The Chemical Transition

A comprehensive proposal to accelerate the industrial and ecological transitions

Collaborative note

December 2023

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This note was written under the direction of Ismahane Remonnay (Director of Regulatory Affairs and Risks at Veolia), in collaboration with Roxane Bibard (Head of Expertise at SoScience) and with the support of Attali Associates. It is the fruit of a collective reflection by over forty players involved in the entire chemical industry value chain.

The editors of this note would particularly like to thank UNITAR for facilitating Veolia's participation in the IOMC workshops in January and June 2023, to present the concept and development of the chemical transition.

Veolia would also like to thank the signatories of this note, including:

“Without a "just and responsible chemical transition" that is clear and shared across the entire cycle (from extraction to processing, via the formulation of substances and materials, decarbonation and the circular economy), no ecological or industrial transformation will be effective for everyone and in every geography.

Maintaining resources, preventing impacts on ecosystems and populations now and in the future, and repairing our ecosystems are at the heart of this approach. It's not a question of reinventing what already exists, but of proposing a dynamic vision, rethinking what we mean by chemistry, and recalling what has already been done.

This "chemical transition" initiative was born out of a meeting between people who have, each in their own career and organization, understood that the perfect solution doesn't exist, but that to act we need to take things globally, over the long term, with common sense, try to speak the same language and look at things more globally. CO_2, Biodiversity, Water, Health, Resource Depletion, and the Chemical Cycle are all just one challenge for us. This collective contribution, however small and imperfect, invites us to take the necessary step back to avoid strategic mismatches or dead ends.”

Ismahane Remonnay
Director of Foresight & Regulatory Affairs - Coordinator of the "Chemical Transition" Forward Studies Programme

"[The chemical transition is an essential and all too neglected aspect of preserving the planet. It requires high-level technological skills and an unwavering commitment.]"

Jacques Attali
President of Attali Associates

“About formation, it is important that the inventors understand how to learn about toxicity and their environmental impact (..) to have wonderful environmental performance and [add to] profitability as well."

John Warner

Researcher at Warner-Babcock Institute for Green Chemistry, Beyond Benign, University of Massachusetts, Polaroid Corporation

"[The other lever for [reducing greenhouse gases] is the emissions trading scheme (...) the sectors eligible for it - heavy industry, chemicals, etc. - will have to pay more for their right to emit carbon. - will have to pay more for their right to emit carbon. At the same time, greener technologies (...) will gain in competitiveness.]"

Sébastien Treyer

Managing director of Institut du Développement Durable et des Relations Internationales

“Communication around chemicals is very hard and seen as "boring", while many people don't know what they are using in their products. If you want to show that you are progressive and you are implementing a strategy, it is definitely worth thinking about how to communicate it.”

Jonatan Kleimark & Anna Lennquist

Senior Chemicals and Business Advisor & Senior Toxicologist at ChemSec

"[Today, international bodies are debating what definition should be used for green chemistry (...) The OECD has therefore proposed its own concept of Sustainable Chemistry.]"

Bob Diderich

Head of Environment Health and Safety

"[Chemical transition should really be about minimizing the use of chemistry where possible. That's what we understand when we read the current definition.]"

Christophe Mechouk

Head of Design & Construction Division - Lausanne Water Department

"As an international environmental lawyer, one of the underpinnings of "The Chemical Transition" that resonates with me is the call for a consensus that considers the specific reality of different geographies, histories, territories, and cultures with respect. I am inspired to see this diverse group coalescing around the broader concepts of Green Chemistry."

Melissa Owen
Lawyer and founder of Ambientelegal

" The definition [of chemical transition] must include "do no harm" and "do good". We can not only avoid making more harm, but we also now need to improve."

Howard Dryden
Founder and president of Goes Foundation

"[Chemical transition won't come through a simple technical evolution, but through a change in mentality and understanding, by making the various players aware of what is really involved and the need for a global approach.]"

Amélie Rouvin
Regenerative leadership, founder of Echosophia

"[The urgency of the chemical industry's transition means that ecosystems need to be set up faster. Tools exist that considerably reduce the usual practices: players must seize them to put the transition of chemistry at the service of the ecological transition.]"

Mélanie Marcel
Founder and CEO of SoScience

"The focus on carbon will soon no longer speak to future generations, who are calling for the urgency of the changes needed to ensure a sustainable and secure future for all to be taken fully into account. Since the impact of human activities on the environment has been studied, we have talked about ozone, carbon, biodiversity and water, and tomorrow we will have to talk about chemistry".

Maëlle Goapper
Project manager at Veolia

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- JOUVENCEL Julie (SoScience, Director)
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Research

- POIZOT Philippe (University of Nantes, Matter, Molecules and Materials)
- TICKNER Joël (University of Massachusetts, Public Health)
- WARNER John (University of Massachusetts, Green Chemistry)

Civil society

- COLON David (Up2Green, Chairman)
- DALPONT Jean-Pierre (SCF, Chairman)
- DRYDEN Howard (Goes Foundation, CEO)
- L'HOSTIS Germain (Environmental activist)
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Public institutions

- ATEIA IBRAHIM Mohamed (US Environmental Protection Agency, Environmental Engineering)
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- SMITH Ray (US Environmental Protection Agency, Chemical Engineering)
- TREYER Sébastien (IDDRI, Managing Director)
- WOOTTON Oliver (Chemicals and Waste Management)

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- BELHADJ-KAABI Faten (Battery Recycling)
- BERNE Loic (Electrical Engineering)
- BLANCHET Frédéric (Public Relations)
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- GOËTZ Frederic (Health & Safety)
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- HENDOU Mouloud (Engineering and Technical Validation)
- HULOT Benjamin (Performance Purchasing)
- HUMEZ Nicolas (Performance et Orientation des Métiers)
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- MANSUY Michael (Public Affairs)
- MARTIN-IONESCO Nathalie (North America-ESS)
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- RAMBURE Katerina (QHSSE)
- RATOVONA Salohy (Communication and Marketing)
- SCHOCH Marine (OTV Grand Paris Nord Est)
- VIGNA Pierre (Group Purchasing)
- WILD Oliver (Risk and Insurance)
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Veolia - New generations

- BOUANHAK Louiza
- CAPDEVILLE Gabriel
- DE JERPHANION Lorraine
- DULAC Lisa
- FRANCO Claire
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INTRODUCTION

To meet the challenges of the ecological transition, it is essential to tackle environmental, industrial, and societal issues, by adopting a systemic vision. Climate change, the collapse of biodiversity, the pollution of ecosystems, equitable access to resources and the well-being of populations are all complex issues that need to be jointly addressed.

Chemistry has a direct impact on these socio-environmental issues, as it plays a major role in human activities. Our food, buildings, phones, clothing, medicine, transport, and all new products developed, designed, and sold originate from chemical processes. Consequently, the design of sustainable products (recycled clothing, sustainable mobility, green energy, etc.) depends above all on the development of sustainable chemistry and industrial transition. At a European scale, almost 59% of chemical production is supplied directly to other industrial sectors, including for the health, construction, automotive, electronics and textile industries[1]. All ecological transition strategies therefore depend on a sustainable chemistry. Without the Chemical Transition, the ecological transition cannot take place.

Although chemistry plays a crucial role in our societies, it is often underestimated or even absent in the transition strategies of companies and public players, which focus mainly, if not solely, on decarbonization. Since 2012, Veolia and its partners have been working on the Chemical Transition concept, with a scope that goes beyond just considering carbon emissions. From our work, we have concluded that the challenges and impacts of chemistry are still largely underestimated in the industrial, economic, and social aspects of transition plans.

This is why there is an urgent need to establish a framework to help the chemical industry meet the challenges and impacts of the Chemical Transition and accelerate its sustainable transformation, at both industrial and societal levels. This inevitably involves banning or replacing the most dangerous substances and materials that are harmful to health and the environment. Just as the international community reached an agreement to tackle climate change, with the signing of the Paris Agreement in 2015, which defined a precise strategy and action plan, the Chemical Transition must be addressed with the same strength and levers.

In September 2023, the 5th International Conference on Chemicals Management (ICCM5) was held in Bonn under the aegis of the SAICM and UNEP, it brought together researchers, NGOs, the private sector, and government representatives, and established a landmark agreement that defines a new global framework for improving chemicals management. The framework is based on 28 objectives and establishes a roadmap for each country. The agreements aim to foster the transition to a sustainable and safer chemical alternative, by taking into account the whole life cycle of chemicals, from their design to their waste treatment. The ambition of this approach is to take stock of what transition measures have already been implemented, to structure these existing initiatives and rally all players in the chemical sector around clear, ambitious, and positive objectives.

This note sets out our position to realize the Chemical Transition, which was developed in a multilateral and collaborative way with a working group of stakeholders of the transition, such as scientists, industrial

[1] European Commission, Green Deal: Commission adopts new Chemicals Strategy towards a toxic-free environment, Press Release, 14 October 2020.

groups, NGOs, public players, funders, and young citizens, all brought together by Veolia, who offered different expertise, viewpoints, and vested interests. Particular attention was paid to gender, cultural and generational diversity among the stakeholders engaged, which was a decisive factor in the success of this collaboration. It enabled us to adopt a systemic vision and identify a multitude of societal issues, in a spirit of free expression, without conflicts of interest or biases.

To produce this note, the editors relied on the "+1, for an ecology in action" device, created in 2021 by Veolia with its foresight media partners Usbek & Rica and bluenove, the expert in collective intelligence methods. This innovative scheme has enabled dialogue between stakeholders from a variety of backgrounds to accelerate ecological transformation. It highlighted the roles and responsibilities of the various players in the chemical transition, facilitating cooperation and innovation. This method can be summed up in 4 key points: (1) a working issue linked to ecological transformation, (2) a group of stakeholders with diverse and complementary profiles and backgrounds, (3) a three-phase process - #1 Listen, #2 Prioritize, #3 Commit - in a convivial setting, (4) a feedback session to share the lessons learned with the participants and even more widely.

The working group on the chemical transition, made up of a collective of some forty stakeholders, was conducted in this spirit. Individual listening and prioritization phases made it possible to go beyond the interests of each party and come up with useful and impactful solutions, which are publicly shared in this note.

Although the concept of Chemical Transition is still under construction, this note provides an overview of the issues that need to be considered to kickstart it and sets out the first steps to be followed for a comprehensive ecological transition in the chemical sector.

Veolia and its associates gladly welcome all feedback to this note, which is intended to be widely shared and aims to foster discussion. The concept put forward should be seen as a first step, and therefore it should incite reflection and action by all players who wish to voluntarily participate in the Chemical Transition.

EXECUTIVE SUMMARY

Chemistry plays a central role in the ecological transition, given it is essential across all industrial sectors. To accelerate this transition, it is crucial to create a structured, multi-stakeholder approach. Although initiatives already exist, such as legal frameworks, political commitments, or investments in green technologies, it is necessary to effectively organize these resources and mechanisms to mobilize all players in the chemical industry around common and ambitious objectives.

A collective of over 40 contributors, including chemists, major industrial companies, NGOs, financial players, public authorities, scientists, and young citizens, convened by Veolia, has begun to work on the best way to implement Chemical Transition. In this note, we present the first steps in this process, including a definition of the Chemical Transition and the SPC (*Supply, dePollution, Circularity*) model, which facilitate the complete mapping of the existing regulatory frameworks and solutions. This model could serve as a basis for future discussions as part of the co-construction of a methodology to realize the Chemical Transition.

The Chemical Transition is a process that aims to structure and implement a responsible chemistry for all, i.e., one that:

- **Anticipates and considers all its past, present, and future environmental, social, and economic impacts.**
- **Repairs, prevents, and limits negative impacts**, particularly in terms of pollution, by anticipating, acting voluntarily, and going beyond compliance with legislation.
- **Maximizes its positive social and environmental impacts** by adopting a "reparative" approach to ecosystems through soils regeneration and the design of new chemical substances and materials.
- **Contributes to meeting basic human needs, by ensuring access to essential services** (access to water, food, health, etc.) in an equitable and inclusive manner.
- **Is useful, essential, and acceptable to all the people of today and tomorrow** - the Chemical Transition must establish a consensus, integrate all countries and all populations, i.e., it must consider the specific reality of different geographies, histories, territories, and cultures with respect.
- **Support the industrial and ecological transition, and the preservation of ecosystems**, without creating new or reinforcing existing economic, social, and environmental imbalances.

To achieve this, the Chemical Transition must:

- **Be collaborative**, involving all players active in the chemical value chain.
- **Employ a systemic approach**, integrating all stages of the chemical cycle and all associated societal issues.
- **Comply with existing international legal and institutional frameworks.**
- **Be structuring, by enabling the regulatory framework to continuously evolve in line with the objectives and ambitions set out in a voluntary approach.**

To implement this approach, the Veolia working group recommends:

Three guiding principles

1. **Adopt a holistic approach to the life cycle of chemical products, from design to the waste treatment.**
2. **Define a clear and inclusive vision as the basis for a humanistic, science-based, Chemical Transition.**
3. **Act multilaterally and share the responsibilities for risk prevention and damage repair, and the mitigation of dangers generated by chemical activities, in a systemic way.**

Ten practical recommendations

1. **Avoid marketing or limit the use of the most environmentally toxic chemicals,** reserving them only for essential uses.
2. **Define the Chemical Transition to enable a consensual approach and establish a common vision** (cf. p.29).
3. **Upgrade the planetary boundary model by including the SPC model**, focused on the chemical cycle, into it (cf. p.31-32).
4. **Measure the Chemical Transition by using global financial and environmental indicators** to assess all environmental impacts generated across the chemical value chain.
5. **Issue a regular benchmark report, titled "The Economics of Chemical Change",** like the Stern and Dasgupta reports, to gain a global understanding of the economic patterns associated with the chemical sector.
6. **Use innovation methods and research and development (R&D) practices** that enable a systemic and collaborative approach.
7. **Provide for legal measures and cross-sectoral funding** and avoid the accumulation of regulatory contributions and constraints for consumers and economic agents.
8. **Adopt a long-term and global view, alongside a historical approach, to tackle the issue of pollution at source.**
9. **Launch small-scale pilot projects to develop initial alliances with a wide range of stakeholders.**
10. **Invest in prevention and training for all the stakeholders involved in the chemical value chain.**

Part 1. Chemistry, a fundamental pillar of the ecological and industrial transition

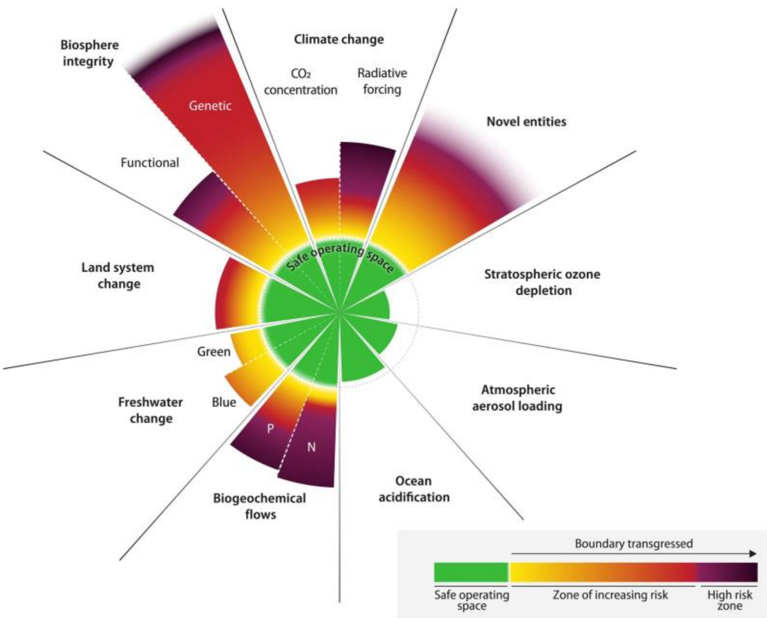
A global paradigm shift is needed

A symbol of modernity and progress in the second half of the twentieth century, chemistry is today poorly perceived by society, more often associated with pollution, risks, and dangers. This does not mean that one must ignore the contribution that 20th-century chemistry has made to improve the quality of human life, but rather one must rethink its aims and practices considering the global paradigm shift necessary to implement ecological transition. For Bernadette Bensaude-Vincent, historian of chemistry, **"it's not so much chemistry itself that's at issue, but rather the economic and social system in which it developed"**.

The facts are clear: our current economic model is no longer viable and needs to be refocused to preserve life and ecosystems, while maintaining the right to sustainable development and access to essential goods for all. In September 2023, a team of researchers re-evaluated all planetary limits (a model developed in 2009 by researchers Will Steffen and Johan Rockström of the Stockholm Resilience Center, which integrates nine environmental limits within which humanity can continue to develop without disrupting ecosystems):

Six of the nine planetary boundaries identified have been assessed as having been transgressed (climate change, biodiversity erosion, land use change, introduction of new entities into the biosphere, disruption of the phosphorus and nitrogen cycle, blue and green freshwater cycle), and **two are likely to soon be transgressed** (ocean acidification and increase in aerosols in the atmosphere). The 2023 report is the third global assessment of planetary boundaries, following those of 2009 (three boundaries exceeded) and 2015 (four boundaries exceeded), which left some boundaries unassessed.

Figure 1. The 9 revised planetary boundaries in 2023



Source: Stockholm Resilience Center

In concrete terms, exceeding the threshold or "boundary" (associated with a physical measure) of each limit risks generating abrupt or irreversible large-scale environmental changes, with negative social, environmental, and economic impacts on all ecosystems.

In the face of this observation, the transformation of our economic and social model becomes essential to ensure the survival and activity of the human species. All stakeholders, including consumers, are affected by this paradigm shift and must evolve (i) their expectations and behaviors, for consumers, and (ii) their practices, products, and businesses, for industrial companies, if they wish to maintain the sustainability of their activities and survive in the decades to come.

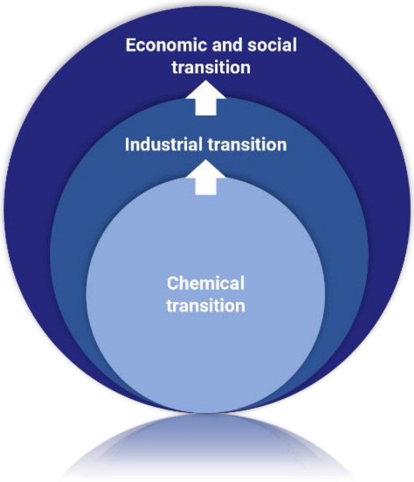
The Chemical Transition is, therefore, a fundamental pillar of the ecological transition of all industrial sectors. However, this aspect is often only partially integrated, mostly through the pollution perspective, and it is often difficult to discern it in corporate strategies across most industrial sectors. Taking chemistry into account in industrial strategies in economic and political terms is essential and critical to accelerate the greater ecological transition.

In other words, the ecological transition is inextricably linked to the Chemical Transition. If conventional chemistry has been the driving force behind the current economic model based on the extraction of fossil fuels, **a shift towards a more sustainable chemistry will bring in its wake the entire value chains of industrial sectors towards a fairer and more sustainable model**. The transition of chemistry thus constitutes one of the fundamental pillars of the industrial and ecological transition (Figure 2).

The challenges related to chemistry are therefore not just limited to a few "green" innovations that need to be accelerated onto the market, or linked to decarbonizing the chemical sector, they arise from a broader need to transform our economic and social model, which prompts for a deeper reflection on our ways of living, producing, consuming, dwelling, and interacting with the entire living world.

To discuss the Chemical Transition, it is therefore preferable to take a more comprehensive approach by considering the whole chemistry cycle, which encompasses all stages of the chemical value chain, from extraction, design, transformation/production, utilization, and recycling, from "mine to mine" (from the mine where raw materials are extracted to the potential chemical product reservoirs that are reusable or recyclable). The chemical cycle involves a wide variety of industrial sectors and stakeholders that utilize chemistry, including mining, chemistry, manufacturing, contractors, and consumers.

Figure 2. The Chemical Transition, a pillar of the ecological transition



Source: Ismahane Remonnay, Veolia.

The three challenges the chemical sector faces to achieve ecological transition

Human development and resource conservation

Since 1950, chemical production has increased fifty-fold[2]. **This global production is expected to double by 2030[3] and triple by 2050**[4], as it supports the production of all our everyday products (food, packaging, electronic devices, vehicles, clothing and sporting equipment, cleaning products, hygiene and beauty products, medicines, etc.). A notable example is global plastic production increasing by 79% between 2000 and 2015[5].

This growth in chemical production is also driven by the need to achieve our sustainable development goals, including our decarbonization objectives (carbon capture, hydrogen production, electrification of transportation, digitization, etc.). Batteries, solar panels, wind turbines, and electric vehicles, for example, rely heavily on chemical components and processes. This growth is also fueled by the increasing production and consumption of essential goods in emerging countries, linked to their rising incomes and the improvement of global living standards. **Developing nations, whose recent contribution to pollution levels must be compared to the historical contribution of more developed nations, are confronted with a twofold task: providing access to vital commodities for their populations while simultaneously striving to adhere to ecological transition objectives. Tackling these challenges is made more difficult for developing nations given they have less resources, which reveals there is a stark inequality when taking into account that, historically, Global North nations are accountable for the pollution levels seen today.**

However, the resources required to produce these goods/technologies** are not infinite, whether they come from raw material mines (metals, oil, organic matter) or secondary material mines (recyclable waste deposits), not to mention the limited availability of water and energy resources. The scarcity, dwindling availability, and fragile accessibility of these resources - due to financial reasons (price fluctuations) or geopolitical factors (armed conflicts, diplomatic pressure) - create acute risks of shortages. **Supply chains for chemical products, due to increasing tensions over certain resources required for their production, are increasingly regarded as strategic assets to be safeguarded to ensure the availability of basic products**[6].

If bio-based chemistry (chemicals entirely or partially derived from biological sources, which rely on biomass and raw materials, as well as plants, algae, crops, trees, marine organisms, and biological waste[7]) can reduce its dependence on petroleum, it will still rely on raw materials that are limited: **the yield and rate of renewal of the material may not be high enough to support the necessary production**. Furthermore, these resources are at risk of conflicting use, as they could be used to meet food demand or their use could be limited to preserve biodiversity (changes in land use, monocultures, land expropriation, etc.), which creates significant limitations that cannot be overlooked.

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[2] Persson, L., Carney Almroth, Collins, C.D., Cornell, S., de Wit, C. et.al., Outside the Safe Operating Space of the Planetary Boundary for Novel Entities, *Environmental Science & Technology*, *56* (3) (2022) , pp. 1510-1521. DOI: 10.1021/acs.est.1c04158.
[3] European Commission, Green Deal: Commission adopts new Chemicals Strategy towards a toxic-free environment, Press Release, 14 October 2020.
[4] Persson, L., Carney Almroth, Collins, C.D., Cornell, S., de Wit, C. et.al., *Ibid.*
[5] *Ibid.*
[6] In 2023, in the wake of the Covid-19 crisis and the war in Eastern Europe, the European Commission presented the Critical Raw Materials Act which aims to reduce dependencies on critical materials in the European Union by promoting establishing mining projects and refining plants on European soil and promoting secondary raw materials (i.e., recycled, and reused materials).
[7] European Commission, EU Science Hub,The future of bio-based chemicals in the EU Bioeconomy, News Article, 23 January 2019

If the circular economy is put forward as a solution to the challenges of resource preservation, industrial sovereignty, and reindustrialization, it must be noted it also relies on a finite stock of resources, there is a limited number of cycles possible as there is a continuous degradation of material quality with each one. **Moreover, not everything is recyclable as there is some degree of loss of active ingredients during the first cycle of use of chemicals. The recycling of certain chemical substances can also have a higher energy and environmental footprint (pollutant concentration) compared to the life cycle of raw materials**.

The equation is not so simple, as by contributing to the production of widely consumed goods, chemistry helps meet fundamental human needs. The solution must ensure universal access to essential services (water, food, electricity, healthcare, etc.), for both emerging and developed economies, in an equitable manner, and remain a central and non-negotiable goal despite the pressures of limited resources and limited reusability.

In 2023, on the 75th anniversary of the Universal Declaration of Human Rights (UDHR), the United Nations High Commissioner for Human Rights (OHCHR), Volker Türk, reminded us that a significant portion of the population lacks the means to purchase basic goods or access essential services and lives in extreme poverty, often for generations. Nearly 700 million people live in extreme poverty worldwide, meaning they live on less than $2.15 per day (approximately €64 per month), which represents nearly 10% of the global population[8]. According to a 2017 report by the World Bank and the World Health Organization (WHO)[9], Half of the world's population does not have access to essential healthcare services. According to the OHCHR, these **"current economic systems are unfair, discriminatory, and are simply not sustainable"**, especially given there is no overall improvement: socioeconomic inequalities have deepened within and between countries, and global poverty has increased for the first time in 20 years, exacerbated by events such as the COVID-19 pandemic, the climate emergency, among other ongoing crises. These events have considerably exacerbated the environmental crisis' effects on both the poorest and most advanced countries.

The objective of ensuring universal access to essential services has been translated into various international frameworks and models. These include the 17 Sustainable Development Goals set by the UN (Figure 3) and the "donut" model developed by economist Kate Raworth, which combines environmental issues and social justice. This model combines the 9 planetary boundaries with 11 fundamental human needs, defining a 'social protection floor,' which ensures humanity exploits enough resources to meet basic human global needs while not exceeding planetary boundaries. There are also ongoing discussions among scientists to integrate the topics of social justice, inequality, equitable access to resources, value sharing, power dynamics, conflicts of interest, and compromises into the planetary boundaries framework (the concept of Earth system justice[10]).

[8] Oxfam France, "*La pauvreté dans le monde n'est pas une fatalité*", 3 mars 2023.
[9] OMS, Banque mondiale, *Tracking Universal Health Coverage: 2017 Global Monitoring Report*
[10] Gupta, J., Liverman, D., Prodani, K. *et al.*, Earth system justice needed to identify and live within Earth system boundaries. *Nat Sustain* 6, 630–638 (2023). DOI: 10.1038/s41893-023-01064-1

Figure 3. The 12 Sustainable Development Goals (SDGs) defined in 2015 [11]

Source: United Nations.

The following strategies are proposed:

- **Avoid marketing dangerous substances, simplify the transformation, the formula design, of products and processes** while increasing safety, performance, and sustainability: use only what is necessary to achieve a result, limit excess, and favor the use of the term 'sufficiency' (used in IPCC reports) over 'sobriety'. It must furthermore be noted that this is the area where green chemistry principles and digital technologies (artificial intelligence, cheminformatics) make the biggest difference: they could help develop more efficient processes using mathematical modelling tools.

- **Favor a culture of maintenance as the first course of sustainable action**. Materials should be designed to last longer and be easily repairable and disassembled, all while maintaining their performance and ensuring the safety of humans and ecosystems from the outset.

- **Focus on the essentials and address the essential needs of the global population.** This raises the question of product selection and, therefore, of the societal model to be favored, which is answered by the *Essential Use* approach of the European Commission. This methodology advocates for the phase-out in the use of chemicals which have known or suspected risks in products or processes, unless they have essential uses related to health, safety, or the functioning of society[12]. What needs must chemistry address? All sectors (packaging, mobility, etc.) are currently thinking and developing the products of tomorrow.

  What needs must chemistry address? How are they developed and chosen? Based on what criteria and with whom? What governance is needed to define and develop these products? What cannot be overlooked? What can be relinquished in privileged consumer markets? And what must we guarantee for less developed regions? Producing less globally is necessary but not applicable everywhere: the essential needs of some regions must be met first. **Thus, local context, specificities, social, cultural, territorial, and economic needs and the challenges facing different populations and regions must be considered as significant parts of any initiative dealing with the Chemical Transition.** This is a question of political choices and democratic decision-making that should be incorporated in the values, interests, and perspectives of all countries and actors when redesigning our economic and

[11] The Sustainable Development Goals (SDGs) are a set of 17 priorities for the year 2030 aimed at promoting sustainable economic and social development while fostering social justice and preserving ecosystems. They were formulated and adopted in 2015 by the member states of the United Nations, following the 8 Millennium Development Goals (MDGs) set for the period 2000-2015.
[12] Rapport Wood, "Supporting the Commission in developing an essential use concept", 2022. Accessible au lien suivant : https://environment.ec.europa.eu/system/files/2022-05/Essential%20Use%20Workshop%20Report%20final.pdf

social model. United Nations High Commissioner for Human Rights (OHCHR), Volker Türk, reminded us in 2023 that: **"Poverty and inequality are not inevitable, they are political choices".**

Ensuring access to a clean, healthy, and sustainable environment

Preserving resources is not the only major societal challenge to address. An analysis[13] conducted by scientists has shown that concepts developed around sustainable development, including that of planetary boundaries, are too narrowly focused on resource limits, at the expense of considering waste accumulation and pollution, which are some of the fundamental causes of ecosystem collapse. **The issues of pollution and access to essential services, especially in emerging countries, are often missing in sustainable development models and approaches, which reveals that these concepts or models are primarily designed for developed economies, who are responsible for most of the pollution accumulated to date.**

In 2022, the United Nations General Assembly adopted a historic resolution declaring that **access to a clean, healthy, and sustainable environment is a universal human right.** Therefore, it is no longer acceptable to sideline this right, under the pretext that access to essential goods has not yet been achieved. Equitable access to essential services needs must include access to a healthy ecosystem. Regarding this issue, the OHCHR emphasizes that civil, political, economic, social, and cultural rights, the right to development, and the right to a clean, healthy, and sustainable environment are strongly interdependent. One of the goals of the 12th UN SDG ("Responsible Consumption and Production") is to establish, by 2030, environmentally sound management of chemicals and all the waste they produce throughout their life cycle, in accordance with internationally agreed principles. The aim is to significantly reduce their release in the air, the water, and the soil, so their negative impacts on human health and the environment can be minimized.

Throughout the chemical cycle (extraction, production, use, end of life, and recycling), there are numerous sources of pollution emitted from various actors (companies, industrial accidents, consumers), such as: air pollution (greenhouse gases and hazardous air pollutants), water, and soil pollution, which have directly negative social, environmental, and economic impacts on climate, biodiversity, and human health.

At European level, in 2021, 214 million tons of chemicals which are hazardous to health were produced (4% more than in 2020 and 1% more than in 2019), as well as 85 million tons of chemicals which are hazardous to the environment (6% more than in 2020 and 2% more than in 2019)[14]. **The WHO estimates that in 2019, there were 4.2 million premature deaths worldwide caused by outdoor air pollution** [15].

Nearly 99% of the global population in 2019 lived in areas where the WHO-recommended thresholds for air quality were not met [16]. The exposure to harmful chemicals also has an impact on the health of workers in the chemical industry, during the production phase, and on consumers, during product use. For endocrine-disrupting chemicals alone, the health effects were estimated to be worth an estimated

[13] Andrea S Downing et al., Learning from generations of sustainability concepts, *Environ. Res. Lett*. 6 (2020), 15 083002. DOI 10.1088/1748-9326/ab7766
[14] Eurostat, Production and consumption of chemicals up in 2021
[15] World Health Organization, Media Center, Ambient (Outdoor) Air Pollution.
[16] *Ibid.*

157 billion euros per year in Europe, in 2015 [17], and approximately 340 billion euros per year in the United States, in 2016[18].

In January 2022, a team of researchers[19] demonstrated that the "introduction of novel entities into the biosphere" or "chemical pollution" planetary boundary was exceeded. This boundary is related to the introduction of new chemicals into the environment through human activities that can have unknown and potentially harmful effects on ecosystems and human health. The boundary was exceeded as **"the rate at which these pollutants are appearing, far exceeds governments' understanding of their global and regional risks and, therefore, they cannot control the resulting problems"**, explained Bethanie Carney Almroth, a professor of ecotoxicology at the University of Gothenburg (Sweden) and co-author of the study. Once released into the environment, many of those chemical compounds are highly persistent and do not degrade for centuries or millennia, hence being term "forever chemicals". **Scientists estimate that nearly 80% of the plastic materials produced by human activity to date remain in the environment**[20].

This pollution is difficult to quantify today because the effects of such chemicals have not all been scientifically identified and measured. As chemical pollution accumulates, substances can combine, creating a "cocktail effect", whose harmful effects are also unknown. While the circular economy and chemical recycling are widely promoted internationally, there is an additional risk of concentrating pollutants when applying these principles. The term **"chemical iceberg"** (Figure 4) is used to describe this unknown chemical pollution, whose scale and hazardousness have not been scientifically assessed.

There is a growing risk for all industries that produce or use chemicals of health scandals coming to light: a major worry is that future research could demonstrate that certain practices or substances, which are widely used and thought to be safe, are actually hazardous, such as for asbestos, Per- and polyfluoroalkyl substances (PFAS) or neonicotinoid pesticides. Industrials who are developing and designing new chemicals, to replace harmful or banned substances, must therefore ensure, from the initial conception of their product, the use of molecular structures which would be easily modifiable in the case they are also found out to be hazardous in the future.

To ensure access to a clean, healthy, and sustainable environment, it is necessary to:

- **Address the issue of pollution holistically, using the scientific *one-health* approach, which recognizes and considers the correlation between the environment, humans, and wildlife in terms of health, and therefore limits the tackling pollution using only environmental regulations (CSRD, green taxonomy, ESG, etc.) or the predominant, but narrow, theme of decarbonization**. In this regard, the scientific concept of the exposome[21] is useful, which is defined as the totality of environmental exposures an individual experiences throughout their life. The exposome integrates the one-health approach by adopting a more comprehensive view of exposures to all forms of pollutants in the environment, including chemical pollutants. Research on the exposome seeks to identify and characterize all environmental factors related to health, beyond just genetic parameters.

[17] Leonardo Trasande et al., Estimating Burden and Disease Costs of Exposure to Endocrine-Disrupting Chemicals in the European Union, *The Journal of Clinical Endocrinology & Metabolism*, Volume 100, Issue 4, April 2015, Pages 1245–1255, DOI:10.1210/jc.2014-4324

[18] Teresa M Attna, MD, Prof Russ Hauser, MD, Sheela Sathyanarayana, MD, Prof Patricia A Hunt, PhD, Prof Jean-Pierre Bourguignon, MD, John Peterson Myers, PhD, et al., Exposure to endocrine-disrupting chemicals in the USA: population-based disease burden and cost analysis, The Lancet. Diabetes & Endocrinology, Vol 4, Issue 12 (2016), 996-1003. DOI: 10.1016/S2213-8587(16)30275-3

[19] Persson, L., Carney Almroth, Collins, C.D., Cornell, S., de Wit, C. et.al., *Ibid.*

[20] *Ibid.*

[21] This term was first coined in 2005 by Christopher Wild, who is now the director of the International Agency for Research on Cancer, in an article published in the journal Cancer Epidemiology, Biomarkers & Prevention. The article is titled "Complementing the Genome with an 'Exposome': The Outstanding Challenge of Environmental Exposure Measurement in Molecular Epidemiology," by Christopher Paul Wild, Cancer Epidemiol Biomarkers Prev (2005) 14 (8): 1847.

It is an interdisciplinary field of research at the intersection of toxicology, epidemiology, ecology, and social sciences, as it considers factors such as behavior, the socio-economic environment, and psychological state.

- **Clarify and define where responsibilities lie for avoiding, managing, and mitigating historical and current pollution and preventing future pollution.** This includes actions for decontamination, remediation, and ecosystem regeneration.

- **Generalize the reversing of burden of proof**: Historically and still today, most regulations allow a chemical substance onto the market if it does not present any proven risks. **It is necessary to reverse this burden of proof system to require companies to prove, as far as possible, the safety of their product, before it is put into circulation, and ensure it is traceable throughout the entire value chain**. In accordance with the "do no harm" principle, each chemical substance or product should undergo a comprehensive analysis to ensure it is harmless to humans and the environment (**Safe and Secure by Design approach**). Among current initiatives, the European Union has implemented the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulation in 2007[22], which shifts the burden of proof onto companies. **The EU is now moving towards ensuring the absence of hazards rather than the absence of risks** (risk being the probability that a hazard will occur). In April 2022, as part of the European Green Deal's "zero pollution" strategy aiming to achieve a "toxic-free environment" by 2030, the European Commission published a list of the most dangerous chemicals to health and the environment, to be banned by 2030. This ban now targets entire families of components rather than individual substances, including phthalates, bisphenols, PVC, parabens, glycol ethers, brominated flame retardants, and PFAS, which are found in many everyday items, such as: toys, bottles, pacifiers, food packaging, clothing, furniture, electronics, cosmetics, paints, and cleaning products. At European level, a "grouping" approach prevails, with the European Chemicals Agency (ECHA), Member States, and the European Commission working together to accelerate the assessment of the various groups of chemical substances registered in the ECHA's chemical universe[23]. **In the United States, the Environmental Protection Agency (EPA) has introduced a Safer Choice label to inform consumers about products that use substances identified as the safest choice available on the market.**

- **Make preventive impact assessments mandatory for products, in addition to the REACH regulation,** regarding their sustainability potential, material traceability, treatability (the treatability of a chemical substance must be validated before it is placed on the market), and circularity. More generally, the aim is to avoid, replace or limit the use of fossil raw materials and other materials of concern that have a negative impact on environment, and thus align with the Global Framework on Chemicals.

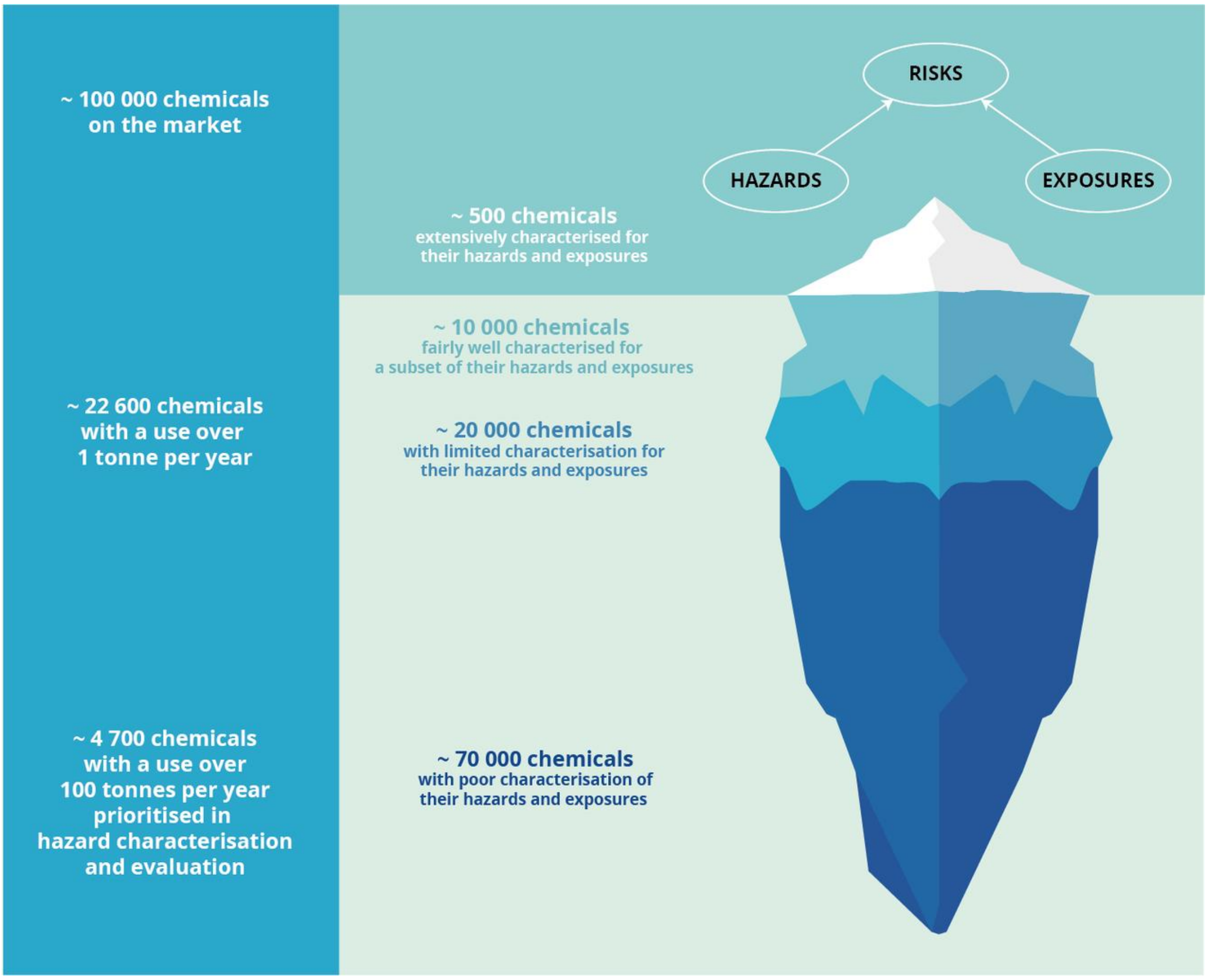
- **It is essential to understand and track the life cycle of chemical substances, from their extraction to their end-of-life, for both environmental and social reasons**. A report published in 2016 by Amnesty International raised concerns of child labor in mines, notably for cobalt, a metal essential to manufacture smartphones and electric vehicles, highlighting that there is lack of traceability among major electronic brands regarding this issue[24]. New technologies such as AI and cheminformatics can be valuable tools to enable this traceability. With a circular model, such control

[22] https://europa.eu/youreurope/business/product-requirements/chemicals/registering-chemicals-reach/index_fr.htm#:~:text=REACH%20est%20l%27acronyme%20utilis%C3%A9,Authorisation%20and%20Restriction%20of%20Chemicals).
[23] Agence européenne des produits chimiques (ECHA), Travailler avec des groupes.
[24] Amnesty International, “Le travail des enfants derrière la production de smartphones et de voitures électriques”, 19 janvier 2016.

of the material cycle can also be facilitated if products are returned to the factory at the end of their life.

- **Promote an approach that goes beyond regulatory compliance and maintain constant vigilance**: the effects of a chemical product cannot always be fully scientifically assessed (concept of the chemical iceberg, Figure 4), and analyses must be continuously updated to ensure the safety of substances on the market.

Figure 4. The chemical iceberg: the unknown territory of chemical risks



Source: EEA, The European Environment – State and outlook report, 2020.

Promote dialogue by creating a common language based on science

Historically, more than any other scientific discipline, chemistry has always been oriented towards industry and society, helping shape our economic and social model. Thanks to its strong connection to practical applications, **chemistry can now serve as a platform for dialogue and be a tool to transform our current model into a more sustainable and equitable one**.

To facilitate this dialogue, it is first necessary to define the terms of the debate precisely and scientifically. Today, we observe the use of a multitude of different terms or concepts by different actors in the field of chemistry, such as “sustainable chemistry”, “responsible chemistry”, “recyclable chemistry”, or even “sobriety”, which are not clearly defined and delimited. They do not correspond to a shared reference framework. These terms can have different definitions depending on the actor using them. These vague, unsupported concepts are widely used by some companies, especially in marketing strategies, and can appear, or turn out to be, void of meaning. Such usage devalues pioneering and committed companies that are already implementing concrete and more advanced actions.

Other concepts, which are clear from a scientific perspective, are also co-opted for marketing purposes. For instance, some **bio-based products are presented as "chemical-free" products, which reinforces the false dichotomy between chemicals and natural substances that is deeply ingrained in the perception of most consumers**.

Taking advantage of and perpetuating these inaccurate perceptions by using a scientific perspective is undoubtedly an effective marketing strategy. However, it ultimately risks hindering the establishment of a clear and constructive dialogue among stakeholders, which is necessary given the urgency of societal issues to address. **How can we establish a constructive dialogue with society, one that carries solutions, mutual compromises, and promotes the learning of chemistry, if the terminology used today is confusing to the public and policymakers?**

The absence of harmonized vocabulary and scientifically grounded definitions, as well as a lack of clarity which favors greenwashing, create a significant risk for industrial sectors, that should not be underestimated. Companies run the risk of being held accountable for misleading citizens. In March 2023, the **European Commission published a proposal for a directive on environmental claims (the Directive on Green Claims), as part of the European Green Deal**. **This directive aims to eliminate misleading environmental messages across EU markets and ensure consumers have access to "reliable, comparable, and verifiable" information on the environmental performance of companies and their products, with the goal of combating greenwashing.** These new requirements require significant changes in the way many companies currently report and communicate their environmentally impactful actions.

It is also important to implement an inclusive dialogue - essential for creating a consensus - where every perspective is expressed, and which takes into account the history and local culture of communities, as well as the characteristics of the territories, within an open and respectful framework.

A Chemical Transition already underway

Over the past few years, many levers and factors are already in place to drive a transition in chemistry that serves both the industrial and ecological transitions:

- **The creation of international legal and institutional frameworks for governments and industry** (license to operate) such as the international strategy on chemicals management (SAICM) adopted in 2006, and revised in 2023, by defining objectives and associated action plans, in key areas of the chemical sector, and over the entire lifecycle of developed products[25]. In this respect, the commitments made by global representatives of the private chemical sector at ICCM5 in Bonn (Figure 5) set a 2030 objective to:

  - **Enable and facilitate access to chemical industry data on the safety and sustainability of their products.**
  - **Support 30 countries in difficulty to implement effective chemicals management systems.**
  - **Orient product portfolios and industrial processes towards sustainable solutions.**

Figure 5. ICCA commitments to 2023[26]

Chemical Industry Announces Global Ambitions At landmark UN conference on the future of Chemicals Management

Published on September 21, 2023

Washington DC, 21 September 2023 – The International Council of Chemical Associations, representing more than 90 percent of global chemical sales, announce the launch of three high-level ambitions on the sound management of chemicals and waste ahead of an upcoming key UN conference that will define the future of the Beyond 2020 Instrument, the global UN-led policy framework to promote chemical safety around the world.

The global chemical industry strives to fulfill the following three ambitions:

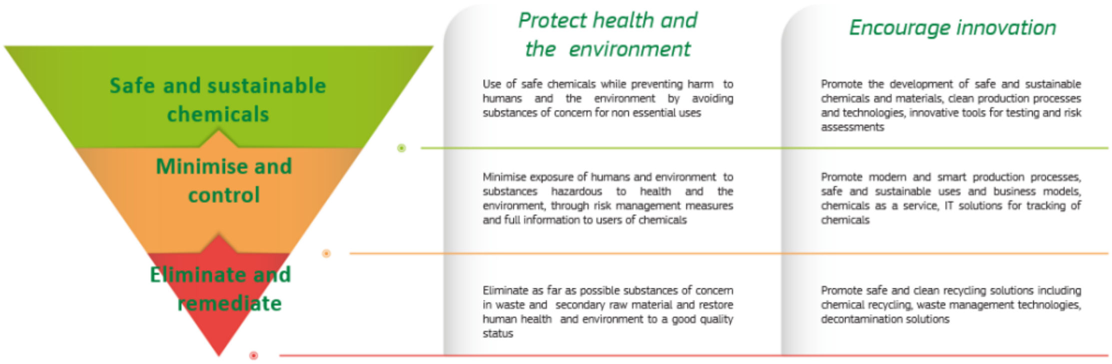
- By 2030 we have provided access to available data on the safety and sustainability of our products.
- By 2030 we have supported 30 countries in their implementation of effective chemical management systems.
- By 2030 we will guide product portfolios, including processes, toward sustainable solutions.

Source : International Council of Chemical Association (ICCA).

[25] "Global framework agreed in Bonn sets targets to address harm from chemicals and waste" (unep.org)
[26] https://icca-chem.org/news/chemical-industry-announces-global-ambitions-at-landmark-un-conference-on-the-future-of-chemicals-management/

- **The implementation of regulations and public policies at national and regional level to support and frame Chemical Transition initiatives,** such as the measures advocated by the Chemical Sustainable Strategy (CSS), established within the overall framework of the EU Green Pact (Figure 6).

Figure 6. The toxic-free environment initiative (CSS)



Source: European Commission.

- **The growing concerns and demands of consumers and citizens** (having access to safe and environmentally friendly products), **as well as players in the financial sector, such as investors and insurers seeking more "responsible" products or guarantees to maintain their investments** (Figure 7).

Figure 7. *Investor Initiative on Hazardous Chemicals* (IIHC) [27]

SUSTAINABLE FINANCE

Investors launch initiative to tackle chemical pollution crisis

Published on 14 Feb 2023

Fifty institutional investors and their representatives with more than US$10 trillion of assets under management or advice have launched an initiative to address the global health and environment crises related to the use of harmful substances. The *Investor Initiative on Hazardous Chemicals* (IIHC) encourages manufacturers to increase transparency and stop producing "forever chemicals".

[27] "Investors launch initiative to tackle chemical pollution crisis" (chemsec.org).

- **Initiatives already underway by pioneering actors within the chemical sector**. Many initiatives are carried out internally by committed individuals who are motivated by interests that go beyond those of the company. These initiatives may not be visible or easily understood at this time. Some companies also prefer not to communicate their actions, for fear of being criticized for not doing enough, or for not being quick enough. We notably highlight:

  - **New processes and methods for the extraction and production of chemical components that are cheaper, more efficient, and less polluting**, thanks to green chemistry (Figure 5) and biotechnology.

  - **New approaches to reduce negative impacts at the source** (eco-design, LCA, impact analysis, predictive health/safety/environment methods...).

  - **The development of new chemical substances** to renew the product offer of chemical companies.

  - **Investments in technologies developed by *Cleantech* or *Greentech* startups** that improve and optimize the efficiency of industrial processes, energy systems (renewable energy, smart grids), water and air cycles, waste treatment, and transportation, with the goal of reducing resource consumption.

Figure 8. The 12 principles of green chemistry [28]

	1	Preventing pollution at the source by avoiding the generation of waste.
	2	The economy of atoms and steps, which allows for the cost-effective incorporation of functionalities into desired products while minimizing issues related to separation and purification.
	3	The design of less hazardous syntheses with mild conditions and the preparation of products that are minimally or non-toxic to humans and the environment.
	4	The design of less toxic chemicals through the development of more selective and non-toxic molecules, involving advancements in the fields of active ingredient formulation and vectorization, as well as toxicological studies at the cellular and organism levels.
	5	Reducing the use of polluting solvents.
	6	Limiting energy expenditures through the development of new materials for energy storage and the search for new low-carbon energy sources.
	7	The use of renewable resources instead of fossil products.
	8	Reducing the number of derivatives that can generate waste.
	9	Preferential use of catalytic processes over stoichiometric processes, with the search for new, more efficient reagents that minimize risks in terms of handling and toxicity. The modeling of mechanisms using theoretical chemistry methods should identify the most effective systems to implement, including new chemical, enzymatic, and/or microbiological catalysts.
	10	Designing products/substances to be non-persistent, with the aim of their ultimate degradation under natural or forced conditions to minimize their impact on the environment.
	11	Developing real-time analysis methodologies to prevent pollution by monitoring chemical reactions. Maintaining environmental quality requires the ability to detect and, if possible, quantify the presence of chemical and biological agents known to be toxic in trace amounts (sampling, treatment and separation, detection, quantification).
	12	Developing a fundamentally safer chemistry to prevent accidents, explosions, fires, and emissions of hazardous compounds.

[28] Anastas, P. T.; Warner, J. C., Green Chemistry: Theory and Practice, Oxford University Press: New York, 1998, p.30.

- **Initiatives that anticipate upcoming regulations.** Companies that develop new products and processes contribute to tomorrow's regulations by demonstrating technically responsible practices.

  - **The signing of the *Responsible Care*® Charter** (Figure 9) is a voluntary commitment launched in 1985 by the global chemical industry for the safer management of chemical products throughout their life cycle. Actions implemented by companies in the chemical sector, which have been guided by the Charter, have produced tangible results in a number of areas, such as: reducing the number of workplace accidents, reducing the consumption of material and energy resources and environmental emissions, increasing waste recovery or recycling, increasing the number of corporate social responsibility initiatives, developing more sustainable downstream supply chains, creating local jobs and opportunities for skill development, promoting diversity and equal opportunities, a multiplication of societal commitment or

  - **The launch of the Sin List database by the NGO ChemSec**, which lists chemical substances considered to be of particular concern due to their impact on human health and the environment. The aim is to encourage companies to phase out the use of these substances in their products and manufacturing processes by finding safer alternatives. This list is now widely used as a reference by companies, regulators, and environmental organizations to help them make informed decisions on chemical management and sustainability.

Figure 9. The Responsible Care® Charter

Source: CEFIC

Figure 10. The ChemSec SinList database

Source: ChemSec

The transition in chemistry has already begun. There are already initiatives and pioneering actors. So how can we coordinate all these actions to accelerate the transition of the chemical sector? How can we guide this transition and make it visible?

Part 2. Recommendations for implementing the Chemical Transition

How can the chemical industry create the momentum needed to accelerate the ecological transition? The nature of the challenge is not exclusively regulatory, as the relevant legal frameworks either already exist or are in the process of being established. The solution also does not exclusively lie in developing new technological innovations, since ready-made solutions are available, and traditional wisdom and nature-based approaches can be reclaimed and applied anew, and investments are consistently being channeled into the development of new innovative technologies. **There is no unique solution to the problem; a wide range of local and diverse solutions are needed, which must consider the social, cultural, territorial, and economic aspects of the local environment and the specific needs of local populations.** An open and collaborative atmosphere must be fostered; it is important to be able to learn from one another, so that all can benefit from the past and present experiences of different innovators in this area. For example, **developed economies could learn much from innovators in emerging countries, as they have developed a strong culture of ingenuity, given they have had to innovate simply and effectively given their limited access to resources - called "frugal innovation"**. This constraint has allowed some developing countries to develop sober, agile, and resilient technologies (low tech) and implement effective circular economy models (little or no waste, robust maintenance, reuse, or recycling of products), which are now being strongly promoted in developed countries.

The issue is above all one of political choice and **a question of which social and economic model is favored.** We must ask ourselves: What needs does chemistry meet? What products should be developed to meet them? How should these choices be governed? **A key issue is also where does responsibility lie**, not only legal responsibility, but also risk management, transparency in actions, and **what ethical stance should be favored so that it is in interest of all**. The diverging interests of various players (companies, legislators, consumers, etc.) undermines this issue of responsibility, with each one trying to pass on the burden of implementing change to the other. Yet, ultimately, all players are involved, at every stage of the chemical cycle, even if they do not all have the same levers for action.

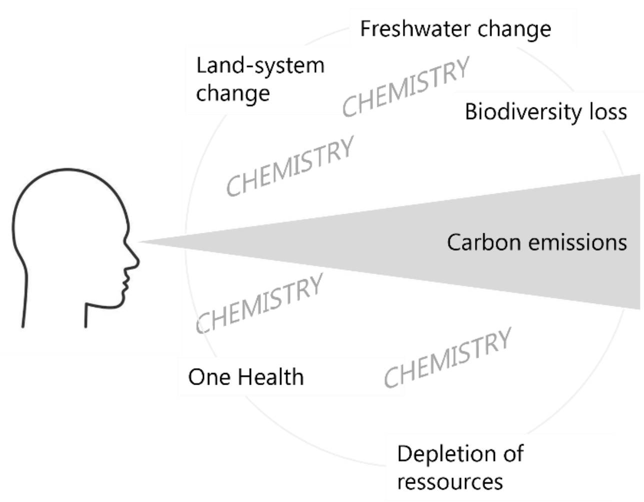
Initiatives and advances such as the international strategy on chemicals management (SAICM-UNEP) or the global treaty against plastic pollution (UN) have had little echo, neither in economic and political circles, nor in the media and public debate, even though they address major issues to accelerate the industrial and ecological transitions. These initiatives call for a rethinking of the model in which chemistry fits in today.

Adopting a global approach to chemistry

A systemic approach to chemistry, based on the chemistry cycle, is an essential prerequisite to take into consideration all the societal issues that need addressing and to identify the existing initiatives and solutions related to the Chemical Transition.

Most societal issues (climate change, resource scarcity, biodiversity collapse, pollution, health, etc.) are dealt with in silos (*Figure 11*), when in fact they are interdependent. **Today, there is a strong preoccupation and focus on tackling carbon emissions in political and industrial circles, to the detriment of social and environmental issues**. Yet chemistry, and more generally, the industrial sector has an impact on all these issues. Developing the industrial and ecological transitions primarily around the issue of climate change and GHG emissions ultimately reduces the room for maneuver necessary to maintain the balance of ecosystems. While a silo approach may seem the easiest way to deal with an issue, in practice it runs the risk of developing solutions that are neither relevant nor appropriate, and ultimately less viable, as they will not take all the necessary parameters into account.

Figure 11. The silo approach to social issues[29]



Source: Attali Associates (inspired by the work of Jan Konietzko)

Past experiences – such as the challenge of the depletion of the ozone layer in the 1990s – are enlightening in this respect. In the early 1990s, the discovery of ozone depletion (designated as one of the nine global limits in 2009) was a major environmental issue. At the time, all domestic refrigerators used ozone-depleting chemicals as refrigerants. These chemicals - known as chlorofluorocarbons (CFCs) - were then banned. The chemical industry replaced them with hydrofluorocarbons (HFCs), which are less harmful to the ozone layer. But HFCs are harmful in another way, as they are powerful greenhouse gases that contribute massively to climate change. The NGO, Greenpeace, has warned that industry players focusing solely on the issue of ozone depletion risk neglecting this HCF greenhouse effect and therefore still having negative impacts. Greenpeace has therefore teamed up with a German company to develop an alternative cooling technology, known as "green freeze"[30], which is just as efficient as the one developed using HFCs, and which does not damage both the ozone layer and the climate. This alternative coolant has since been adopted in many countries and by many companies, although its propane component might present safety concerns for users.

The above example demonstrates the **crucial importance of adopting a systemic approach to tackle climate change and not treat environmental and social issues in silos**. If the alternative to HFCs had not been developed, the impact on climate change would have been multiplied, even it remains one of our major environmental concerns. We cannot afford to repeat the same mistakes today by focusing solely on climate change and GHG emissions.

[29] "Moving beyond carbon tunnel vision with a sustainability data strategy", Dr.Jan Konietzko (cognizant.com).
[30] https://www.greenfreeze.eu/

Practical recommendations

8. **Avoid marketing or limit the use of the most environmentally toxic chemicals,** reserving them for essential uses only when there are no alternatives, based on the EU Green New Deal's "Sustainable Chemicals Strategy for a Toxics-Free Environment"[1].

9. **Evolve the planetary limits model by associating it with the SPC model** which focuses on the chemical cycle (cf. p.31-32).

10. **Measure the progress of the Chemical Transition by using global financial and environmental indicators, making it possible to assess all the impacts avoided or generated along the chemical value chain** (carbon emissions, health risks, scarcity of resources, waste recovery, damage to biodiversity, etc. Three indicators are currently being explored: one for the supply chain, from mining to production and use, one for pollution, and one for the circular economy).

Define a common vision on Chemical Transition

What kind of chemistry do we want to use today and in the future? What needs should it meet? What products should be developed? What common goals do we want to achieve? What is the right strategy to get there? What are the levers of action? What issues should we work on collectively?

Although the Chemical Transition is already underway and many approaches and initiatives are being implemented, they are not sufficiently coordinated, clear or visible. There is no overall framework for the entire chemical cycle, one that both articulates these different initiatives and unites all players around shared objectives. This framework has yet to be built, to set a course, coordinate actions, and pool efforts and resources towards a common goal.

What is necessary is not to develop a new concept for the Chemical Transition, but to create a global framework that integrates and articulates existing concepts, that reinforce and complement them and enforces them. The concept of green chemistry, which was defined in the 1990s, consists of 12 principles (Figure 5) that promote more sustainable and virtuous practices and reduce the negative environmental and social impact of the chemical sector. Specifically, green chemistry promotes eco-design, biodegradation, or environmental non-persistence, minimal ecotoxicity, waste reduction and even bio-sourced chemistry, that used renewable resources. While the principles of green chemistry are a major lever for the sector's transition, the concept, according to its author John Warner, is first and foremost a roadmap for chemists in laboratories and a R&D guide. **The concept is insufficient to develop a global framework which integrates a holistic vision for the chemical cycle and all the players concerned by the sector's transition, beyond only chemists. Similarly, the concept of sustainable chemistry so far used by the OECD[31] is not sufficiently disruptive, too focused on the optimization and efficiency of practices. Furthermore, the OECD concept has not established itself as a benchmark for the chemical industry**.

[31] The OECD defines sustainable chemistry as a scientific concept that aims to improve the efficiency with which natural resources are used to meet human needs for chemicals and services. Sustainable chemistry encompasses the design, manufacture and use of chemicals that are efficient, effective, safe, and more respectful of the environment.

Practical recommendations

4. **Define Chemical Transition to enable a consensual approach and establish a common vision** (cf. p.29).
5. **Publish a benchmark report**, similar to the Stern Review on the Economics of Climate Change and the Dasgupta Review on the Economics of Biodiversity, **that provides a comprehensive overview of the economic models associated with the chemical sector.**
6. **Mobilize innovative methods and R&D practices** that enable the development of a systemic and collaborative approach to the Chemical Transition (responsible research and innovation, open innovation with impact), considers all societal issues and fosters the development of ecosystems of innovation.
7. **Implement cross-industry regulatory and financing mechanisms** that integrate and facilitate collaborative approaches, while avoiding the accumulation of unnecessary contributions and constraints for economic agents.

Acting multilaterally with a diversity of stakeholders

The construction of alliances between a **diversity of stakeholders** who operate in **different sectors, who face different challenges and have different expectations, values, and points of view,** needs to take place, even **between competitors**, in a pre-competitive way. The alliances can work together to address Chemical Transition issues that have not yet been explored. No single player or small group will be able to realize such a transition on their own. Here too, we need to think in terms of ecosystems and address the problem systemically.

These alliances must enable:

- **Global and long-term action:** all countries, whatever their level of development, must be involved in the transition to a more sustainable chemical industry.

- **Mutual aid, the sharing and pooling of resources and knowledge in a collaborative, multi-sectoral and international approach**. Collaboration involving public authorities and industrial groups must be constructive and respectful of all stakeholders: the aim is not to simply transfer technology on a top-down basis, which runs the risk of destabilizing local economic models.

- **Shared responsibility**, that involves all stakeholders in a collaborative, voluntary approach.

- **Action based on local and social contexts, which takes into account geographical and cultural realities**: we need to bring together all the players involved in the field (operators, residents and all the players in society concerned by this transition, including NGOs, associations, towns and territories) at the heart of discussions and working groups, in order to devise and co-construct sustainable solutions, as well as models adapted to local conditions and local populations' needs.

Implementing these measures requires a major shift in attitudes and practices, in favor of openness and collaboration, which should not be underestimated. Bringing such a wide range of players to the table and getting them to work together requires specific methods, skills, and respect for all the players involved in the process.

Practical recommendations

8. **Take a long-term vision and a historical approach to address the issue of pollution comprehensively:**
    a. Avoid polluting products and develop a standard approach to reduce their impact at the source.
    b. Identify actions for remediation and clean-up of historical pollution.
    c. Develop a standardized source reduction approach (product design).
    d. Create a "chemical iceberg" of the circular economy to identify and better understand pollutants in recycled materials.
    e. Identify and utilize tools for predicting the fate of chemical substances during their lifecycle, including their treatment methods and long-term effects, considering their behaviour in nature (cocktail effect, degradation, transformation...). This will involve combining various fields of study such as biology (with biotechnologies being underutilized), physics, chemistry, and mathematics (including artificial intelligence).

9. **Launch small-scale pilots** (region, country, economic zone), based on local priorities and needs, notably to **establish the first alliances between a variety of stakeholders**. **The shift towards greater collaboration shall be driven by experimentation** (a *"learning by doing"* approach).

10. **Prioritize investment in prevention and training for all stakeholders involved in the chemistry cycle,** notably to make it clear that CO_2 is just one part of chemistry (decarbonizing is depolluting):

    a. Regarding prevention, the goal is to avoid or reduce concerning chemical substances, **consistently apply green chemistry principles, and adopt a safe and sustainable approach from the initial design or redesign.**
    b. In terms of training, it is essential that **"inventors know how to research toxicity and environmental impact (...) to achieve excellent environmental performance while increasing profitability"** as emphasized by John Warner[1].

Part 3. A joint proposal for a methodology to implement the Chemical Transition

The collective of 40 contributors (chemists, major industrial groups, NGOs, etc.) brought together by Veolia is today proposing **the first steps of this methodology**, including a **definition of the Chemical Transition and the SPC model**.

This joint proposal is the fruit of collective and collaborative work, involving a multi-actor collective with varied interests (scientists, industrial groups, NGOs, public players...). This innovative approach allowed us to harness a diversity of expertise and viewpoints in favor of a systemic approach to bring together players who are not used to work together towards a common goal.

Objectives of the methodology

As a reminder, this joint methodology, which is currently being defined, should enable the:

- **Adoption of a global and systemic vision for the chemical industry**, that considers the complexity and interdependence of the various environmental and societal challenges throughout the chemical cycle. Specifically, it should enable us to consider the diversity of stakeholders involved and their associated impacts and allow us to move away from restrictive scopes that only consider decarbonization, biodiversity, or water preservation.

- **Take a long-term approach to Chemical Transition**, considering the negative and positive impacts of chemistry in the short, medium, and long term. On this basis, bring about a global paradigm shift while considering short and medium-term conflicts, with the interests of players and the maturity of the market taken into account.

- **Propose a common, shared definition of the Chemical Transition**, at the service of a greater economic and social transition. This will make it possible to establish consistent communication for all chemical players, especially the major groups.

- **Explain in simple terms the path(s) to be followed to support this vision** (existing resources and levers for action to accelerate the transition).

- **Bring together, federate, and engage all the players involved** in the chemical value chain.

- **Rethink current business models** and propose **common measurement indicators** on avoided and generated impacts of the chemical sector.

This approach must therefore be **deliberately simple, universal, and adaptable** to all types of players, regardless of their geography.

Although the defining characteristics of the Chemical Transition concept is less important than the common vision it must convey, the concept may suffer from certain limitations:

- The terminology used could be confused with other scientific processes/jargon (for example, a transition state being a particular chemical configuration).
- It does not immediately convey the idea of a virtuous, environmentally friendly transformation.

The term "Chemical Transition" may therefore be subject to change.

The definition of Chemical Transition given below is neither fixed nor exhaustive. It is open to feedback, challenges, and additions. It should be considered more as a starting point, rather than a final statement.

The Chemical Transition: a proposed definition

The Chemical Transition is a process that aims at structuring and implementing a responsible chemistry for all, i.e., one that:

- **Anticipates** and considers all its avoided or generated environmental, social, and economic impacts; past, present, and future, over the long term.

- **Prevents the use of most dangerous substances, remedies or even cancels out** their negative impacts, particularly related to pollution, by anticipation, and beyond compliance with legislation. This implies a review of the relevant legislation.

- **Maximizes its positive social and environmental impacts**, notably through a "regenerative" approach to ecosystems (e.g., soil reconstitution).

- **Contributes to meeting basic human needs**, by ensuring access to essential services (access to water, food, health, etc.) in an equitable and inclusive manner.

- **Is useful, essential, and acceptable** to all individuals, now and in the future.

- **Contributes to the industrial and ecological transition**, and to the preservation and regeneration of ecosystems, by neither creating nor reinforcing existing economic, social, and environmental imbalances.

To achieve this, the Chemical Transition must be necessarily:

- **Collaborative** - involving all players in the chemical value chain, including manufacturers and consumers.

- **Systemic** - integrating all stages of the chemical cycle, as well as societal issues.

- **Compliant with existing international legal and institutional standards**.

- **Structuring** - it must enable the regulatory framework to evolve in line with the stated objectives and ambitions.

Figure 12. The 3 pillars of Chemical Transition [32]

Systemic vision

- Integrate the chemical transition into a broader transformation (industrial transition, ecological transition).
- Adopt a systemic vision of chemistry (the "chemistry cycle" approach).
- Correlate all societal issues, consider their correlation, and address them together.
- Move away from the focus on greenhouse gas emissions and climate change.
- Adopt a holistic approach ("one health") to pollution emitted by chemistry.

Responsibility

- Ensure safe chemistry (the "do no harm" principle).
- Ensure access to essential needs (social justice).
- Focus on the essentials (the concept of sufficiency) in the design of formulas and products.
- Incorporate a long-term perspective (anticipating long-term impacts).
- Clarify and share responsibility for pollution.
- Address historical pollution and prevent future pollution (preventive impact measurement, widespread adoption of the burden of proof reversal, material cycle control).
- Anticipate regulation.
- Adopt and promote a science-based language.

Collaboration

- Define a common vision of the chemical transition.
- Take comprehensive action with the commitment of all countries.
- Share and pool knowledge, technologies, and other resources.
- Adopt a cross-sectoral and transnational approach.
- Promote constructive dialogue that leads to solutions and compromises.
- Experiment with multi-stakeholder alliances (including NGOs, civil associations, cities, etc.)
- Engage on-the-ground actors (operational, beneficiaries, etc.).

Source : Veolia, SoScience, Attali Associates.

[32] Source: Ismahane Remonnay (Veolia), Roxane Bibard (SoScience), Floriane Benichou (Attali Associates).

The SPC model: a tool to help structure the implementation of the Chemical Transition

The SPC model (Supply – dePollution – Circularity), developed by Veolia, is a tool designed to facilitate the adoption of a systemic approach to chemistry.

The SPC model is part of the evolution of the planetary limits model, as it intends to be complementary from the chemistry point of view. The Planetary Boundary Model has several drawbacks, which have been highlighted by the researchers who developed it[33] : it is primarily a communication tool, which has the merit of being able to communicate what the major environmental issues are – beyond just talking about climate change - and what critical state they are in, in a simple way.

Nevertheless, the Planetary Boundary Model offers a fragmented vision, when in practice all limits are interdependent. Chemistry is often restricted to the planetary boundary known as "novel entities" or "chemical pollution". Chemistry however exerts an influence and an impact on all planetary boundaries (chemical pollution strongly determines the state of ozone depletion and the disruption of the biogeochemical cycles of phosphorus and nitrogen). Thus, the Planetary Boundary Model is not an operational tool sufficient for facilitating Chemical Transition, that's why the SPC model should be used.

The SPC model visually represents the chemical cycle (*figure 13*), i.e., all the stages in the value chain (extraction, production, use and end-of-life), from the mine where the raw materials are extracted to the deposit of potentially reusable or recyclable chemicals back into it ("mine to mine" concept).

The SPC model is divided into **three scopes covering all stages of the chemical cycle**:

- **Scope 1 – "S" is for Supply or Sufficiency** – covers the extraction, transport, processing of earth-based natural resources (oil, mining, organic matter) and recycled materials, as well as design, marketing, and use of chemical substances.

- **Scope 2 – "P" is for dePollution and decarbonation** - concerns the steps related to reducing pollution at each stage of the chemical cycle. It also covers actions to decontaminate and repair historically accumulated pollution, and ecosystem regeneration.

- **Scope 3 – "C" is for Circularity** - covers the processing, recycling, and reuse of chemical substances.

[33] Frank Biermann and Rakhyun E. Kim, The Boundaries of the Planetary Boundary Framework: A Critical Appraisal of Approaches to Define a "Safe Operating Space" for Humanity, *Annual Review of Environment and Resources*, Vol 45 Issue 1 (2020), 497-521. DOI: 10.1146/annurev-environ-012320-080337
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Figure 13. The SPC Model:
The chemical cycle, within planetary limits [34]

Each scope involves different players, different obligations, and different challenges.

These perimeters are not stages that follow one another in a linear process; they are concurrent and need to be considered simultaneously. For example, the Scope 2 linked to decontamination must be integrated right from the extraction and production phase of chemical substances, to prevent pollution. Pollution can be reduced not only at source, but also during when chemical substances are being recycled and reused, which helps avoid circulating pollution.

The SPC model aims to establish a set of actions, that will enable the development of the Chemical Transition, which include:

- **Avoid the use of concerning substances for humankind and ecosystems.**
- **Taking stock of the negative, positive, and avoided impacts** of chemicals.
- **Defining the scientific, economic, social, and environmental stakes** at each stage, including the role of Chemical Transition in respecting planetary limits.
- **Mapping the existing frameworks, regulations, and solutions**, or those currently being explored by various players, and analyze their advantages and limitations.
- **Identifying all the players involved at each stage of the chemical cycle** (miners, chemists, plants, manufacturers, contractors, consumers).
- **Co-constructing comprehensive indicators and impact criteria** for the Chemical Transition.

The SPC model should therefore be considered as more of a starting point than an end point in the development of the Chemical Transition framework; it is a tool designed to facilitate discussion and collaboration when building the framework. Thus, the model ensures that a global vision of the chemical cycle is considered, leaving no stone unturned.

[34] Ismahane Remonnay & Maëlle Goapper - Veolia 2022.

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If you have any feedback, comments, or suggestions on the content of this note, please contact ismahane.remonnay@veolia.com.