Resilient reformulation strategies for PFAS and beyond

Building workflows that endure rapidly evolving regulatory landscapes

CAS
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Executive summary

PFAS regulations are broadening across jurisdictions, with additional pressures from Original Equipment Manufacturers (OEMs) and downstream customers often driving change ahead of formal legislation. Legacy reformulation workflows built for isolated substitution decisions struggle to keep pace, introducing operational and competitive risk. By developing agile reformulation strategies, grounded in structured, well-documented scientific evidence and broader regulatory context, organizations are better positioned to adapt as regulatory definitions, evidentiary expectations, and market requirements continue to evolve.

A shifting landscape for reformulation

Widely used across industries for their performance characteristics, including durability, chemical resistance, and water- and oil-repellency, per- and polyfluoroalkyl substances (PFAS) have come under increasing regulatory scrutiny due to their persistence and potential environmental and health impacts.[1] The trajectory of PFAS regulations, from initial substance bans toward class-based scrutiny, illustrates a broader shift in chemical oversight, exemplifying the challenges organizations face when reformulating now and in the future.

Reformulation has historically been approached as a discrete compliance activity: once a restricted substance is replaced, the issue is considered resolved. However, this model does not hold up in the evolving PFAS landscape with expanding regulatory definitions, increasing reporting and documentation expectations, and material standards from OEMs and downstream customers.

In this context, approaches built around one-time substitution decisions are no longer sufficient. As external requirements become more dynamic and interconnected, many internal reformulation workflows struggle to keep pace across repeated cycles, increasing the risk of regrettable substitutions, duplicated effort, and loss of competitive standing.

This whitepaper examines how regulatory and industry expectations are evolving, where current reformulation approaches fall short, and how organizations can establish resilient strategies to maintain compliance as requirements continue to change.

The expanding impact of PFAS regulations

Over the past two decades, PFAS regulations have expanded across jurisdictions and industries.[1–3] What began as restrictions on a limited number of individual compounds has evolved into a more **complex regulatory environment,** described by the Organization for Economic Co-operation and Development (OECD) as the PFAS universe.[4]

Companies now navigate overlapping international, federal, and state frameworks governing the manufacture and use of PFAS and PFAS-containing products.[5] In the United States, the Environmental Protection Agency's Toxic Substances Control Act (TSCA) has expanded its reporting requirements, with the section 8(a)(7) PFAS reporting rule requiring reporting from manufacturers and importers of PFAS or PFAS-containing articles dating back to 2011.[6]

In several states, product-specific bans on categories such as textiles and food packaging are already active.[7] One such example is Minnesota's PFAS in products program, which prohibited intentionally added PFAS in 11 product categories from January 2025.[8] The program sets a broader prohibition from 2032 unless a use is deemed unavoidable, in line with the additional restrictions and reporting timelines on the horizon across the US.

Regulations follow a similar pattern in Europe, with the European Chemicals Agency already broadly restricting PFAS use at the EU level and proposing a universal PFAS restriction.[3] Organizations must also navigate country- and region-specific bans, such as France's 2026 bans on PFAS use for cosmetics, ski waxes, and certain consumer textiles, with broader textile restrictions from 2030.[9]

Beyond global regulations, OEMs and downstream consumers are introducing material standards that often precede formal legislation. These requirements vary by region, sector, and product line, complicating compliance planning.[10]

The scientific case for managing PFAS more broadly has been articulated for years, arguing that their persistence and potential hazards justify class-based management rather than piecemeal control.[11] As such, the current PFAS regulations represent only the leading edge of broader chemical scrutiny, with the European Chemicals Agency's (ECHA) ongoing universal restriction proposal demonstrating the direction of travel: restrictions should evolve to cover all PFAS, and all uses.[3]

In line with this approach, regulators are increasingly evaluating related chemistries, degradation products, and transformation pathways alongside historically defined compounds, as well as introducing environmental standards, such as drinking water limits and expanded reporting requirements.

For organizations, this means PFAS replacement requires continuous monitoring and adjustment across multiple markets, creating sustained pressure on reformulation processes that must now operate in repeated cycles.

Key challenges for reformulation workflows

Under growing regulatory and commercial pressure, internal reformulation processes are being asked to operate faster and more frequently. But compressed timelines encourage rapid replacement at exactly the point when deeper performance evaluation, long-term safety review, and regulatory foresight are hardest to complete. As organizations transition from static compliance to continuous, multi-dimensional scrutiny, they must overcome several critical challenges.

Essential technical use cases

In high-tech sectors, transitioning from PFAS can pose significant technical challenges due to the unique properties of these substances. From photolithography in the semiconductor industry to providing metabolic stability in pharmaceuticals, substitutes often lack the properties or efficacies of PFAS compounds. In such cases, researchers are left to determine which applications are essential and which should be replaced with safer alternatives.[12]

Subsequent regulation of alternative chemistries

Achieving a "PFAS-free" label no longer guarantees long-term market or regulatory durability. Hexafluoropropylene oxide dimer acid (HFPO–DA), for example, was developed to replace perfluorooctanoic acid (PFOA), but it has since come under public, scientific, and regulatory scrutiny. This demonstrates how today's alternative chemistries may themselves become targets of future regulations as scientific and policy frameworks continue to evolve.[13,14]

Essential use as a prioritization framework
Not all PFAS applications are equally important, and they do not all face the same technical barriers to substitution. First developed for the Montreal Protocol to phase out ozone-depleting substances, the "essential use" framework can be used to prioritize transition efforts by categorizing PFAS applications into "non-essential uses", "substitutable uses", and "essential uses".[12]

"The history of PFAS regulation tells you what to expect: restrictions widen, alternatives come under scrutiny, and yesterday's solution becomes today's problem. Designing for that pattern is the only durable approach."

Jeremy Krogman, Ph.D. Materials Lead Scientist, CAS.

Exponential growth of affected literature

As expanding regulatory definitions of PFAS continue to increase the scope of affected substances and associated scientific literature (**Figure 1**), substance-by-substance reformulation will become increasingly resource-intensive and difficult to sustain. Additionally, most legacy reformulation workflows rely on fragmented information sources, siloed decision-making between R&D and compliance, and knowledge concentrated in individuals or project teams, making knowledge management challenging to scale.

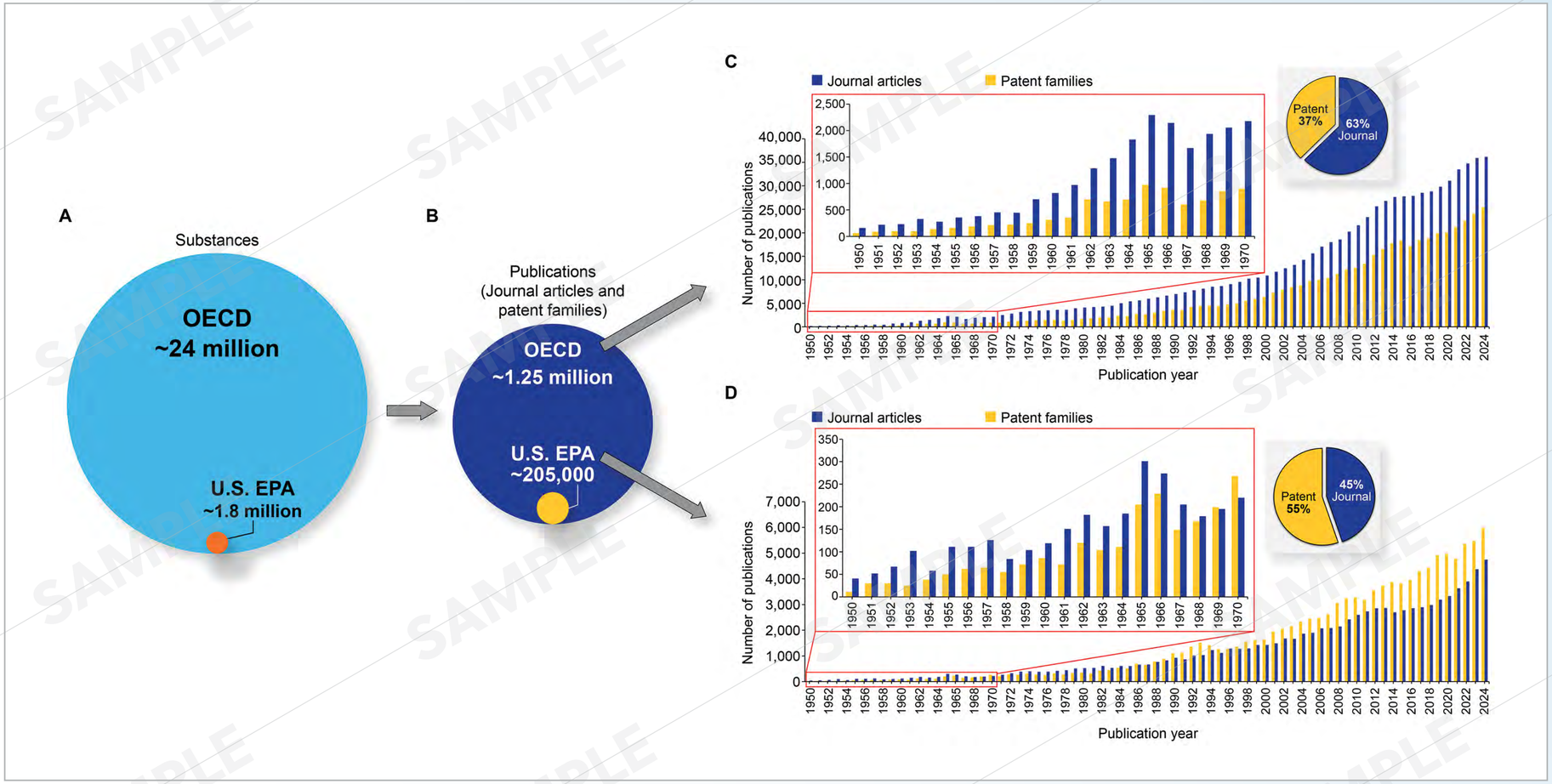


Figure 1. (**A**) Substances and (**B**) publications fitting the OECD and U.S. EPA's definition for PFAS molecules. Yearly trends for publications (journal articles and patent families) encompassed by the (**C**) OECD and (**D**) U.S. EPA's definitions of PFAS molecules. Data includes journal and patent publications from the **CAS Content Collection** for the period 1950 to 2024.

Source: CAS Content Collection

Expanding management implications

In addition to the scale of scientific and regulatory information, companies must also manage the direction of change. As the PFAS regulatory landscape evolves across multiple dimensions, the management implications escalate accordingly (**Table 1**).

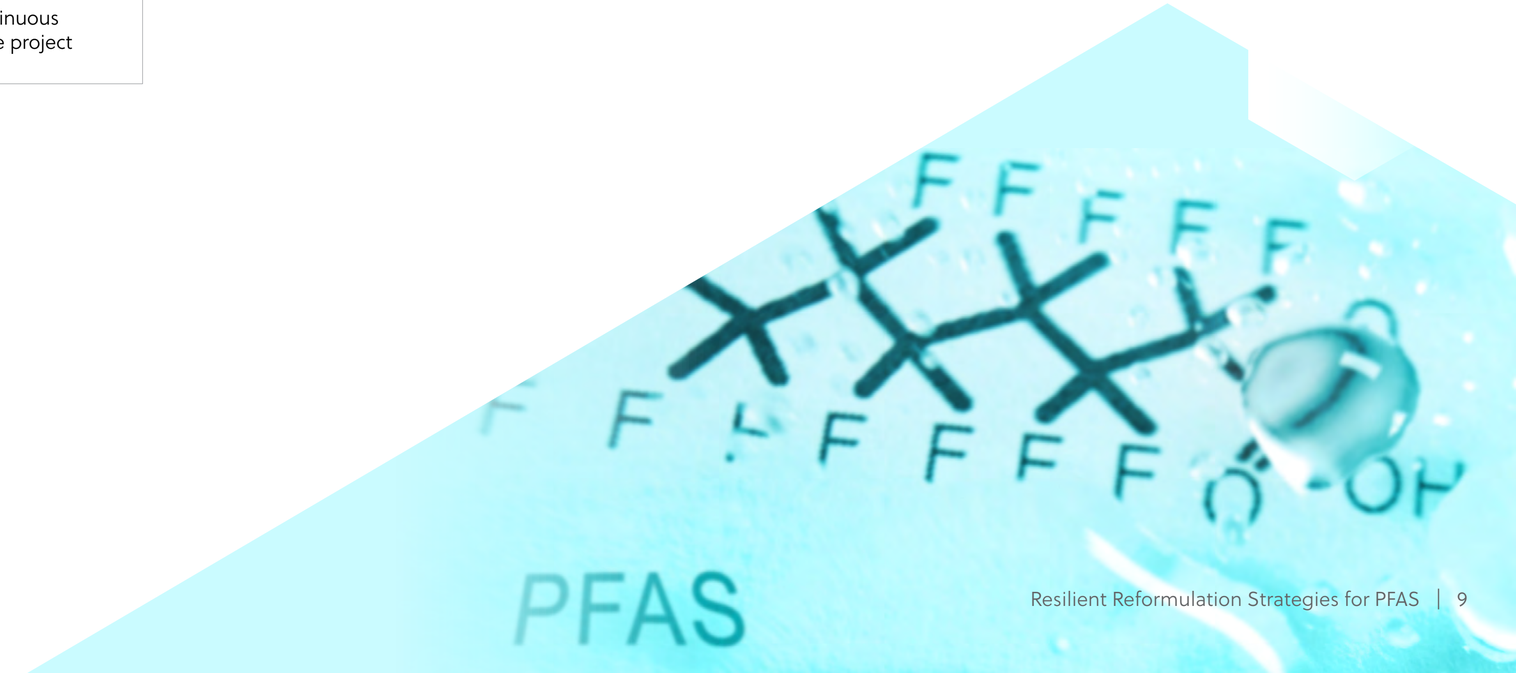
	Regulatory change	Management implication
Scope	From named substances to broader classes, product groups, and structurally related chemistries	Inventory and substitution work cannot start and end with a restricted-substance list
Actors	Governments, states, OEMs, certifiers, and downstream customers all set requirements	Reformulation can no longer sit only with regulatory affairs
Evidence burden	Reporting, documentation, and justification demands are increasing	Decisions need a traceable rationale that expands beyond project notes
Timing	Bans, reporting windows, proposal updates, and market phase-outs overlap	Reformulation becomes a continuous capability rather than a discrete project

Table 1. Management implications of four-dimensional change within the PFAS regulatory landscape.

Uneven maturity of replacement chemistries

A 2025 study identified 530 PFAS-free alternatives but concluded that these were suitable for only 40 applications, with no alternatives identified for a further 83 applications.[15] This challenge will result in a disproportionate impact across industries, depending on the availability of alternatives for a specific application, and underscores the need for access to broad functional context for replacement chemistries during reformulation.

To find out more about how to transform the regulatory challenges surrounding PFAS into innovation and market leadership, download our report:
PFAS regulation and research: Impact, landscape, and outlook.



Building a resilient reformulation framework

In practice, resilient reformulation workflows share several core characteristics. To ensure they keep pace with regulatory change, resilient reformulation workflows aim to anticipate regulatory shifts, ground decisions in chemistry-level understanding, and eliminate information silos to properly leverage institutional knowledge.

> "Reformulation has to stop being a project and start being a capability. Projects end, regulatory pressure doesn't."
>
> Jeremy Krogman, Ph.D. Materials Lead Scientist, CAS.

Anticipating regulatory change and evaluating long-term risk

A resilient workflow does not wait for a ban, customer mandate, or compliance deadline to trigger action. Instead, it monitors regulatory direction on an ongoing basis, shifting the starting point of reformulation from responding to defined restrictions toward proactively assessing exposure to future regulatory expansion.

When selecting a replacement chemistry, resilient reformulation workflows evaluate how candidate materials may be affected by expanding regulatory definitions, broader persistence-based scrutiny, and evolving customer or market requirements. These considerations help identify alternatives that may satisfy current requirements but carry an elevated risk of future reassessment, reducing the likelihood of regrettable substitution.

Grounding decisions in structure-function relationships

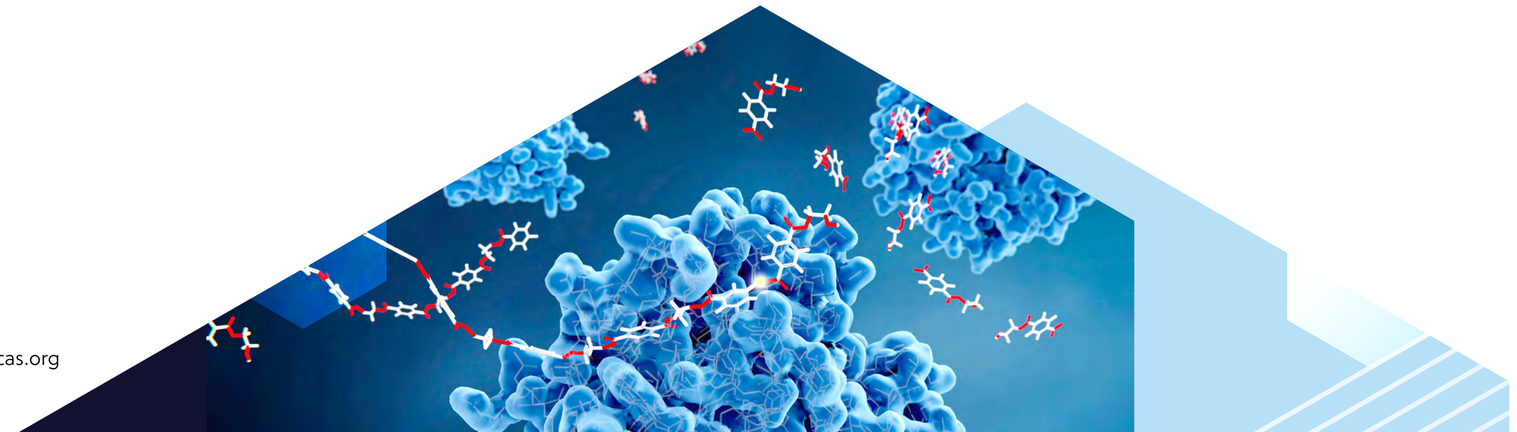
Understanding the chemistry-level structure-function relationships within a formulation or material system is critical to successful PFAS reformulation. Teams need clarity on which performance thresholds are non-negotiable, where non-fluorinated alternatives are already sufficient, and where trade-offs must be explicitly managed. Grounding evaluation in structure-function relationships enables a more meaningful comparison between alternatives, which is particularly important in sectors such as coatings, textiles, and electronics, where functional requirements vary significantly by end use.[16]

Retaining traceability across reformulation cycles

Strong reformulation processes retain the evidence behind each decision, including structural logic, performance trade-offs, hazard assumptions, supplier constraints, regulatory interpretations, and known uncertainties. This ensures that decisions remain interpretable over time, allowing teams to revisit the rationale for prior choices without having to reconstruct the analytical process from scratch.

Aligning ownership across R&D, regulatory, and procurement

Fragile workflows tend to rely on sequential handoffs between functions: R&D selects a replacement, regulatory assesses its compliance status, and procurement sources it, often with limited shared visibility into each team's constraints. Resilient workflows establish shared evaluation criteria across R&D, regulatory, compliance, and procurement from the outset, ensuring that decisions reflect the full range of technical, regulatory, and supply chain considerations before committing to a direction.



Data integrity and curation as the foundation for resilient reformulation

The quality of any substitution decision directly depends on access to comprehensive, structured scientific knowledge. However, relevant data spans chemical identity, structural features, physicochemical properties, toxicological data, degradation pathways, regulatory status, and documented performance characteristics. These data are distributed across journal literature, patent publications, regulatory filings, and internal technical records.

"PFAS regulation uses structural and functional features as defining criteria. Recognizing those features in your own portfolio requires chemistry data that connects structure, function, and regulatory status across millions of substances and decades of literature."

Jeremy Krogman, Ph.D. Materials Lead Scientist, CAS.

To avoid critical blind spots, organizations must build or access datasets with expert indexing, standardized substance identification, and contextual linkage between publications, patents, and regulatory references. This approach supports several critical capabilities, including:

- **Identification of structurally related substances** that may fall within evolving regulatory definitions
- **Traceable linkage** between scientific evidence and regulatory status
- **Systematic comparison** of alternative chemistries based on documented properties and risks
- **Preservation of analytical rationale** for future reassessment

In this way, scientifically curated, structured data creates the foundation for any resilient reformulation strategy.

Designing reformulation strategies that endure regulatory evolution

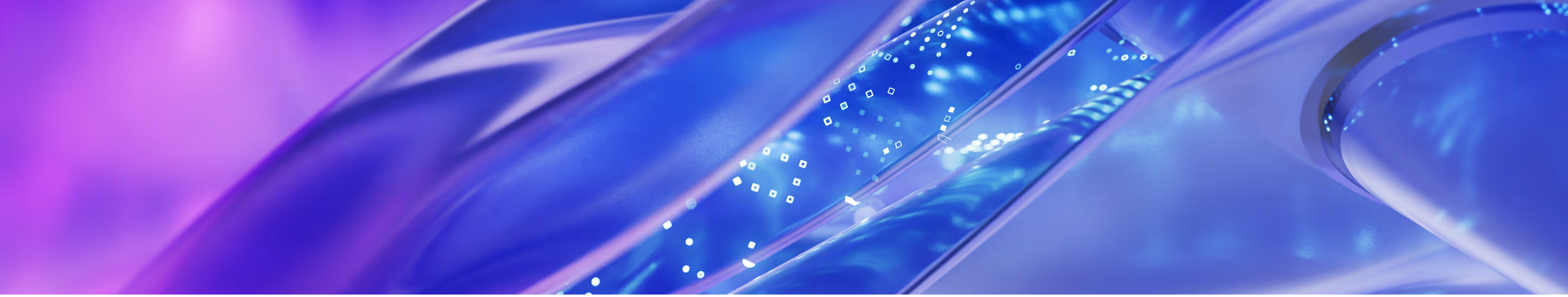
PFAS regulation is a clear test case for a broader trend facing reformulation teams: chemical oversight is expanding in scope, market expectations are moving in parallel, and replacement chemistries can come under scrutiny after adoption. No organization can predict every turn in that process, but teams can design how they respond.

The long-term advantage lies in making chemistry-aware decisions, retaining the evidence and rationale behind those decisions, and managing reformulation as a repeatable cross-functional capability. These choices position organizations to reduce repeated analysis, preserve institutional knowledge, and make defensible decisions that protect their competitive standing as regulatory environments continue to evolve.

Explore how CAS Formulus® supports resilient reformulation strategies

CAS Formulus® helps organizations navigate complex reformulation challenges by combining scientifically curated data with advanced search and AI-driven insights. By connecting information across ingredients, formulations, literature, patents, and regulatory sources, it supports more informed, traceable substitution decisions and helps teams adapt as requirements evolve.

Learn more



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