% of the total volume of PFAS.

- Textile, upholstery, leather, apparel, and carpets including applications of Polymers (G3) and Classic PFAS (G1),
- Medical devices (e.g. metered dose inhalers) using F-Gases (G2),
- Applications of F-gasses such as refrigerants and air conditioning (G2)
- Transport (such as seals and gaskets)
- FCM (Food contact materials, including food processing)

[7] The acronyms in this section are not spelled out because the full name of these complex chemicals would not bring extra clarity to a reader not already familiar with these substances.

7.2 PFAS and Global regulation

Since the early 2000s, global efforts have been made to regulate PFAS and to halt their emissions to the environment (Brennan et al., 2021)[8]. The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in 2001 and ratified in 2004 with the aim to eliminate the production and use of substances of very high concern. The Stockholm Convention has a restriction in place for some of the most toxic long-chain PFAS, such as PFOS (since 2009), PFOA (since 2020) and most recently the substance group PFHxS (since August 2023). PFCAs are another long-chain PFAS substance group, which is proposed for listing under the convention (Stockholm Convention, 2023).

In a similar manner, regional sea conventions with EU relevance such as HELCOM or OSPAR have already included PFOS in their action plans for their competent mandates. Nevertheless, OSPAR has stated that additional work and measures should be taken by the EU (Nyström, 2018).

7.3 PFAS and high-level EU policy objectives

In 2019, the European Commission introduced the Green Deal, which outlined the Commission's commitment to safeguarding citizens and the environment from harmful chemicals through the management of hazardous chemicals like PFAS to ensure a toxic-free environment. Subsequently, in 2020, the Commission unveiled the Chemical Strategy for Sustainability, acknowledging the special attention needed for PFAS due to mounting evidence of water and soil contamination and their impact on human health (COM (2020) 667). The Strategy defines PFAS as substances of concern with the potential to be harmful to human health and the environment. They are also seen as hampering the recycling of PFAS containing products for safe and high-quality secondary raw materials in a circular economy.

The Chemical Strategy for Sustainability requires actions under REACH for non-essential uses of PFAS and actions in other relevant directives, such as those on Groundwater, Food, Industrial Emissions, and Sewage Sludge. Between the key actions around PFAS, the Strategy also mentions plans for financial support for innovative solutions as well as the introduction of criteria for identifying chemicals of ‘essential use’ (SWD(2020) 247; COM (2020) 667).

Of equal relevance, the Zero Pollution Action Plan seeks to develop pollution indicators for chemicals such as PFAS. This action plan focuses on reviewing the Environmental Quality Standards and Groundwater Directive with the possibility of adding PFAS. At the European level existing regulations primarily focus on preventing water quality degradation due to PFOS, as seen in the Waste Shipment Regulation and the proposed revision of the Sewage Sludge Directive (Devriese et al., 2023).

One of the key proposed actions mentioned in the Chemicals Strategy section 2.2 is a revision of the European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). It entered into force in 2007, with the main goal of safeguarding the human and environmental health, promoting alternative hazard assessment methods and facilitating the free flow of substances in the EU market while fostering competitiveness and innovation (Filipec, 2017). REACH is considered as an

[8] Further information is available in D2.1. The Zero Pollution Ambition (Devriese et al., 2023).

important and comprehensive regulation for chemicals, influencing environmental policy discussions from the local to international level as well as establishing the most ambitious standards globally (Botos et al., 2019).

Indeed, the Commission in its work programme for 2023 announced a targeted revision for REACH, for "securing European competitive advantages and innovation by fostering sustainability" (COM(2022) 548). This revision gathered broad support, with many recognizing its relevance in preventing delays in the implementation of regulatory risk management (EEB, 2022). It is seen as significant for improving the suitability of new initiatives, including the PFAS restriction proposal (Corporate Europe Observatory, 2023a) and as a necessary step in supporting a non-toxic circular economy (CHEMSEC, 2022). However, the work plan for 2024 published on 17th of October 2023, does not include such a revision in its agenda, thus excluding it from the current Commission's agenda for the next year. It is worth emphasizing that the delay in revising REACH and the ongoing proposed universal PFAS restriction are distinct processes, although there are similarities in the dominant discourses and actors involved.

7.4 PFAS in EU regulations and directives

In 2004, the European Union adopted a Regulation on Persistent Organic Pollutants to safeguard both public health and the environment from these harmful substances. The regulation was designed to align with the provisions of the Stockholm Convention at the European level. As such, PFOS, PFOA, and PFHxS, along with their salts and related compounds, are listed in Annex I, restricting the manufacture, placing on the market and use of POPs with specific exemptions for intermediate use or other specifications (Regulation (EU) 2019/1021 amended by (EU) 2022/2400).

Under the Industrial Emissions Directive, measures to prevent and reduce emissions to the environment are placed on industrial activities in sectors of energy, metal production, chemicals, waste management and others (Publications Office of the European Union, 2020). Currently, the Industrial Emission Directive sets limits on PFAS emissions from production as well as the obligation to clean up (European Environmental Bureau, 2023). The review of this directive was listed in the action plan of the Chemical Strategy for Sustainability proposing to address emissions and reporting of PFAS from industrial plans (COM (2022) 156). However, the report with the amendments (COM (2022) 156) does not include further measures targeting PFAS. The revision is still ongoing and the trialogue negotiations are taking place at the time of writing this report (Parliament, 2023).

The Environmental Liability Directive became effective in 2007, outlining a comprehensive EU liability framework for addressing environmental damage while adhering to the 'polluter pay's principle. The enforcement of this Directive places those responsible for environmental harm to undertake necessary remediation actions thereby creating a powerful incentive to prevent such damage from happening. The Environmental Liability Directive supports other environmental laws protecting the environment (Directorate-General for Environment, 2023).

There are two environmental directives that control and monitor the levels of PFAS in the environment. First of all, the Water Framework Directive with its daughters directives on Priority Substances and Priority Hazardous Substances, and the Environmental Quality Standards Directive that outlines the standards to achieve a good environmental status in water bodies and reduce the pollution of surface waters (Department of Agriculture,

Environment and Rural Affairs, 2016; Devriese et al., 2023). Furthermore, the Marine Strategy Framework Directive defines threshold values for contaminants in coastal waters and beyond within its descriptors, especially D8.1: Concentration of contaminants and D9.1: Levels of contaminants in seafood.

The EU has a dedicated regulation for fluorinated greenhouse gases, the F-gas regulation (EU) No 517/2014. These gasses are used as refrigerants and cause concern primarily for their significant global warming potential. While not all F-gases are PFAS, the most common one is hydrofluoroolefin (HFO) which breaks down into trifluoro acetic acid (TFA) which is a very persistent, mobile and toxic PFAS. Despite a dedicated F-gas regulation, the Dossier Submitters have included F-gases in the scope of the universal restriction proposal, with the argument that the existing regulation aims at reducing global warming and does not aim to ensure the safe use of chemicals (Interview Dossier Submitter, October 2023; ECHA, 2023d).

Annex XVII of REACH shows that three restrictions on PFAS have been adopted so far: restriction 68 on PFOA (effective 2020, but subsequently revoked as it was listed under the POP legislation), restriction 73 on C6 silanetriols in spray products (effective 2021), and restriction 68 on perfluorocarboxylic acids (C9 – C14 PFCAs), phasing them out of the market from February 2023 onwards (ECHA, 2021; Regulation (EU) 2021/1297). Moreover, three restrictions under REACH are currently pending (see Figure 7). These are a group restriction on PFHxA, a restriction on the use of PFAS in firefighting foams, and the universal restriction proposal that is the focus of our analysis.

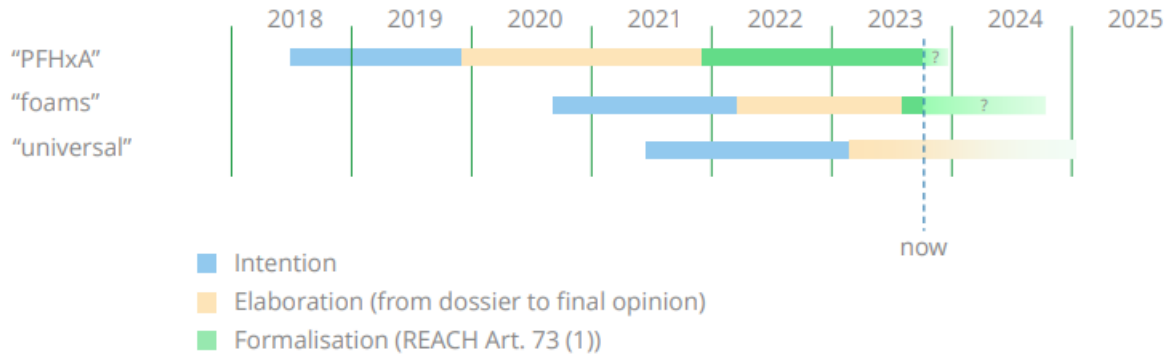

Figure 7 Timeline of ongoing PFAS restriction proposals in REACH (Source: EEB, 2023)

While PFOS, PFOA and PFHxS had already largely disappeared from the market by the time the restrictions came into force, the restriction on PFHxA, it's salts and related substances will for the first time affect industrially relevant PFAS.

7.5 The universal PFAS restriction proposal under REACH

The universal restriction proposal, if adopted, will become the most far-reaching PFAS regulation measure in the world. The restriction proposal was drafted under Article 68 of the REACH regulation by the German Federal Institute for Occupational Safety and Health, the Dutch National Institute for Public Health and the Environment (RIVM), the Swedish Chemicals Agency, the Norwegian Environment Agency and the Danish Environmental

Protection Agency. The restriction proposal was submitted as Annex XV Restriction Report to the European Chemicals Agency (ECHA) on 13 January 2023.

The Annex XV restriction report, consisting of 204 pages with 7 annexes and 4 appendices, is considered the most substantive dossier on PFAS to date. The restriction report is structured in four parts. The first part introduces and identifies the problem, including the hazard, exposure/emissions and risks, as well as the justification for an EU-wide restriction measure and baseline. The second part outlines the impact assessment, including regulatory risk management options, restriction scenarios and the assessment of economic, human health and environmental impacts, as well as the practicability of restriction options and approaches to enforcement and monitoring. The third part provides answers to uncertainties, such as the risk, extent of the problem and benefits to society. The fourth chapter concludes with a need for a restriction based on several considerations.

The scope of the proposed restriction encompasses more than 10.000 PFAS, excluding PFAS used in firefighting foams because these are regulated separately, and a few fully degradable PFAS subgroups. It also excludes active substances used in biocides, pesticides, pharmaceuticals, and veterinary products, as these substances can potentially be regulated by other EU legislation. Due to their high persistence and accumulation in the environment, PFAS are approached as one chemicals group (Regulation (EC) No 1907/2006 of the European Parliament and of the Council, 2006, ECHA, 2023; Wollin et al., 2023). The pursued objective of this regulation is to avoid PFAS emissions by prohibiting, where possible, the manufacture, placing on the market and use of PFAS (ECHA, 2023, p.76). The underlying rationale of the restriction proposal is the application of the precautionary principle due to the potential adverse effects of PFAS on human health and the environment through their persistence and bioaccumulation (ECHA, 2023a; Obolevich, 2023).

Two restriction options are presented in the dossier. The first restriction option consists of a full ban with an 18-month transition period for all PFAS and uses. The second option allows exceptions for certain applications, which are called derogations. The second restriction option suggests a ban with a total of 25 use-specific and time-limited derogations from 5 up to 12 years, following the universal 18-month transition period. There are very few time-unlimited derogations proposed, e.g. for PFAS used for reference in environmental monitoring. Five-year derogations allow for the use of PFAS where PFAS alternatives are available in principle but have yet to be developed at scale. 12-year derogations allow for PFAS uses where alternatives must still be developed. The proposed time-limited derogations would be based on socio-economic considerations and the availability of PFAS-free alternatives, in particular, if technically and economically feasible alternatives are not available at all or if they are not available in sufficient quantities (Wollin et al., 2023). Based on the dossier submitters' assessment for the 14 sectors in which the largest amount of PFAS are produced and used, the proposal recommends the second restriction option (Obolevich, 2023).

As of November 2023, the public consultation has closed resulting in an unprecedented 5600 contributions. The Risk Assessment Committee (RAC) and Socio-Economic Analysis Committee (SEAC) committees are developing their opinions, aided by the dossier submitters, who are addressing the issues raised in the consultation to feed into their final opinions. While there are legal timelines for this process, due to the scope of the proposed restriction this will likely take longer than usual (Interview DG Grow, October 2023).

8 Governance arrangement for PFAS restriction proposal

This chapter addresses the first research question for PFAS: **Which governance arrangements exist or are emerging that – as response to the Zero Pollution Action Plan - (will) govern PFAS generation and release into EU waterways that ultimately reach the marine environment?** The existing EU governance arrangement for the PFAS restriction proposal is shaped by the rules of the game of the REACH regulation, the involvement of multiple actors, their power relations, and the discourses in relation to the concerns and preferences of how to regulate PFAS as summarized in Table 8.

Table 8 Summary of governance arrangement dimensions of PFAS restriction under REACH

	PFAS restriction
Rules of the game	Three-phase process led by ECHA, with stakeholder consultations and scientific committees, as articulated in REACH legislation
	Revision of REACH (potential inclusion of 'essential use')
Actors	EU policy makers (European Commission, DG environment, DG grow, Member States)
	ECHA
	Primary producers (BASF, 3M, Gore, VCI, Chemours etc.)
	Industry trade organisation, with their PFAS sector groups (CEFIC with FFP4EU, Plastics Europe with FPG)
	Manufacturers across many sectors (pharma, transport, textile, etc.)
	European Court of Justice
	Environmental NGO's and academia (EEB, Client Earth)
	Investigative journalists (Le Monde, The Investigative Desk)
	Citizens, consumers and victims
Discourses	The universality of the PFAS restriction proposal, and the grouping of PFAS is debated
	The need to avoid 'Regrettable Substitution'
	Possibility of contained, non-polluting PFAS production
	How to operationalise an 'essential use' concept?
	PFAS as essential for the green transition and the EU's policy goals
	To what extent should industry have a say in their own regulation?
Power relations	Chemical industry has large lobbying budgets and access to decision-makers, both formally and informally.
	The PFAS industry have an information advantage, which gives them the upper hand in relation to policy makers, NGOs and the general public
	High-level policy objectives, as well as concrete legislation (proposals) have far-reaching effects

	Litigation power is emerging as a key manifestation of power, with companies challenging policy makers, and the public, NGOs and government filing cases against polluting PFAS producers
	Environmental regulatory enforcement at EU level and Member State level is low
	Public awareness is increasing, manifesting in changed consumer preferences and citizen-led litigation

8.1 Rules of the game

The rules of the game are to a large extent institutionalised in the REACH regulation, which stipulates a structured process with distinct phases, as illustrated in Figure 8.

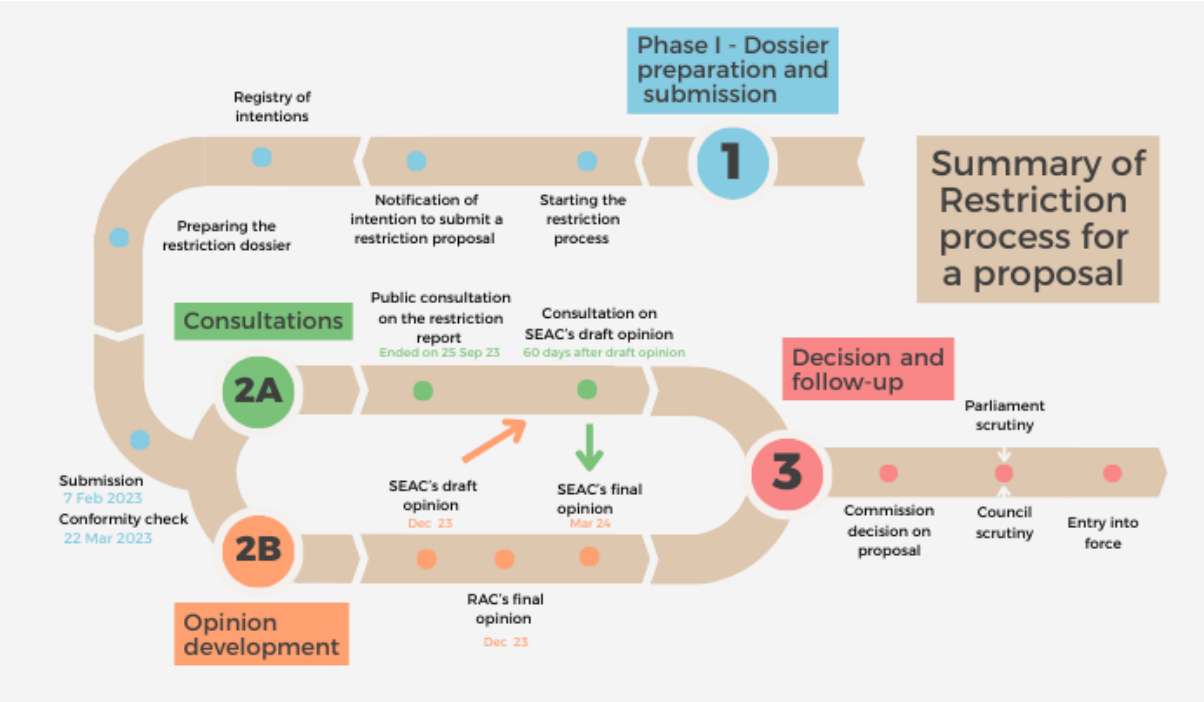

Figure 8 Flowchart of restriction process under REACH

Phase I - Dossier preparation and submission

Any Member State or ECHA (under the request of EC) can start a restriction procedure on a certain substance that poses concerns and unacceptable risks for human or environmental health. A public register of the intention to prepare a restriction is made before the proposal is prepared. The dossier must include information on hazards and risks, available information on alternatives and a justification for restriction at EU level. In this phase, comprehensive data and information gathering takes place including an analysis of the socio-economic impacts. The period of submission is 12 months since the intention register. During the preparation process, ECHA or Member States launch a call for comments and evidence. Later, the dossier submitters compile the data and adapt the dossier to meet the requirements of REACH (Annex XV). Once this information has been gathered the dossier is submitted for review by ECHA, who is responsible for assessing the proposal's compliance with REACH (ECHA, n.d.-b).

On 13 January 2023, Denmark, Germany, the Netherlands, Norway and Sweden submitted the dossier to ECHA proposing a restriction of more than 10.000 PFAS to reduce their introduction into the environment. The process leading up to the submission of the proposal included a call for evidence from May to July 2020 and two stakeholder consultations. The second stakeholder consultation took place from July 2021 to October 2021 and was followed by a drafting period of the proposal from October 2021 to January 2023. The first meeting of the submitting parties took place in January 2020.

Phase II A –Public Consultations

On its website, ECHA publishes the restriction reports and launches a public consultation. Any interested party can provide comments within six months of the date of publication. The public consultation regarding the universal restriction in PFAS was launched between the 22nd of March and the 25th of September 2023. The consultation received around 5600 comments on the proposal, from which 58.7% came from companies, 27.3% Individuals, 9.8% Industry or Trade associations and 4.1% Others (e.g., Academia, NGOs, International, National and Local authorities) (ECHA, 2023c). In this phase there is also a consultation on the draft opinion of the SEAC, which is published after 9 months from the publication date of the proposal. Once the draft is published, a consultation will run for 60 days from the publication date of the draft opinion (ECHA, n.d.-b).

Phase II B –Opinion development

Simultaneously, the committees develop their opinion. An important part of the development is the Forum for Exchange of Information on Enforcement, which contributes with advice to the committees promoting a harmonised enforcement of regulations. This Forum is a network of authorities responsible for the enforcement of REACH and related regulations in EU, Norway, Iceland, and Liechtenstein. Other participants for developing the Forum's advice are the ECHA secretariat, experts from Member States, European Commission, and accredited stakeholder organisations (ECHA, 2023d). The Forum provided their advice on the enforceability of the universal FAS restriction proposal on the 8th of November.

The Risk Assessment Committee (RAC) prepares its opinion looking at how the proposal will reduce the risks posed to human health and the environment. The RAC's final opinion is developed within 9 months from the publication of the restriction report and takes into account the Forum's advice as well as comments from the public consultation. During the same period, the SEAC prepares and agrees on a draft opinion considering the assessment of socio-economic information. The draft opinion considers the Forum's advice and opinion on the consultation of the restriction report and socio-economic analysis. Integrating the comments on its draft opinion, the SEAC formulates its final opinion after 3 months from the draft opinion (ECHA, n.d.-b). The opinion of the committees is expected during 2024.

Phase III – Decision and follow up

The Commission prepares a draft amendment to the list of restrictions within 3 months. If the Council or the European Parliament do not oppose, then the restriction is adopted. The final decision is published in the official journal, while ECHA publishes the restrictions on its website (ECHA, n.d.-b). The Commission's decision for entry into force is expected for 2025 and the restriction is expected to become effective in 2026/2027 (Wollin et al., 2023).

8.2 Actors

Actors involved in the governance of PFAS include a range of EU institutions, industry organizatons and other organizations, such as NGOs, media and the general public.

EU and national institutions

The European Commission has the mandate to ensure that chemicals are safe for human health and the environment. The commission can adopt measures to update and complete the regulation such as new restrictions, laying down testing methods, or determining the fees companies pay for the European Chemicals Agency (ECHA) (DG GROW, 2023). In the EU policy making process there is an important role for other actors such as the Council of the EU. The Member States and European Parliament are two decisive actors, as they will vote on the proposal presented by the European Commission.

Ensuring the effective implementation of EU's chemical legislation, ECHA is the competent agency of the European Commission that manages the technical, scientific, and administrative aspects of REACH (DG GROW, 2023). ECHA collaborates with DGs for specific policy areas within the Commission. For PFAS this responsibility is shared between DG ENV, which is responsible for the alignment between policy documents related to PFAS in the environment, and DG GROW which is responsible alongside DG ENV for the REACH and CLP regulation (Devriese et al., 2023; ECHA, n.d.-a).

At the national level, concerning REACH, it is the duty of National Authorities to enforce the regulation, conduct official controls and impose penalties for non-compliance, also when they consider that risks are not adequately managed, they may restrict manufacturing and use of substances (ECHA, n.d.-a; Publications Office of the European Union, 2022).

Initiating the proposal, the Netherlands commissioned Bureau REACH of the RIVM to draft the proposal on behalf of the Dutch Government. Later, four countries joined the initiative, and the Netherlands and Germany assumed a coordination role (RIVM, 2023). From Germany, the Federal Institute for Occupational Safety and Health, the Federal Environment Agency and the Federal Institute for Risk Assessment were involved in the preparation of the proposal (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2023). Moreover, the Swedish Chemicals Agency, the Norwegian Environment Agency and the Danish Environmental Protection Agency joined the drafting in support of the proposal.

The Court of Justice of the European Union (CURIA) takes an important role in the governance of PFAS in the EU (Jones Day, 2023). For example, in 2022, the European Court of Justice overruled Chemours and confirmed the inclusion of GenX chemicals in the Substance of Very High Concern list under REACH (ClientEarth, 2022).

Industry and their trade organisations

Among chemical and plastic industry actors, 3M, AGC, Archroma, ARKEMA; BASF, Bayer, Chemours, Daikin, Dongyue, Honeywell, Merck and Solvay, are the 12 world's largest PFAS producers (International Chemical Secretariat, 2023). Since 2021, their interests are represented at EU level through the lobby group FluoroProducts and PFAS Europe (FPP4EU) (Corporate Europe Observatory, 2023b). In 2022, Plastics Europe, representing plastic pellet producers at EU level, set up a similar group focusing on PFAS, namely the Fluoropolymers Product Group (FPG) representing Europe's leading fluoropolymer producers and experts. Among its members are 3M, AGC, Arkema, Chemours, Daikin Chemical, DuPont, W. L. Gore & Associates, Gujarat Fluorochemicals, Honeywell, and

Solvay. Industry actors operating more closely to consumers, including retailers and product brands, increasingly support measures at source, such as the phase out of PFAS uses under the restriction proposal (Greene, 2022; The International Chemical Secretariat, 2020). Drinking and wastewater service operators also support a PFAS restriction at source and are at EU level represented through EurEau. Producers of PFAS alternatives appear to be less vocal in the discussions. They either constitute of the same PFAS manufacturers or operate in a value chain where they cannot risk jeopardising their relationship with PFAS producers (Interview DG Environment, October 2023).

Other actors

The NGOs Client Earth, acting as a legal watchdog, and the NGO CHEM Trust and the ChemSec Business Group have provided substantial support to ECHA and the Dutch government in the GenX litigation case (ClientEarth, 2022). Furthermore, environmental NGOs, as represented through the European Environmental Bureau (the largest network of environmental citizen's organizations in Europe), take an important role in influencing the EU agenda on recognizing PFAS as an environmental problem, requiring effective regulation. Among academia, PFAS only very recently appears as a topic of primary interest and ongoing research remains rather limited.

More recently, the media has raised public awareness of the effects and associated potential risks of PFAS to human health and the environment by showcasing locally affected communities, such as in Belgium and the Netherlands. The Forever Pollution Project has uncovered and mapped 17.000 PFAS contamination sites and hot spots in Europe. The project was initiated by multiple media and news outlets such as Le Monde, NDR, WDR, Süddeutsche Zeitung, RADAR Magazine, Le Scienze, The Investigative Desk and NRC (Forever Pollution Project, 2023). Moreover, the project revealed the lobbying power of industry towards the European Commission and EU Member States to influence the proposed PFAS restriction (ibid.).

In the general public, awareness of the characteristics and the governance of PFAS remains rather limited but is seen as rapidly increasing. This is driven by increasing media mentions of PFAS, often covering stories of local communities near PFAS emission hotspots in Belgium, the Netherlands, France and Italy. While PFAS has not emerged as an issue of great electoral relevance, it might become a factor in EU elections due in 2024. Consumers are already having an impact. In 2016, IKEA[9] banned PFAS from its textile products, and since 2013 H&M Group[10] has phased out PFAS in a range of products. Many brands are following suit in response to – or in anticipation of - consumer pressure.

[9] https://www.ikea.com/global/en/our-business/our-view-on/chemicals/

[10] https://hmgroup.com/our-stories/phasing-out-pfas/

8.3 Discourses

This section covers the most relevant discourses around the restriction proposal for PFAS under REACH. It is a highly polarized debate where the stakes are high. The strong C-F bonds that give PFAS their unique application in many production processes and product applications are the very reason for concern in terms of persistence in the environment with accumulating health- and ecosystem effects. A summary of the discourses in relation to the main actor groups is shown in Figure 9.

The universality of the PFAS restriction proposal

One of the unique and defining features of the restriction proposal is the broad scope and 'universal' approach. The dossier submitters argue that the group approach is warranted because of the persistence that is the common factor across all PFAS, as well as additional risk factors that may indeed vary across specific substances, such as toxicity, bio-accumulation and mobility (ECHA, 2023f). This is in line with recent scientific findings arguing that "the continual release of highly persistent PFAS will result in increasing concentrations and increasing probabilities of the occurrence of known and unknown effects" (Cousins, De Witt, Glüge, Goldenman, Herzke, Lohmann, Ng, et al., 2020).

The move towards grouping approaches is also in line with the EU Chemicals Strategy for Sustainability and is already implemented through the restriction proposal of PFHxA and the recent restriction on intentionally added microplastics. During the consultations on those restrictions, the 'group approach' was not questioned as much as with the universal PFAS restriction. Our interviews indicate that there is also broad support for the universal approach in both the RAC and SEAC committees (Interview Dossier Submitter and DG Grow, October 2023).

In contrast, the industry is highlighting the diversity of PFAS and thereby questioning the very foundation of the universal restriction approach, in particular in reference to fluoropolymers and F-gasses (see e.g. 3M, 2023)) which together constitute approximately two-thirds of all PFAS. In the interview with PlasticsEurope (November 2023), the respondent portrayed fluoropolymers as 'polymers of low concern', and as inert materials that do not pose a significant risk to users or the environment. They argue that the risk profiles for PFAS are very diverse, and this should be reflected in a more differentiated approach to a restriction, rather than classifying all PFAS as substances of concern (FFP4EU, 2023).

The dossier submitters, however, argue that fluoropolymers in the EU are not considered polymers of low concern, predominantly, but not exclusively, because of high emission during the manufacture and the end-of-life stage (ECHA, 2023d; Dossier Submitter, October 2023). This is based on recent research by Lohmann et al. (2020) who argue that on the grounds of the "extreme persistence; emissions associated with their production, use, and disposal; and a high likelihood for human exposure to PFAS, their production and uses should be curtailed except in cases of essential uses".

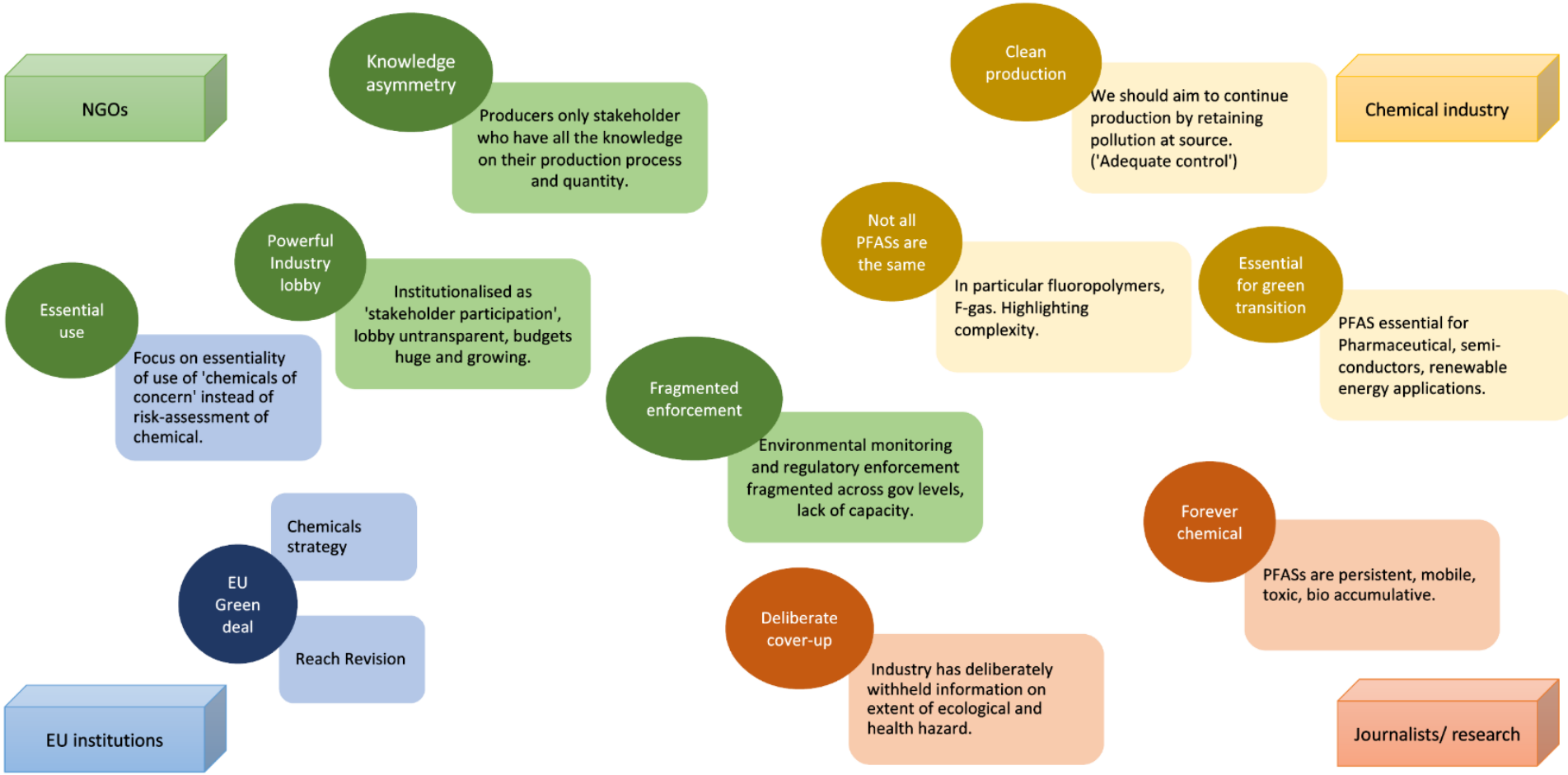

Figure 9 Discourses around EU universal restriction proposal for PFAS

Chemical producers furthermore argue that REACH is unfit for restrictions of such large groups of substances and have questioned its legal basis. Their argument is that REACH necessitates the identification of 'unacceptable risk' before imposing bans or restrictions on chemical substances. With the extensive scope of the proposal, it is likely to encompass substances for which a detailed risk assessment has not been conducted (3M, 2023). However, the proposal submitters have stressed that the broad scope is grounded in the shared persistence characteristics within the group, a factor proven to elevate toxicity risks through accumulation and combination effects (ECHA, 2023 Client Earth). ClientEarth (Interview November 2023) highlights that the PFAS restriction can legally be adopted under the current REACH regime set out in Article 68.1 which does not rule out the adoption of group restriction. Annex I, 0.10 confirms the possibility of taking a case-by-case approach to the shaping of the risk assessment, which is what the dossier submitters have implemented.

Regrettable substitution

The key argument for the proposed universal ban of the PFAS group is to avoid regrettable substitution (Interview Dossier Submitter, October 2023). This is a situation where a known hazardous substance is being legislated after extensive research, only to be replaced by an unregulated substance with effects that are as bad or even worse than the originally banned substance. A well-known example is DuPont's use of the harmful short-chain PFAS GenX after it phased out the long-chain PFOA (Ahearn, 2019). This substance-by-substance approach, sometimes referred to as chemical 'whack-a-mole' would be unworkable from a regulatory perspective, and the concern for regrettable substitution is responsible for the broad political support for group restrictions (interview EEB, October 2023; Ahearn, 2019). For example, the Chemical Strategy for Sustainability concluded in its Staff Working Document on PFAS that a group approach will be beneficial (SWD/2020/249).

Interestingly, the industry is also using this argument with the opposite intent: to advocate for the continued use of known hazardous substances because being forced to rapidly abandon PFAS might drive producers to replace them with worse substances. For example, the Fluoropolymers Product Group in their position paper on the PFAS restriction proposal argue that the lack of alternatives could 'open the door for regrettable substitution' (FPG, 2023). This appears to downplay the extensive procedures specified in REACH Annex XVI, which includes impacts on possible benefits for human health and the environment, and social and economic benefits of PFAS, as well as availability, suitability and technical feasibility of the PFAS alternatives.

(Im)possibility of contained, non-polluting PFAS production

The 'adequate control' route of continued PFAS production seems to be preferred by industry actors. They argue that if emissions can be contained, it should be possible to use substances of very high concern for societal benefit. NGOs and researchers have expressed doubts about the feasibility of this option on the short-term and argue that a restriction is currently the only technologically feasible way of limiting emissions to the environment (interview European Environmental Bureau, October 2023). In the interviews with industry representatives (CEFIC, November 2023; Plastics Europe, October 2023) examples were highlighted of improved remediation at production sites, worker safety measures as well as the development of end-of-life measures as a promising route to contain and minimise the risks of PFAS.

In the interview with EEB and Le Monde, it was argued that that shifting attention and responsibility to another life cycle stage is a recurrent tactic of the petrochemical industry, which allows chemical producers to continue the production of chemicals of concern, while simultaneously showing that they recognise the importance of pollution and are doing something about it (Tilsted et al., 2022).

The potential for remediation of PFAS once they have entered the air, soil or water systems is also subject to different perspectives. Industry actors highlight the emerging technological possibilities for filtering PFAS on contamination sites. Annex XV of the restriction report concludes that "removal or remediation might only be feasible for contamination hotspots in few specific cases, but not for the majority of the environment, such as large aquifers, surface waters and the world's oceans". Even where technically feasible, the costs of continued emission and thus also remediation of PFAS would become prohibitively expensive (ChemSec, 2023). The combination of sky-rocketing healthcare costs from accumulating hazard and exposures, and the need for widespread environmental remediation could effectively result in the bankruptcy of society if no restriction is agreed (interview Le Monde, 2023).

PFAS and the essential use concept

One of the few topics all actors seem to agree on is that there should be exceptions to the restriction of PFAS. However disagreement quickly starts when it concerns the extent of these exceptions and the specific approach taken to determine candidate derogations. While the industry aims to achieve exceptions for (groups of) *chemicals*, such as fluoropolymers, there is increasing attention to implementing an essential use concept which would look at the essentiality of the *use or function of a chemical* (group) (Cousins et al., 2021).

In a Staff Working Document, Member States extended their concerns about the absence of the definition of 'essential use' for chemicals as presented in the Chemical Strategy for Sustainability to be a key part of regulatory frameworks including those that apply to PFAS (SWD2023/0239). The dossier submitters decided early in the dossier preparation process that they would not use the essential use concept, even though it was initially seen as an attractive approach to take with regulating PFAS. They sensed that it would direct discussions away from the objective of the proposal since essentiality has not been defined within the current legal framework of REACH (interview Dossier submitter, 2023).

While the word 'essential use' indeed does not feature in the Annex XV restriction report, it is nevertheless a hotly debated topic and one that emerges as a cross-section between concrete discussion about the universal PFAS restriction and more fundamental and broader discussions about the need to reform chemicals regulation in terms of the effectiveness, processing speed and clarity for all actors (Santos et al., 2022).

Since all PFAS are considered substances of concern, the dossier submitters did not include derogations for chemicals based on a chemical risk assessment. The derogations were proposed for certain applications, which were only considered justified if evidence on the non-availability of alternatives was conclusive. While this appears to approach an 'essential use' concept by proxy, it requires a detailed assessment of the availability of alternatives, even if the use could be considered non-essential. The proponents of the idea suggest that implementing the essential use concept could speed up the process and provide clarity to industry which would allow them to direct innovation towards non-polluting chemistry.

The concept of essential use was first applied in 1977 in global discussions about the restriction of ozone-depleting substances as defined under the Montreal Protocol in Decision IV/25. Figure 10 illustrates how the categorisation as 'essential' hinges on 1) the uses' necessity for health and safety, or being critical for the functioning of society, and 2) the availability of technically and economically feasible alternatives (Cousins et al., 2021). This approach results in three use categories: non-essential uses, substitutable uses, and essential uses (Cousins et al., 2021). The concept has been mentioned in the discussion around restricting PFAS and was adopted in the Chemical Strategy by the European Commission in 2020, however, the industry poses strong criticism towards the concept (Cousins et al., 2021; Wood, 2022a).

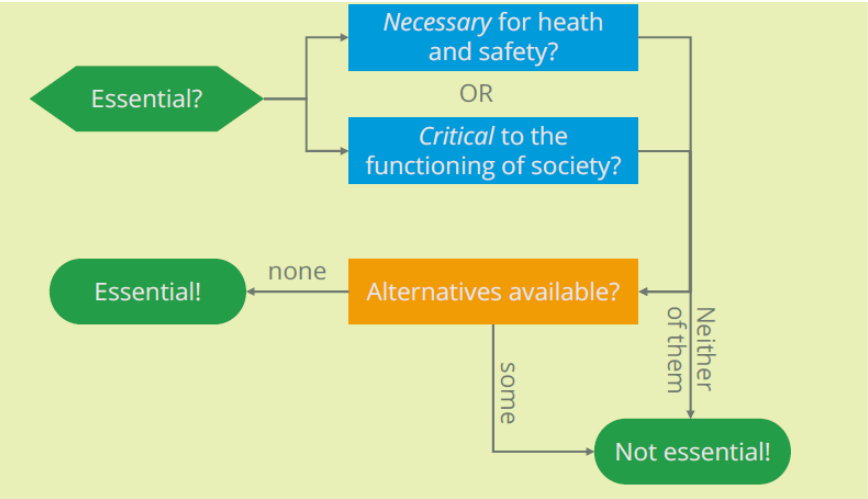

Figure 10 Flowchart for definition of essential (EEB, 2023)

In the interview with EEB (October 2023) it was highlighted that even for essential uses, the second question should continue to be addressed, i.e., whether there are technical and economically feasible alternatives. Industrial PFAS producers and manufacturers have been invited and actively engaged in providing evidence that the use of PFAS in their application is not substitutable. However, in the media and the responses to the public consultation, industry actors are primarily framing the definition of essentiality around the importance of PFAS for a wide range of processes, products and applications, exemplified by the claim that PFAS are essential for the green transition (see next section) rather than addressing substitutability.

The debate shows that the 'essential use' concept is very fluid, and that actors are adapting the 'essential use' label to strengthen their position, be it continued production and use of PFAS with a broad definition of 'essential', or the importance of investing in alternatives with very few, time-limited derogations and a narrow definition of 'essential'. This is exemplified in the order of steps in decision-making. NGOs propose that the question of essentiality for society should be asked as a first filter, already excluding many uses from derogations on the use of substances of concern, followed by substitutability. In a decision tree proposed by FPP4EU, the question of 'vitality for society' only features towards the end of the decision tree, if all other steps have been completed, including detailed risk assessment (FPP4EU, 2022). That keeps many more avenues open for continued production and use of harmful chemicals and emphasises evidence-based risk assessment and the consideration of containment methods during production and end-of-life.

PFAS for the sustainability transition and the economy

One argument put forward by industry actors is that PFAS are essential for the green transition, the EU sustainability agendas and more generally the economy. This narrative hinges on the fact that PFAS are used in e.g., solar panels and semi-conductors. It challenges the group approach, with a claim of essentiality and non-substitutability and a threat of unacceptably high societal costs to imposing restrictions on PFAS as a group.

In particular around fluoropolymers the argument is voiced that they "are used in critical applications that help deliver strategic EU and UN climate objectives and are an enabler of the European Green Deal, the Chips Act, Hydrogen Strategy, and Sustainable and Smart Mobility Strategy" (FPG, 2023). The proposed restriction is also seen as creating "general uncertainty that would undermine investment decisions and innovation in these and other important EU ambitions" (ibid.). In the financial times, a Chemours director says: "It's really amazing to me that we would think of walking away from a group of chemistries . . . that enables the green economy. [...] Such a decision would direct investment out of the bloc, and 'deindustrialise' Europe" (Hollinger & Ting-Fang, 2023).

Indeed, the second restriction option creates an additional burden to PFAS manufacturers and importers required to provide an annual report outlining the basis of their derogations and types and quantities of used PFAS (Obolevich, 2023). Consequently, voices from industry associations as well as policy makers, such as the German economy and climate minister, have raised concerns about the proposed restriction of PFAS due to the hampering effect for growth and technological development and their important role for a green transition (Dahm, 2023; German Association of the Automotive Industry, 2023). Without PFAS there would be "No wind turbine, no energy storage, no electric car, no semiconductors" (German Association of the Automotive Industry, 2023).

Whether this is an accidental or deliberate misunderstanding of the restriction proposal is unclear, but dossier submitters recognise the need to maintain PFAS for critical applications and have for that reason included time-limited derogations. The NGO Chemsec argues that there is 'a tendency to overestimate the role of PFAS as essential', citing the example of the fluoropolymer application in the EU for which an exception is being sought by industry groups. They claim that only about 8 per cent of the total production volume for fluoropolymers goes towards the often-cited examples of renewable energy, semiconductors and pharmaceuticals, of which the latter is already mostly exempted from the restriction proposal (CHEMSEC, 2023; Wood, 2022b)). In most other applications there are viable alternatives. Dossier submitters have explicitly stated in the annex XV report, and in subsequent webinars and information sessions, that the derogations currently listed in the restriction proposal are incomplete and that they welcome additional data supporting new or broader derogations to support critical applications (interview Dossier submitter, October 2023). Nevertheless, the main rationale of the proposal is, also for critical applications, that innovation and investment should be directed away from PFAS, while balancing the industry requirements for a realistic transition time (interview EU Policy maker, October 2023).

The role of the chemical industry as a stakeholder in policy making

It is primarily because of the efforts of investigative journalists, documentary makers and the court cases against petrochemical industry that regulators and society have slowly become aware of the serious health and environmental effects of PFAS (Gaber et al., 2023). Arguably the most concerning aspect emerging from these stories is the deliberate

and strategic nature of some PFAS producers in holding back crucial information on the toxicity of their product to obstruct meaningful interventions (Gaber et al., 2023). This has drawn comparisons with 'big-tobacco': "In some ways, C8 [...] is the tobacco of the chemical industry - a substance whose health effects were the subject of a decades-long corporate cover-up" (Lerner, 2015), as well as accusations of 'deceit and denial' tactics (Markowitz & Rosner, 2013).

The interviews with Le Monde, Follow The Money and The Investigative Desk (October 2023) highlighted the fundamental importance of limiting the influence of industry lobbies in policy making if their commercial interests are clearly not in line with public and environmental health priorities, potentially through similar measures as Article 5.3 of the WHO Convention on Tobacco Control (FCTC) which restricts policy makers' interaction with tobacco industry actors in the process of setting and implementing public health policies with respect to tobacco control. This would be very complicated, because, contrary to tobacco, PFAS actually still play an important role in society for some critical applications.

Not only NGOs, researchers and journalists draw parallels to the tactics of 'big tobacco', or indeed 'big oil'. Also, PR companies urge PFAS industry actors to take a different approach by firmly acknowledging the concerns around PFAS, and then demonstrating how they are taking measures that reduce risks and help with remediation (Commetric, 2023).

In early June 2023 in The Netherlands, the public imagination was caught by the documentary called 'The PFAS cover-up', in which Prof. De Boer questions the EU's common practice of industry self-regulation and self-monitoring for even the most toxic chemicals. In our interviews with EEB and Client Earth the need for a more fundamental revision of the 'rules of the game' was also argued for, which would shift power away from the industry lobby to a more robust design and implementation of REACH, in line with the Chemicals Strategy for Sustainability goal of a 'toxic-free environment' (e.g. Roger, 2023). However, in the current governance arrangement of chemicals regulation under the REACH regime, the centrality of industry actors is hardly questioned by policymakers, mostly because they are the only actors with unfiltered access to production data and are seen as largely cooperating and necessary in the process.

8.4 Power

Based on the interviews we identify five main manifestations of power in the debates around the EU universal PFAS restriction proposal. These are: the extent to which a stakeholder has a formal position in the regulatory processes; access to decision-makers through lobbying; influence on knowledge and monitoring resources; financial resources; and litigation and enforcement powers (see Table 9). This qualitative, comparative assessment is visualised in the colouring (darker colour means higher power), with the more powerful actors listed at the top of table 9. These manifestations of power are further explored in the following sections.

Table 9 Power of actors involved in PFAS restriction proposal process under REACH

Actors	Formal position in regulatory processes	Lobby and access to decision-makers	Knowledge and monitoring resources	Financial resources	Litigation and enforcement power
Chemicals and plastics industry					
European Commission		n/a			
Member states					
ECHA		n/a			
NGO's					
Court of Justice		n/a	n/a	n/a	
Media					n/a
Consumers					

Policy and legislation

The high-level policy objectives such as the European Green Deal and its Chemical Strategy for Sustainability set the tone for future EU legislation but also played a significant role in addressing the concerns of PFAS in actions such as the PFAS restriction proposal or the review of thresholds in directives such as the Drinking Water Directive (Devriese et al., 2023). However, EU policy makers highlight the challenge of bringing these political statements and ambitions into practice at the national and European levels (interview DG environment, 2023).

While the consultations in the process of the restriction proposal aimed at gathering knowledge to contribute to an evidence-based approach, the sharing of knowledge is often constrained by factors like conflicts of interest and competition policies in EU[11] that ensure the data protection of companies over their products (Interviews CEFIC and PlasticsEurope, November 2023). This limitation poses a challenge in the development of a more differentiated approach of restricting PFAS for certain uses (Interviews EEB and Follow the Money/ The Investigative Desk, October 2023), while this approach is demanded by the industry (Interviews CEFIC and PlasticsEurope, November 2023).

There is no doubt that knowledge plays an influential role in the formulation of new policy and legislation and the constant demand for evidence reflects the complexity of the matter (Interview CEFIC, November 2023). ECHA reported that comprehensive information is still lacking on emerging substances such as PFAS particularly on polymers and nanomaterials (ECHA, 2023e). While industries own knowledge of their materials/products, the slow

[11] https://www.europarl.europa.eu/factsheets/en/sheet/82/competition-policy

process of handing over this knowledge could be a strategy to postpone the regulatory frameworks (Interviews EEB, Client Earth, Follow The Money, The Investigative Desk and Le Monde, 2023; Gaber et al., 2023). It has been reported that 40% of restrictions under REACH still await a decision (Santos et al., 2022).

Achieving the EU environmental targets for PFAS will be challenging due to the limited environmental data and knowledge available (Devriese et al., 2023). Filling the data gaps and current knowledge will enable an informed risk assessment to base decisions upon (Wollin et al., 2023). ECHA therefore argues that enforcement should focus on analytical methods for assessing the presence of restricted and authorized substances, or additionally, a holistic group approach for assessing and managing the risk of PFAS needs to be explored (ECHA, 2022, 2023e).

The power of the Member States in proposing a restriction and ECHA providing its technical committees' opinion is limited after these are passed to the Commission. It is then that the European Commission, which prepares the text of the regulation, displays power by adjusting the text based on the evidence provided by the ECHA Committees (Interviews EEB and Follow The Money/The Investigative Desk, October 2023). A concern is the possibility that the Commission will weaken the proposed measures and disregard ECHA's committee evidence, something that happened previously with the PFHxA restriction (another PFAS) (EEB, 2023; Interviews EEB, DG grow, Follow The Money and The Investigative Desk, October 2023).

As challenges in the policy and legislative landscape arise around this proposal, one common agreement is the need for regulation for the risks that PFAS pose (especially those proven toxic). Industry representatives support regulation, however, they perceive the blanket ban on PFAS as challenging and demand a differentiated approach and sensitive times for implementation. Meanwhile, NGOs, the dossier submitter and journalists expressed during the interviews that the wide scope of the proposal is based on the existing evidence of the persistency of PFAS as well as the many knowledge gaps about the impacts of PFAS which require a precautionary approach. Ultimately, policy and legislation are instrumental in paving the way for EU towards effective protection of human and environmental health from PFAS pollution (Santos et al., 2022; Sonne et al., 2023).

Lobbying

The chemical industry has a huge, almost unparalleled lobbying budget in the EU, which has increased in response to the announcement of the PFAS restriction proposals (Interview Follow The Money/ The Investigative Desk, October 2023). The 15 largest producers of PFAS in the world[12] as identified by ChemSec and Corporate Europe Observatory have an estimated self-declared EU lobby budget between €18.6 million and €21.1 million, with 72 lobbyists, and 59 Parliament passes at their disposal (Corporate Europe Observatory, 2023). These companies have bundled forces in two new PFAS sector groups of CEFIC (FFP4EU) and PlasticsEurope (FPG), to put forward their view in the public and policy spheres.

The successful lobby against the REACH revision, as well as the ongoing lobby against the universal PFAS restriction proposal are already being considered to be the biggest lobby

[12] 3M, AGC, Archroma, ARKEMA, BASF, Sidenote Bayer, Chemours, Daikin, Dongyue, Honeywell, Merck, and Solvay (ChemSec, 2023) and DuPont, ExxonMobil and Gore (Corporate Europe Observatory, 2023b)

campaigns ever seen since REACH was first set up 15 years ago (interview Le Monde, October 2023). Lobbying is already happening at the highest level i.e. where company CEO's meet with members of parliament and members of the commission. That this is happening even well before the scientific committees of REACH have finalised their opinions is seen as unusual (interview EEB, October 2023).

Knowledge and public awareness

All stakeholders acknowledge that industry actors have a big knowledge advantage. When recounting the initial stages of the 'Forever Pollution project', a cross-country collaborative investigation PFAS hotspots in the EU, the extent of the knowledge asymmetry was a surprising factor (Interview The Investigative Desk, October 2023). They came to realise that even the most basic information - Where is PFAS being produced? In which quantities? And in which products does it end up? - was hard to come by. Public authorities relied almost exclusively on industry information as opposed to independent monitoring or data collection (Interview Le Monde, October 2023). It continues to be very difficult to find reliable data, and a lot of information is not published because it is confidential business information. There is also a lack of information about the characteristics and availability of PFAS alternatives, often for the same reasons (Glüge et al., 2022).

Interviews with industry representatives show that access to information is also unevenly spread in the complex value chains of many products. One of the developments in CEFIC's new PFAS sector group is increasing awareness of PFAS uses across industries, with many downstream actors for the first time trying to find out 'Does my product contain PFAS'. While this information is mobilised in part to argue for wider derogations, the increased awareness is already a side-effect of the restriction proposal. This is challenging the information monopoly of producing industries and thereby shifting the power balance further downstream in the value chain.

At the national level, there are severe limitations to the power of environmental protection agencies, although differences between Member States exist. The lack of political, financial and legal powers of national environmental agencies limits the collection and use of policy-driven monitoring data, the ability to take a proactive and precautionary approach to health and the environment, and the possibility to respond to infringements (Interview Follow The Money / The Investigative Desk, October 2023). This in turn reinforces the power of chemical industry actors who are often relied on for self-regulation and self-monitoring (Interview Client Earth, November 2023).

Finally, public awareness of PFAS' health- and environmental effects is growing fast in the EU. It started first around specific local pollution hotspots but is now reaching the general public through documentaries and frequent news items in mainstream media (Interview Follow The Money/ The Investigative Desk, October 2023). The potential power and impact of public awareness are difficult to assess. It appears to be an important amplifier of power in other domains, for example by demanding to know what chemicals are in products and opting for PFAS-free pans and jackets thereby steering demand (interview Le Monde). Public awareness also reinforces the potential for (mass) litigation against polluters such as happening in The Netherlands, and indirectly contributes to political pressure on policymakers.

Litigation and regulatory enforcement

Due to the increasing number of court cases, initiated more by industry than governments, litigation has appeared as an alternative tool used by industry to hinder the policy process of restricting PFAS (interview Client Earth). This is expressed in cases, such as the above mentioned GenX case or the 2023 BPA case, where ECHA's decision of classification or identification of substances is being challenged by industry actors in court. Although the ECHA does not have legislative power, the industry has used its financial resources to bring the ECHA to court. The threat of litigation used by industry has resulted in concerns raised by ECHA on the proposed PFAS regulation due to the impediment of the process by industry through resource-intense court cases and appeals, which limit ECHAs work (Interview Client Earth).

In turn, both PFAS producers and users are exposed to extensive liability and insurance risks (The International Chemical Secretariat, 2023). As such, the Investor Initiative on Hazardous Chemicals, acknowledging the risk of mass litigation, advises producers to move away from PFAS (The International Chemical Secretariat, 2023). The number of PFAS contamination cases against PFAS producers is increasing and includes chemical companies, such as BASF, Clariant and Chemours (Hollinger & Ting-Fang, 2023; Scully et al., 2023). Cases brought forward by states and targeting PFAS producers focus on seeking damage for the harm caused by PFAS pollution (Scully et al., 2023). Cases brought forward by individuals target PFAS users, which operate closer at the consumer level, such as the food packaging or cosmetic industry and focus on groundwater contamination, misleading advertising and marketing, as well as consumer protection violation (ibid.).

Effective governance relies on effective monitoring and regulatory enforcement. While the commission theoretically holds power to take legal action against the member states, it's preferred route is to provide funding and technical guidance on how to improve policy implementation. The Green Deal has amplified the importance of the environmental implementation review as a tool through which the commission reports on and addresses infringements and governance challenges of Member States (European Commission, 2023d). The lack of legal consequence for non-compliance is seen as weakening the power and impact of environmental legislation (interview Client Earth).

Most environmental protection agencies in the EU are severely underfunded, influenced by party-political priorities, and with limited legal powers (Interview Le Monde, October 2023). When the initial scale of the health hazard from PFAS became evident to the Forever Pollution Project, they contacted the French Environmental Protection Agency, but they decided not to act because it would be too challenging (Interview Le Monde, October 2023). Regulatory fragmentation across government levels also limits effective environmental enforcement across EU Member States (interview DG environment). In an extensive review of the state of Dutch environmental enforcement practices fragmentation across government bodies was identified as a main constraint (Van Aartsen, 2021).

9 Best practices and constraints for REACH restriction proposal to achieve zero pollution of PFAS

The analysis of the governance arrangement of the PFAS restriction under EU REACH regulation points towards factors that influence the adoption and implementation of a more ambitious chemicals regulation for PFAS. In this section, we address the second research question for PFAS: **What are the best practices and constraints within existing and emerging governance arrangements for developing EU regulation to achieve the zero pollution objective for PFAS in EU's waterways and marine environment?**

9.1 PFAS restriction: Best practices

Group approaches

The use of a group approach in registering or restricting chemicals is not new, but it is increasingly being recognised as a tool for more rapid and effective legislation. The departure from a chemical-by-chemical risk assessment approach, as envisioned in the Chemicals Strategy for Sustainability is an important opportunity to phase out the use of toxic chemicals and avoid regrettable substitution. Our discourse analysis shows that group definitions are dynamic and can be contested, but they can also contribute to a regulatory landscape that provides producers with the clarity to guide investment and innovation towards better-defined non-polluting chemistry.

High-level policy ambitions

The high-level policy ambitions laid out in the EU Green Deal and its flagship policies such as the Chemicals Strategy for Sustainability and the Zero Pollution Action Plan have a significant influence on the direction of concrete legislation. Even though the REACH revision has not materialised during the tenure of the current Commission, our discourse analysis shows that these policies have nevertheless managed to influence the agenda of many actors and stirred a deeper discussion about the EU's approach to pollution, which enables the implementation of these policy ambitions. Even if the restriction proposal would not come into force, the universal approach has already had an impact across many actors, within and outside the EU.

9.2 PFAS restriction: Constraints

Developing the essential use concept

One of the underlying themes in the universal restriction proposal debate is the potential for developing an essentiality concept. While the word 'essentiality' does not feature in the dossier, the debates are strongly influenced by the concept. By considering derogations for applications, the dossier submitters already show the potential impact of this emerging approach to chemical legislation. Proposed derogations are also time-limited, which encourages a focus on the substitution of PFAS even when their current use could be labelled as essential. The discourse analysis shows, however, that much depends on the concrete operationalisation of the essential use concept – through the use of derogations - which makes this a contested space and a potential constraint and opportunity at the same time.

REACH is tested to its limits

The PFAS restriction proposal is unprecedented for a number of reasons, which is challenging the institutionalised 'rules of the game' stemming from the REACH regulation. The restriction proposal employs a group approach that groups together very diverse chemicals with many different uses, affecting a great number of sectors and industries. The sheer volume of contributions to the consultation highlights the broad interest in PFAS regulation but also challenges the capacity of ECHA and the dossier submitters. To avoid regrettable substitution, the dossier submitters were forced to find novel ways to classify a wide range of chemical substances being of very high concern, not based on detailed risk assessments but on persistency. While legally this is possible under REACH, it opens up new spaces of contestation, in a situation where REACH regulation is already being questioned by NGOs and industry alike. The link between the PFAS restriction proposal and the need for REACH revision makes the process of this current proposal therefore more political. More fundamental issues than 'just' PFAS are being drawn into the debate, most notably, but not exclusively, the essential use concept. This broader discussion about REACH could also turn into a governance opportunity towards zero pollution if the emerging challenges can be the starting point of a new chemical legislative approach beyond PFAS.

Power asymmetries

The power analysis shows significant and interconnected power asymmetries between the chemical and plastics industry actors on the one hand, and the public authorities and environmental NGOs on the other hand. Underlying these asymmetries are the tremendous lobbying budgets of multinational companies, as well as their unfiltered access to production data and the chemical composition of products. The lack of this production information, both in terms of quantities and composition, from the side of public authorities, both at EU and Member State level, is limiting their ability to pick up early warnings and inform adaptive governance. The force field around environmental litigation cases appears to be changing, with polluting companies increasingly being held accountable for pollution damages in court. The threat of litigations emerges as an important factor in motivating the industry to move towards a clean future envisaged in the Chemicals Strategy for Sustainability. Finally, environmental regulatory enforcement is particularly weak, both at the EU level and at the Member State level. The low financial and human resources of environmental protection agencies contribute to limited market surveillance power and frequent non-enforcement of infringements.

10 Conclusions: Best practices and constraints for achieving EU's zero pollution objectives for marine pollution

This report aimed to identify the constraining and best practices of current governance efforts at the EU level to achieve zero pollution of underwater noise, chemicals, nutrients and microplastics by analysing the current and emerging governance arrangements that – as a response to the Zero Pollution Action Plan - (will) govern PFAS and TWP generation and release into EU waterways that ultimately reach the marine environment. The analysis in this report focused on governance arrangements that govern land-based sources of TWPs and PFAS. Five EU governance arrangements were analysed that deal with respectively the production, use and abrasion, end-of-life, and end-of-pipe of TWPs and the production and use of PFAS. Within these governance arrangements, six policy developments are taking place, for which the report identified best practices and constraints:

- Euro 7 proposal to ban most environmental harmful tyres in terms of TWP abrasion
- Eco-design requirements for tyres
- Tyre abrasion rates as part of labelling requirements
- Ban on using granulate from tyres as infill
- Improved wastewater treatment to capture TWPs
- Universal PFAS proposal to ban PFAS

10.1 Zero marine pollution: Best practices

Based on the analysis presented in Part 1 and Part 2, we identify two interlinked best practices that feature in current EU efforts to bring marine pollution to zero.

Best practice 1 Life cycle perspective towards zero pollution

The first is that through an expanding set of regulations, the Zero Pollution Action Plan and the Chemical Strategy for Sustainability are contributing to the institutionalization of a governance approach that addresses all life cycle stages for achieving zero marine pollution. As this report shows, the Zero Pollution Action Plan focuses on changing practices of production and use of PFAS and tyres to reduce pollution at source, while also acknowledging that end-of-pipe and end-of-life approaches will still be required and need to be improved. The need to consider the life cycle stages of a product features in both the shared discourses around TWPs and PFAS as well as in new regulations (rules of the game) being developed.

For TWPs, the alignment of interest of the recycling industry as an end-of-life actor for end-of-life tyres, with NGO's interest in less polluting TWPs is an example of emerging possibilities for both circular economy and zero pollution ambitions. For PFAS, the end-of-life remediation costs and uncertainties of environmental impacts are a driver for the ambitious source-based manufacturing restriction approach, while derogations are shaped around uses still seen as essential. Both case studies therefore highlight a life cycle perspective as a best practice towards the governance of zero pollution.

Best practice 2 Source-based approach to achieve zero pollution

Second, by taking a life cycle perspective, the Zero Pollution Action Plan and the Chemical Strategy for Sustainability also contribute to the development of a source-based approach. By targeting production and use, pollution is prevented, rather than just mitigated. The governance arrangement analysis shows that regulation has moved from focusing only on improving waste management of a tyre (i.e. preventing landfilling and promoting recovery and recycling) to a source-based approach with an upstream focus on the production and use of tyres. The expected labelling and eco-design requirements, in combination with banning the most environmental harmful tyres through Euro 7, represent a best practice in terms of aiming to prevent TWPs from being generated. As a result, the targeted actors of regulation have been expanded from the end-of-life to production industry, most notably the chemical and rubber producers, tyre manufacturers and the automotive industry.

For PFAS, the restriction proposal encompasses a broad grouping of thousands of PFAS chemicals, rather than the single chemical approach that characterized PFAS past restrictions. Group approaches to chemical restriction - including the microplastic ban affecting TWP infill and the PFAS restriction proposal - affect many sectors. Such group approaches are emerging discursive features which are also seen as a new interpretation of the rules of the game, not only for PFAS but in chemical pollution governance more generally.

10.2 Zero marine pollution: Constraints

At the same time, four constraints exist related to achieving EU's zero pollution objectives.

Constraint 1 Increasing power of producing industry

The first constraint in developing preventive approaches towards zero pollution, i.e. targeting pollution at source, is the increasing role and power of the chemical and plastic producers and product manufacturers (e.g. tyre producers) as they are, on the one hand, the actors being regulated, while on the other hand, they play a crucial role in the development of various preventive regulations.

For both TWPs and PFAS, the power and discourse analysis show the different dimensions of power are interlinked, giving the chemicals, tyre and plastics industry a powerful position in regulatory processes. Access to production and product composition information as well as extensive funding for lobby and advocacy and access to decision-makers, influence the course that policies and legislation are taking. It also influences how the rules of the game are shaped, for example in the current prevalence of industry self-monitoring, as well as opposition to the implementation of an essential use concept and reform of REACH. EU policy makers and industry are the most influential actors but appear to struggle to find a way forward that achieves the zero pollution objectives.

Constraint 2 Dependency between policies within different governance arrangements

A second constraint is that policy developments focusing on land-based sources of emissions take place in largely autonomous governance arrangements; i.e. each governance arrangement has its own key focus (one or at most two life cycle stage(s)), with associated actors, rules of the game and discourses. A risk will be that contradictions or conflicts will emerge between this variety of different EU regulations for particular

contaminants and products. In addition to developing different policies, attention should therefore also be placed on ensuring some level of integration and alignment.

For TWPs, integration and alignment between the current four governance arrangements is, for example, expected to emerge as a result of policy developments that will create linkages, in particular between 1) the production and use of tyres through labelling and eco-design requirements, and 2) the end-of-life and production stages through EPR, eco-design requirements and the infill ban. Yet, creating source-based governance for TWPs through the eco-design of tyres requires balancing abrasion with requirements around safety, noise the chemical composition of tyres, and closing the loop by recovering materials of end-of-life tyres to produce new ones.

Similarly for PFAS, the universal restriction proposal under REACH already excludes pesticides, pharmaceuticals and several other sectors, nor does it regulate the end-of-life and end-of-pipe concerns related to PFAS. Even if an ambitious restriction would come into effect, alignment is needed to create consistency between REACH derogations and other regulations, while translating concerns about the limitation of the current regime into a novel approach to chemicals governance.

Constraint 3 Continued and legacy pollution

The third constraint is that in the short to medium term, it will be unfeasible to bring noise, chemical, nutrient and microplastic emissions to zero harmful levels. Moreover, even if emissions are reduced, society will also face the legacy of pollution of the past. This is even more the case for persistent pollution such as microplastics (incl TWPs) and PFAS. This means that an approach of reducing pollution at source, will only be a partial solution to the prevention of emissions. That the end-of-pipe and end-of-life governance arrangements will remain important to achieve further reduction of (legacy) pollution in the future. Recent policy developments indeed evolve around improving the mitigation of TWP emissions generated during use by improving wastewater treatment. Further measures are needed such as improving road construction and capturing run-off rainwater from roads that contain TWPs. For PFAS emission hotspots, continuous remediation will be necessary for many decades to prevent further contamination of groundwater. Legacy PFAS, due to their persistency and mobility, will continue to require careful end-of-life and end-of-pipe governance to ensure clean food, water, and air.

Constraint 4 Policy making based on lack of data

A final constraint is the lack of data and methodologies to determine emission sources, e.g. chemical composition of products and pollution pathways from source to sea and the associated levels of pollution and environmental impact from especially emerging pollution issues such as TWPs (and microplastic more broadly) and PFAS. This lack of data and methodologies compromises the designing of effective legislative interventions to safeguard human and environmental health. One of the limitations to EU environmental monitoring, linked to the previous constraint, is that legislators rely on industry for most of their data.

In addition to data, there is also a lack of methodologies to translate data into e.g. testing methods to quantify TWP release, in order to be able to develop and enforce thresholds. Similarly, the decision making on derogations for PFAS is challenged by lack of data, in particular when group approaches to chemicals are developing that potentially shape the concept of ‘essential use’ in future chemical restrictions.

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12 Annexes

12.1 Abbreviations and acronyms

The abbreviations and acronyms that were used in the report are given in Table 10.

Table 10 Abbreviations and acronyms

Abbreviations/Acronym	Definitions
ACEA	European Automobile Manufacturers' Association
ADAC	Allgemeiner Deutscher Automobil Club
CEFIC	European Chemical Industry Council
DG ENV	Directorate-General for the Environment
DG MOVE	Directorate-General for Mobility and Transport
ECHA	European Chemicals Agency
EEA	European Environmental Agency
EEB	European Environmental Bureau
ELT	End-of-life tyre
EPR	Extended producer responsibility
ETRA	European Tyre Recycling Association
ETRMA	European Tyre and Rubber Manufacturers Organization
ETRTO	European Tyre and Rim Technical Organization
EU	European Union
EUCAR	European Council for Automotive R&D
EurEau	European Federation of National Associations of Water Services
EuRIC	European Recycling Industries' Confederation
FPG	Fluoropolymers Product Group
FPP4EU	FluoroProducts and PFAS for Europe
ISO	International Standardization Organization
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
PFAS	Per- and polyfluoroalkyl substance
POP	Persistent Organic Pollutants
RAC	Risk Assessment Committee

REACH	Regulation on the registration, evaluation, authorisation and restriction of chemicals
RIVM	the Dutch National Institute for Public Health and the Environment
SEAC	Socio-Economic Analysis Committee
SOS-ZEROPOL2030	Source to Seas - Zero Pollution 2030 Project
TIP	Tire Industry Project
TRWP	Tyre and Road Wear Particles
TWP	Tyre Wear Particle
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UWWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive
WWTF	Wastewater treatment facilities

12.2 List of expert interviewees

The list of expert interviews for the TWP case and the PFAS case are listed in Table 11 and Table 12, respectively.

Table 11 List of expert interviews for TWP case study

Tyre Wear Particles case study		
Stakeholder group	Organisation	Date of interview
EU policy makers	DG Environment	21-06-2023
	DG Energy	27-06-2023
Car and Tyre industry	Audi AG	27-06-2023
	Michelin	20-06-2023
	ETRMA	04-07-2023
Water Industry	EurEau / Dutch Water Board	23-06-2023
Recycling Industry	EURIC	13-06-2023
NGO	ECO standard	12-06-2023
	Transport and Environment	23-06-2023

Table 12 List of expert interviews for PFAS case study

PFAS restriction case study		
Stakeholder group	Organisation	Date of interview
Trade organisation chemical industry	CEFIC- FPP4EU	09-11-2023
	PlasticsEurope FPG	03-11-2023
Restriction Dossier submitter		19-10-2023
NGO	EEB	24-10-2023
	Client Earth	07-11-2023
Investigative journalists	Le Monde	25-10-2023
	Follow The Money / The Investigative Desk	18-10-2023
Policy makers	DG Grow	26-10-2023

12.3 Topic list interviews

The interviews were semi-structured in nature, which means that we did have a topic list at hand, but also took the freedom to follow up on responses of the interviewees. The questions on the topic list for both case studies are listed in table 13.

Table 13 Topic list for semi-structured interviews for TWP and PFAS case studies

Topic list semi-structured interviews	
TWP	What are existing and emerging EU policies and regulations influencing (your work regarding) governance of TWP emissions?
PFAS	What is the chronology of the process leading up to the universal restriction proposal? What kickstarted the process? Why now?
	What is the argument for universal restriction under REACH vs other regulatory options?
TWP & PFAS	What are the main actors/ networks/ platforms/ collaborations? Formal or informal? Existing or emerging? Who is included/excluded?
	What is your position regarding proposed regulation to limit emissions?
	What are the main debates around this policy/regulation?
	How are you engaging with the policy formation process? Your lobby strategy?
	Who do you see as the most powerful actors? Why?
	What do you see as obstacles to/ opportunities for more effective regulation?