Module 9 – Chemical Substitution and Alternatives Assessment

Global Greenchem
Innovation & Network Program

Green Chemistry Toolkit

exclusively developed by Saskia van Bergen, H2L Consulting

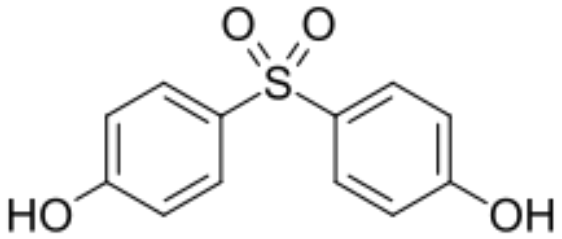
UNIDO

H2L CONSULTING

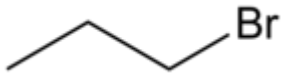
European Union

Learning Objectives

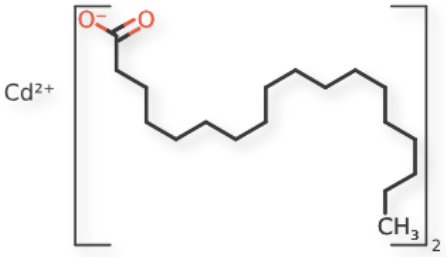
- Explain why regrettable substitutions occur
- Provide examples of the differences between risk assessment and alternatives assessment
- Identify the key steps of an alternatives assessment and the commonly used modules
- Know several resources to find alternatives
- Become familiar with at least one chemical hazard assessment tool
- Be able to screen out chemicals based on hazard lists



Bisphenol S

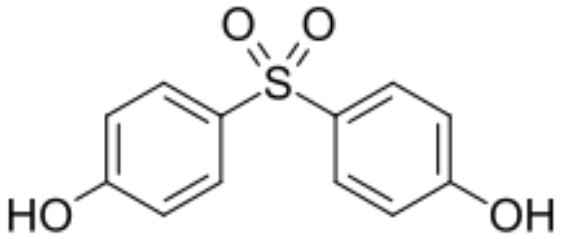


N-Propyl Bromide



Cadmium Stearate

What do these chemicals have in common?



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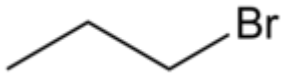

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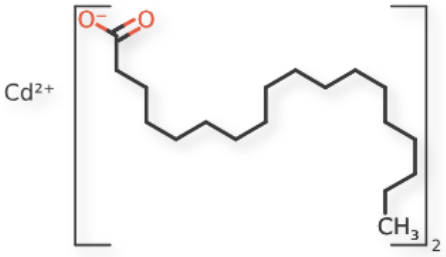


Cadmium Stearate

They are all examples of
Regrettable Substitutions.

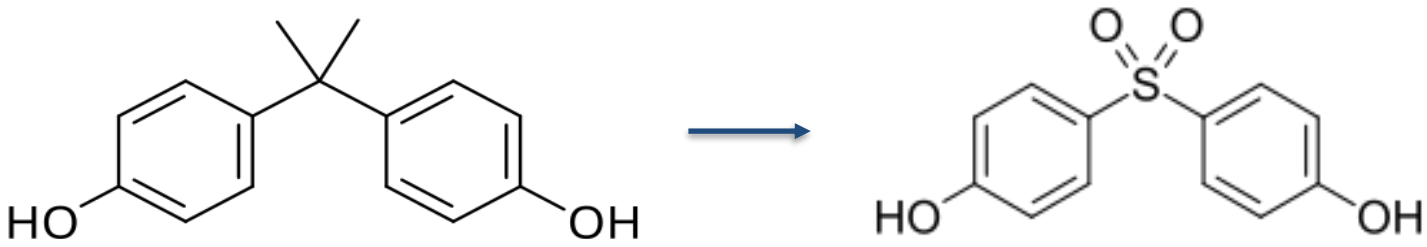
What is a Regrettable Substitution?

Replacing a known toxic substance with another known (or not yet known) toxic substance.

It can also be replacing a toxic chemical with one that fails to meet performance needs.

Regrettable Substitution

The **function** of the chemical is as a developer in thermal paper.



Bisphenol A → **Bisphenol S**

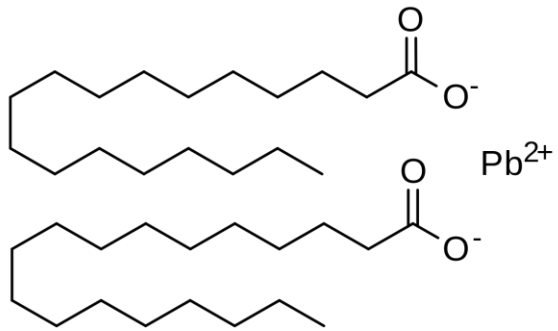
- Toxic to Development
- Endocrine Disruptor
- Acute Aquatic Toxicity

- Toxic to Reproduction
- Endocrine Disruptor
- Chronic Aquatic Toxicity

Example from the EU HERE

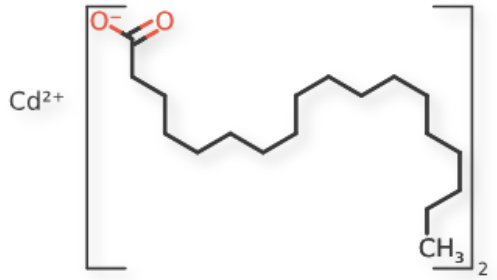
Regrettable Substitution

The **function** of the chemical is as a heat and light stabilizer in PVC



Lead (II) Stearate

- Carcinogenic
- Toxic to Reproduction
- Acute Aquatic Toxicity



Cadmium (II) Stearate

- Carcinogenic
- Acute Mammalian Toxicity
- Acute Aquatic Toxicity

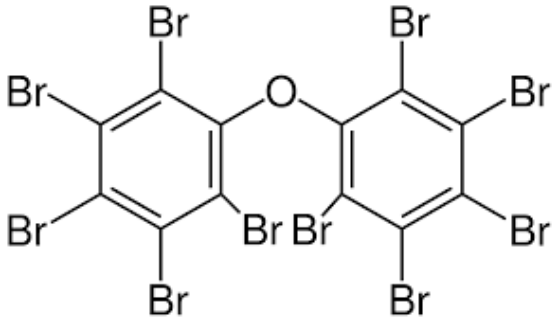
Example from the US HERE

Other Regrettable Substitutions

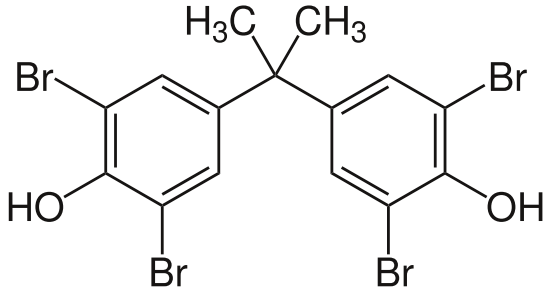
The **function** of the chemical is as a durable water repellent.

C_8F_{17}- and $C_{10}F_{21}$- C_6F_{13}-Side Chain Fluorinated Polymers → **C_4F_9- and C_6F_{13}-Side Chain Fluorinated Polymers**

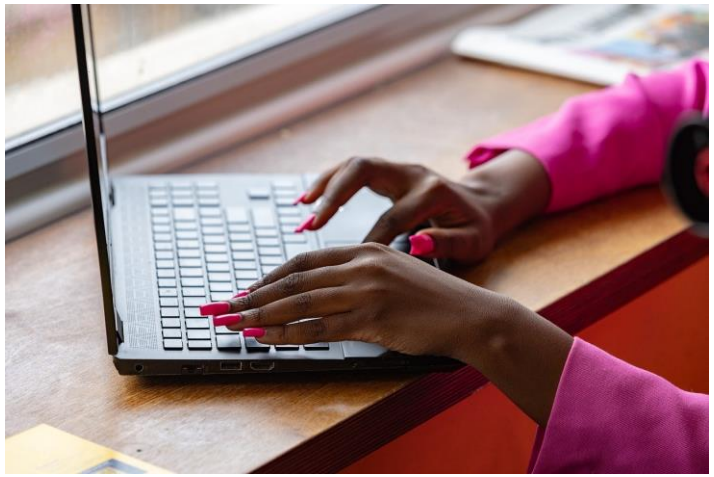
The **functions** of the chemical is as a flame retardant and anti-drip agent.



Decabromodiphenyl Ether



Tetrabromobisphenol A



Why Does This Happen (in the first place)?

One Incorrectly Assessed the Chemical Risk

<u>Chemical Risk</u>- the *probability* of an adverse effect in an organism, system or (sub) population caused under specified circumstances by exposure to a substance.

One can incorrectly assess the risk in a number of ways. Examples include:

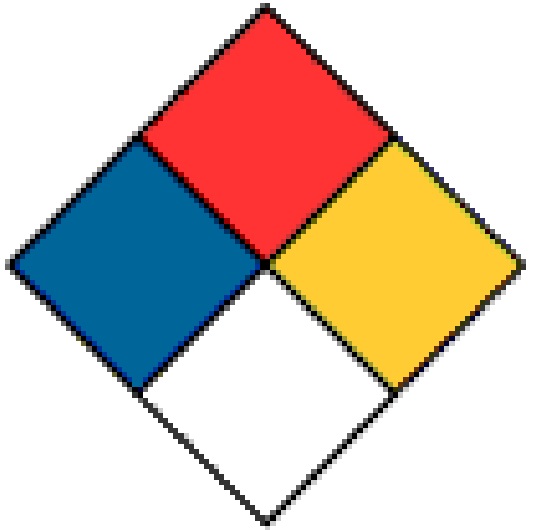
- Considering one route of exposure or exposure from one type of product
- Accidental exposure
- Underestimating the hazard due to lack of data

Risk = ƒ(**Hazard** x **Exposure**)

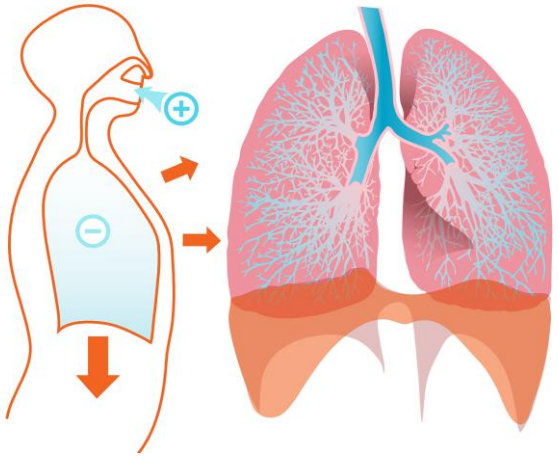
Hazard

Hazard - The inherent property of a substance having the potential to cause adverse effects when an organism, system or (sub) population is exposed.

- **Human Health Effects**
  - Examples – Carcinogenicity, Reproductive toxicity, Endocrine Disruption. Neurotoxicity
- **Environmental Health**
  - Examples - Acute Aquatic Toxicity, Chronic Aquatic Toxicity
- **Environmental Fate**
  - Examples – Persistence, Bioaccumulation
- **Physical/Chemical Properties**
  - Examples – Reactivity, Flammability



Exposure



Exposure- Any condition which provides an opportunity for an external environmental agent to enter the body. It is the extent to which an individual, population or ecosystem is exposed to a chemical substance.

Three main ways chemicals can enter the body:

- **Inhalation** – breathing the chemicals into the lungs
- **Absorption** – the chemicals soak through the skin, or
- **Ingestion** – swallowing the chemicals

Injection is another route of exposure but it is less common.

Controlling Exposure

We try to control chemical risk by controlling the exposure using the:

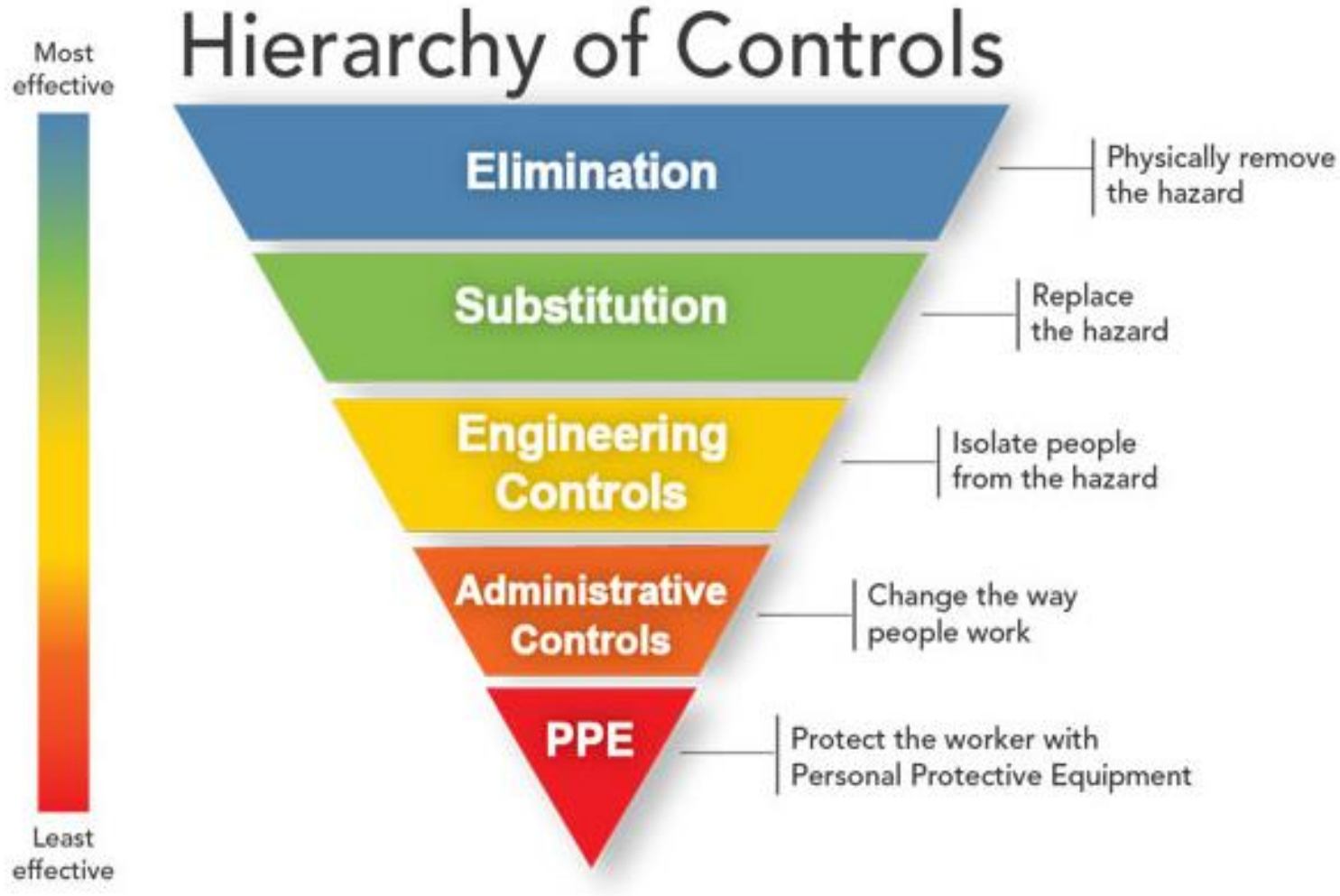


Image from- https://www.cdc.gov/niosh/topics/hierarchy/default.html More information HERE.

Diacetyl in Food Flavoring

Considering one route of exposure/underestimating hazard due to lack of data

- Diacetyl was considered by US FDA as Generally Recognized as Safe (GRAS) based on ingestion in 1980 based on 2 toxicity studies that demonstrated no effect:
  - a cultured cell study looking at mutagenic activity
  - an animal feeding study looking at teratogenicity

- In 1994 there was additional testing based on exposure through ingestion as it was a food additive. <u>No studies looked at effects from inhalation.</u>

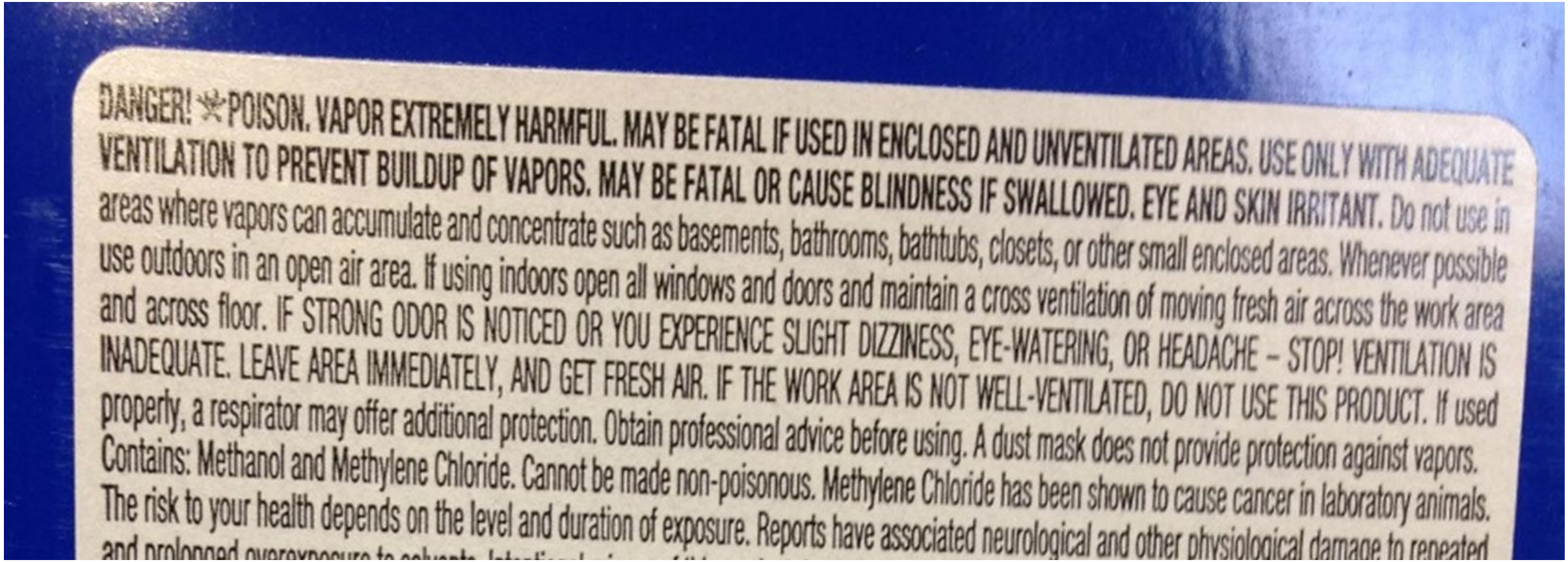
Diacetyl in Food Flavoring

Considering one route of exposure/underestimating hazard due to lack of data

- In 2000, eight cases of bronchiolitis obliterans, a life-threatening and irreversible lung disease, were reported among former workers exposed to diacetyl used in butter flavoring.
- There were no workplace standards controlling its use **as inhalation hazards had not been considered**.

More information HERE (case study 3).

Here is an example of a label from a paint stripper product that contains methylene chloride



For this product, there are recommended engineering controls, personal protective equipment as well as administrative controls. Yet…

…there were still Accidental Exposures

SHARP
Safety & Health Assessment & Research for Prevention

Bathtub Refinisher Deaths from Methylene Chloride (MC)*

(*also known as Dichloromethane)

Washington State Department of Labor & Industries

MC-based paint strippers are an EXTREME hazard

Thirteen bathtub refinishers from ten states have died (2000 - 2011) after inhaling toxic methylene chloride while stripping residential tubs[1]. Ten different products, containing 60 to 100% MC, were associated with the deaths. Products included Klean-Strip Premium Stripper and Tal-Strip II Aircraft Coating Remover[1]. In each case, ventilation and respiratory protection were absent or inadequate[2].

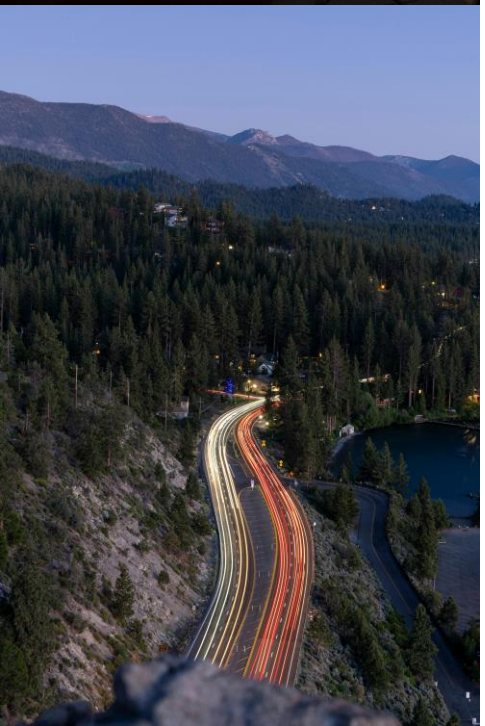
Stripping with MC can have deadly consequences because:

MC vapor is absorbed quickly by the lungs at low concentrations that you cannot smell.
MC vapor is heavier than air. Vapor can sink and remain low in the bathtub and breathing area during stripping.
Bathrooms are difficult to ventilate *effectively*. Standard ceiling bathroom fans cannot remove MC vapor from low inside the bathtub where you are breathing. Ventilation is needed to both suck contaminated air out of the bathtub and to push fresh air into the space. Small bathrooms with limited windows are difficult to ventilate without air turbulence.
Filter and respirator cartridges don't protect you from MC vapor. Instead, you need a full-face supplied air respirator.

DO NOT use MC-based strippers on bathtubs

There are safer alternatives to MC-based strippers.

Watch the story about an individual who used a product improperly HERE
SHARP Hazard alert HERE



Not Understanding the Fate and Toxicity of Transformation Products

6PPD is an anti-degradant used in tires. This chemical prevents cracking and breakdown of the rubber in tires by continuously migrating out of the tires and reacting with the ozone which prevents the oxidation of the rubber.

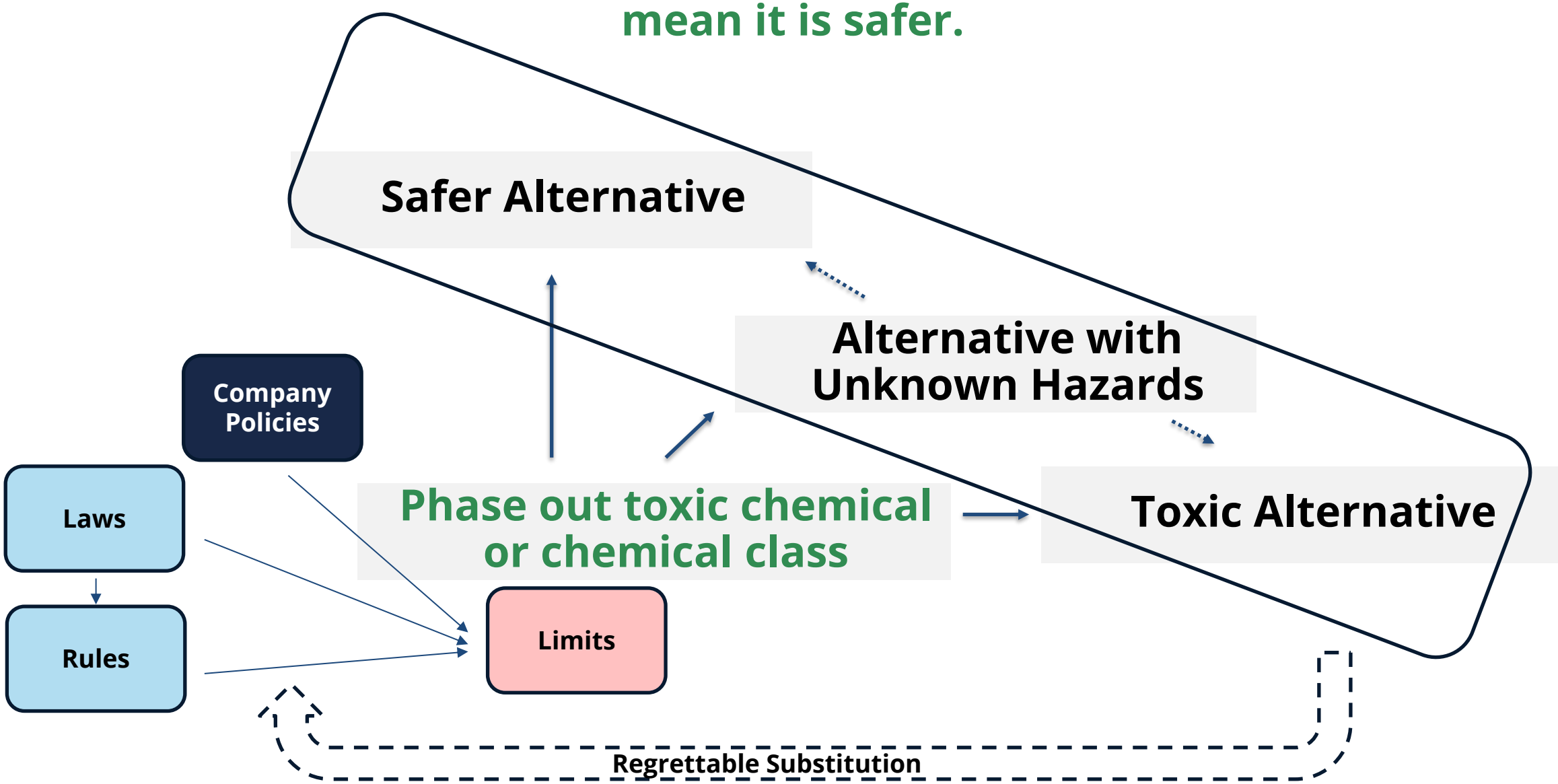
When 6PPD reacts with ozone, 6PPD-quinone is produced. This compound is very highly toxic to the aquatic environment.

Read an Article About it HERE
or Watch a Video HERE
More information on 6PPD is also available HERE.

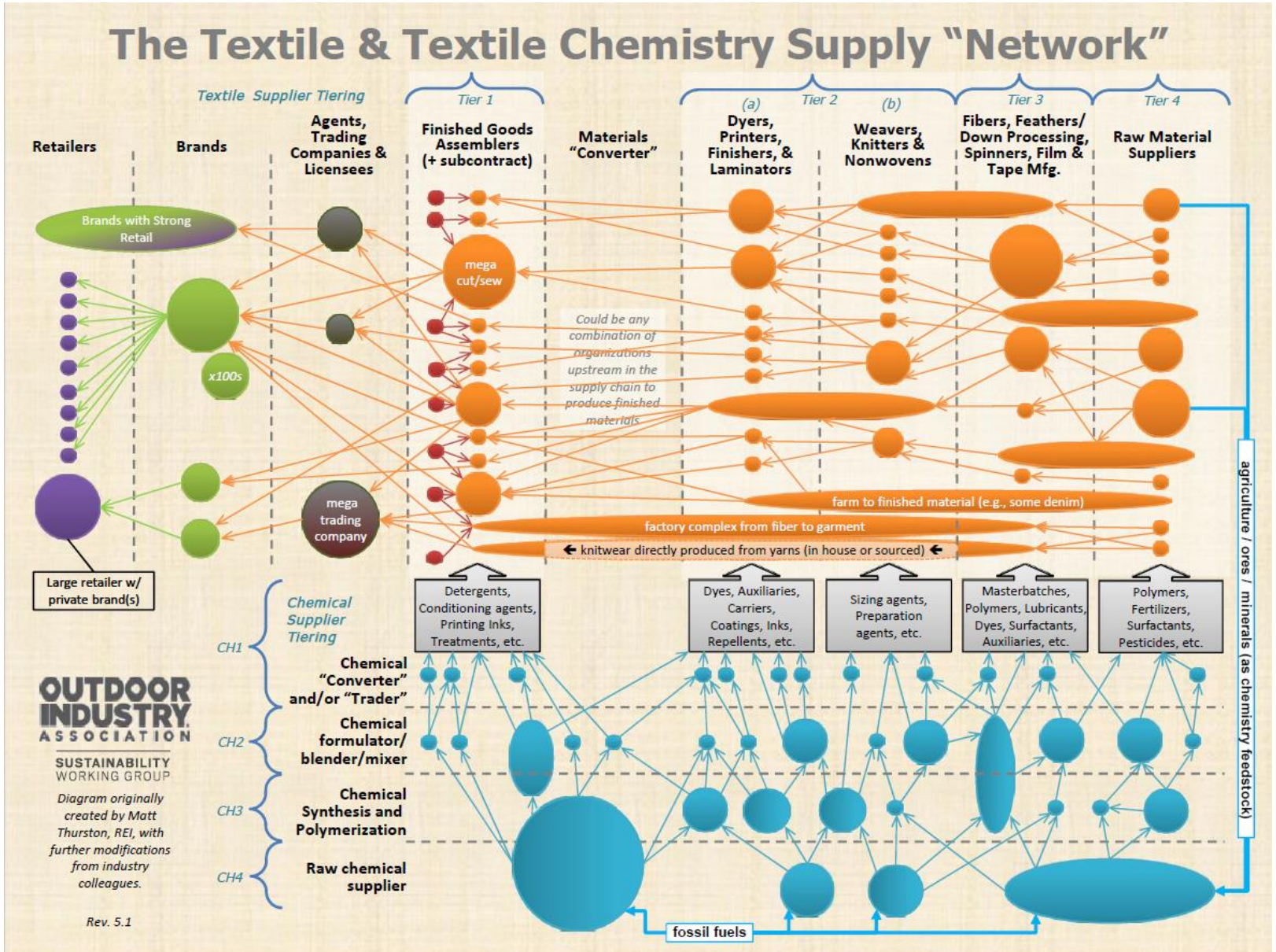
Why Does This Happen (again)?

Result of a Phase Out

When one switches to a compliant alternative, even if it is "greener", it doesn't mean it is safer.



Supply Chains Are Complicated



This is an example of some supply chains for apparel.

It can be hard to know the chemicals being used throughout the supply chain.

It can also be hard to effectively communicate the want of a safer alternative in complex supply chains.

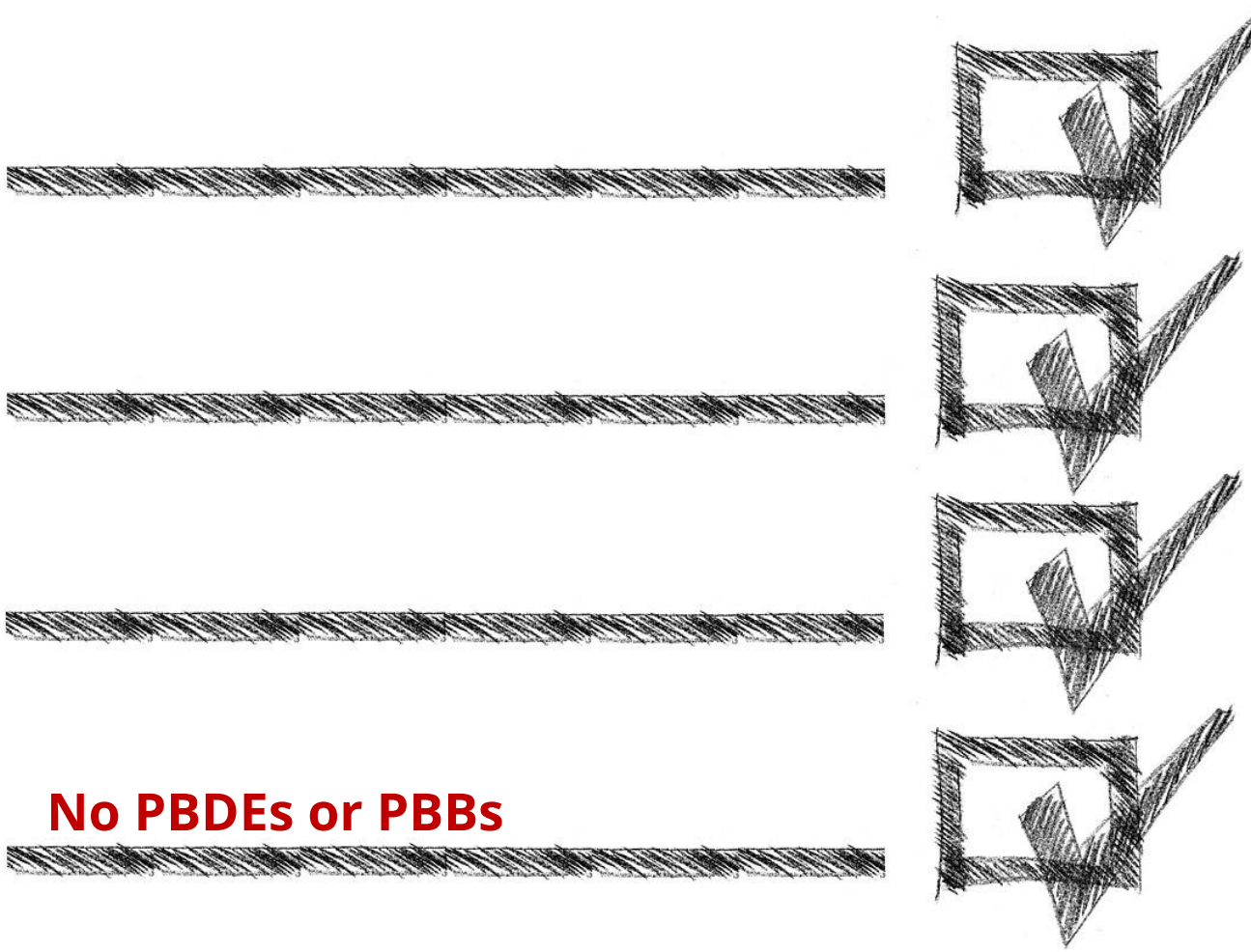
http://oia.outdoorindustry.org/TextileChemistrySupplyWebChart

Lack of Transparency

This is partially due to a lack of transparency in many sectors.

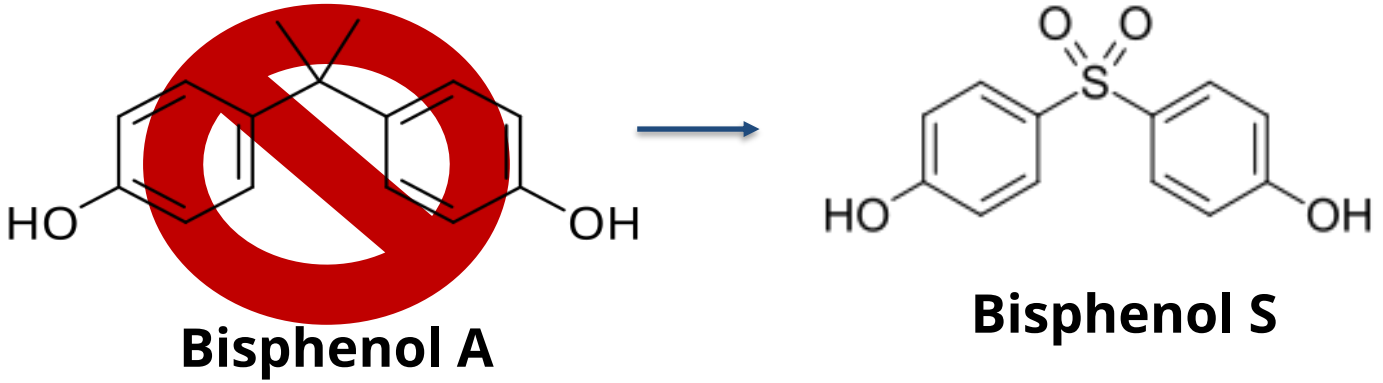
Sometimes a supplier will tell you what the material is not (so it is "Free of" a list of restricted chemicals) but won't tell you what it is.

Specifications Don’t Communicate Hazard



It could also be that one specifies performance needs, quantities and a Restricted Substance List (RSL) but does not list hazard traits that are unacceptable.

Chemists Not Conventionally Taught Toxicology (Neither are Material Scientists nor Designers)



Bisphenol A **Bisphenol S**

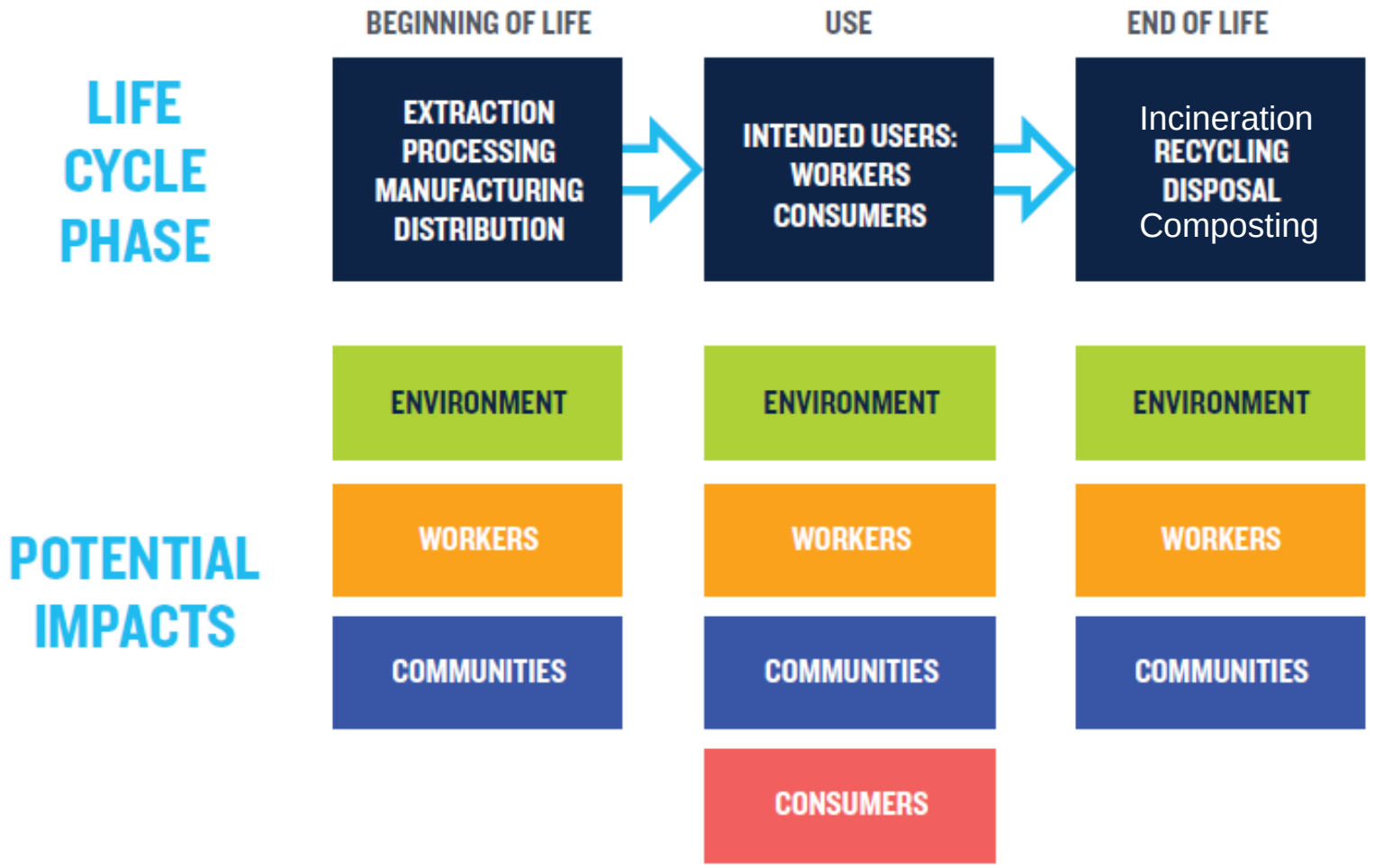
So, when told that you need a chemical with the same function, they often supply an alternative similar in structure. But this could also be similar in hazard.

Not Assessing a Broad Range of Hazard Endpoints

Human Health		Environmental Toxicity & Fate	Physical Hazards
Carcinogenicity	Acute Mammalian Toxicity	Acute Aquatic Toxicity	Reactivity
Mutagenicity & Genotoxicity	Systemic Toxicity & Organ Effects	Chronic Aquatic Toxicity	Flammability
Reproductive Toxicity	Neurotoxicity	Terrestrial Toxicity	Ozone Depleting Potential
Developmental Toxicity	Skin Sensitization	Bioaccumulation	
	Respiratory Sensitization	Mobility	
Endocrine Activity	Skin Irritation	Persistence/ Biodegradation	
	Eye Irritation		

Which might result in the alternative not having the same toxicity as the original chemical of concern but where it has a different toxicological characteristic that is just as concerning.

Not Thinking Holistically

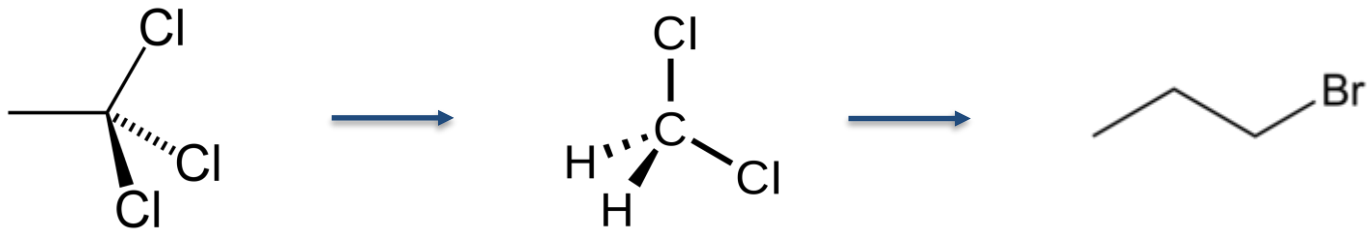


It could be that one is focused on the one population and the alternative ends up negatively impacting another population.

Figure 1 modified from SELECTING SAFER ALTERNATIVES TO TOXIC CHEMICALS AND ENSURING THE PROTECTION OF THE MOST VULNERABLE https://www.nrdc.org/sites/default/files/toxic-chemicals-vulnerable-populations-report.pdf **Examples of Regrettable Substitutions are on p 8-9.**

Another Regrettable Substitution

The **function** of the chemical is as a solvent in a furniture adhesive.



1,1,1-Trichloroethane **Methylene Chloride** **n-Propyl Bromide**

- **Damages Ozone**
- Acute Aquatic Toxicity
- Probable Carcinogen

- **Does not Damage Ozone**
- Probable Carcinogen

- Reproductive Toxicant
- Developmental Toxicant
- Causes Neuropathy

Watch the **Case Study** HERE.

How do we minimize the chance of a Regrettable Substitution?

By Picking the Right Tool for the Job

Chemical Hazard Assessment	Evaluates hazards across a spectrum of endpoints: The inherent potential to harm. Which chemical is inherently safer?
Risk Assessment	Evaluates risk: The probability of adverse harm. Is this chemical safe enough for intended use?
Life Cycle Assessment	Considers multiple impacts across the life cycle and hazard from emissions. Energy usage tends to dominate results. What are the overall impacts of a chemical/product from cradle to <X>?
Alternatives Assessment	Evaluates hazard, exposure, cost/availability, performance, and potentially more. Which chemicals are feasible and pose a lower hazard to what is currently being used, and what are the tradeoffs?

By Prioritizing the Reduction of Hazard When Looking at Alternatives (in addition to meeting the usual requirements of a substitution such as performance, economic viability and compliance).

Alternatives Assessment

A tool for “informed substitution”

Alternatives Assessment- Process for identifying and comparing potential chemical and non-chemical **existing** alternatives used as substitutes to replace chemicals or technologies of high concern.

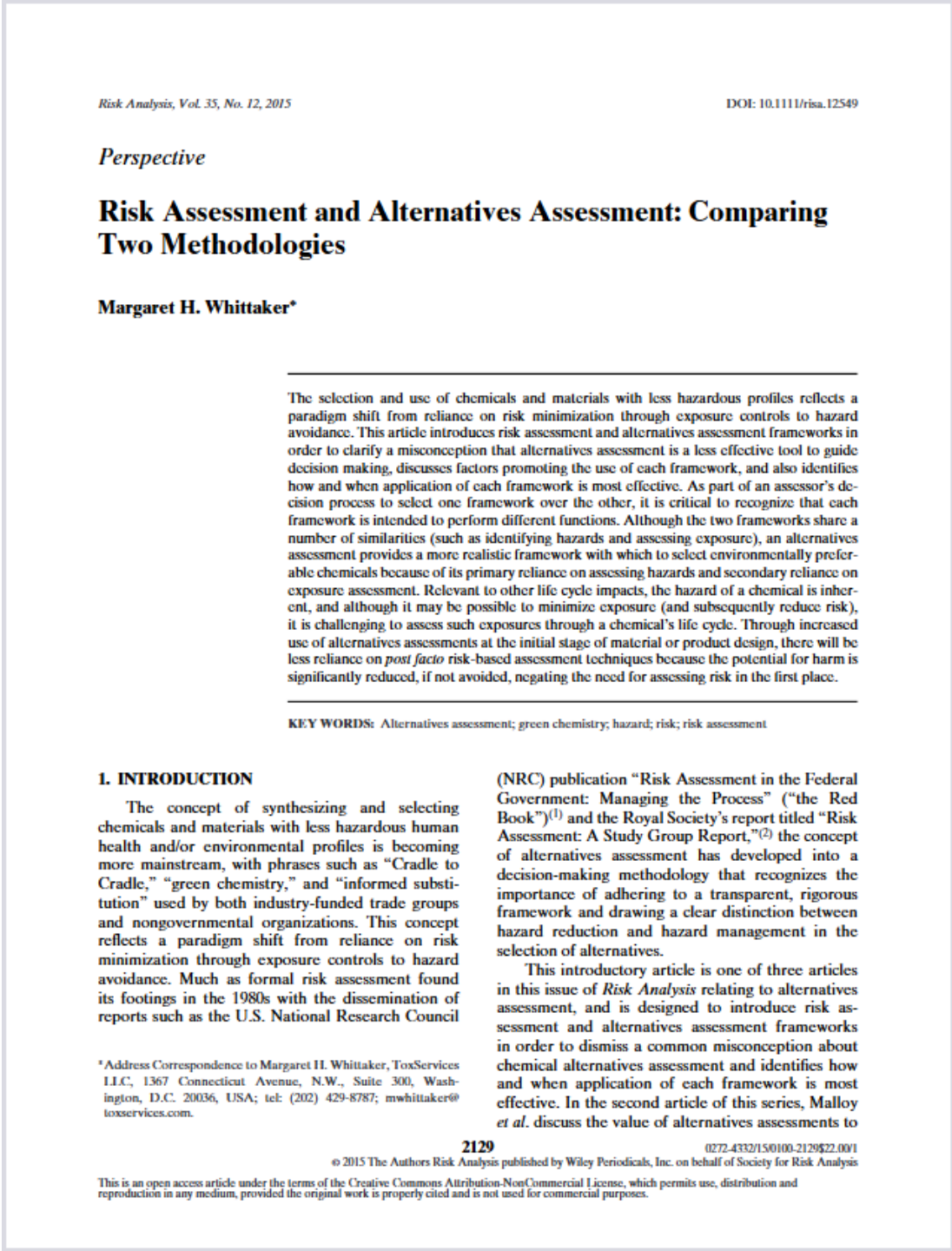
The Objective of an alternative assessment is to replace chemicals of concern in products or processes with **inherently safer alternatives**, thereby protecting and enhancing human health and the environment.

Activity

Read the open access journal article:
Risk Assessment and Alternatives assessment: Comparing Two Methodologies, Risk Analysis, 2015

https://onlinelibrary.wiley.com/doi/full/10.1111/risa.12549)

What are some similarities and differences between a risk assessment and an alternatives assessment?



Risk Analysis, Vol. 35, No. 12, 2015 DOI: 10.1111/risa.12549

Perspective

Risk Assessment and Alternatives Assessment: Comparing Two Methodologies

Margaret H. Whittaker*

The selection and use of chemicals and materials with less hazardous profiles reflects a paradigm shift from reliance on risk minimization through exposure controls to hazard avoidance. This article introduces risk assessment and alternatives assessment frameworks in order to clarify a misconception that alternatives assessment is a less effective tool to guide decision making, discusses factors promoting the use of each framework, and also identifies how and when application of each framework is most effective. As part of an assessor's decision process to select one framework over the other, it is critical to recognize that each framework is intended to perform different functions. Although the two frameworks share a number of similarities (such as identifying hazards and assessing exposure), an alternatives assessment provides a more realistic framework with which to select environmentally preferable chemicals because of its primary reliance on assessing hazards and secondary reliance on exposure assessment. Relevant to other life cycle impacts, the hazard of a chemical is inherent, and although it may be possible to minimize exposure (and subsequently reduce risk), it is challenging to assess such exposures through a chemical's life cycle. Through increased use of alternatives assessments at the initial stage of material or product design, there will be less reliance on *post facto* risk-based assessment techniques because the potential for harm is significantly reduced, if not avoided, negating the need for assessing risk in the first place.

KEY WORDS: Alternatives assessment; green chemistry; hazard; risk; risk assessment

1. INTRODUCTION

The concept of synthesizing and selecting chemicals and materials with less hazardous human health and/or environmental profiles is becoming more mainstream, with phrases such as "Cradle to Cradle," "green chemistry," and "informed substitution" used by both industry-funded trade groups and nongovernmental organizations. This concept reflects a paradigm shift from reliance on risk minimization through exposure controls to hazard avoidance. Much as formal risk assessment found its footings in the 1980s with the dissemination of reports such as the U.S. National Research Council (NRC) publication "Risk Assessment in the Federal Government: Managing the Process" ("the Red Book")[1] and the Royal Society's report titled "Risk Assessment: A Study Group Report,"[2] the concept of alternatives assessment has developed into a decision-making methodology that recognizes the importance of adhering to a transparent, rigorous framework and drawing a clear distinction between hazard reduction and hazard management in the selection of alternatives.

This introductory article is one of three articles in this issue of *Risk Analysis* relating to alternatives assessment, and is designed to introduce risk assessment and alternatives assessment frameworks in order to dismiss a common misconception about chemical alternatives assessment and identifies how and when application of each framework is most effective. In the second article of this series, Malloy *et al.* discuss the value of alternatives assessments to

*Address Correspondence to Margaret H. Whittaker, ToxServices LLC, 1367 Connecticut Avenue, N.W., Suite 300, Washington, D.C. 20036, USA; tel: (202) 429-8787; mwhittaker@toxservices.com.

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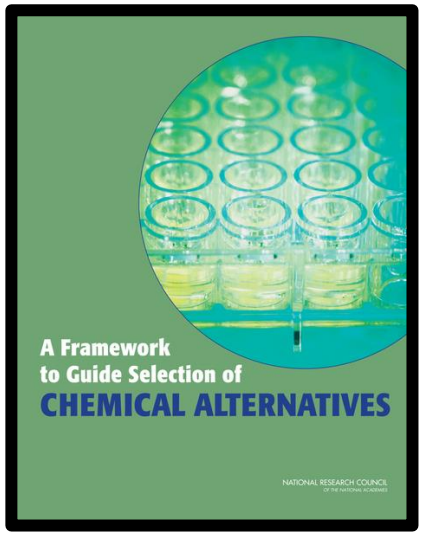
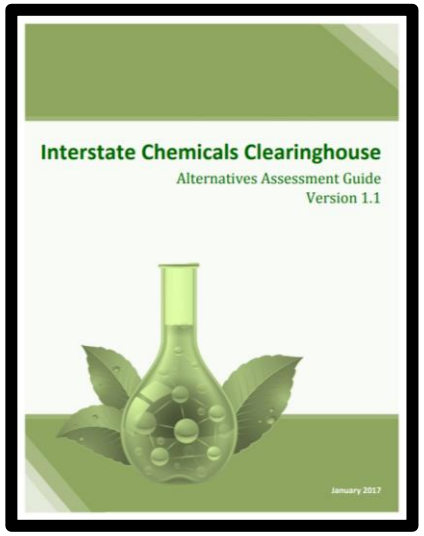
Alternatives Assessment Frameworks





There are several frameworks available. All provide flexible guidance on how to do an assessment.

2 examples of free publicly available frameworks are:

- A Framework to Guide Selection of Chemical Alternatives from the National Academy of Sciences and
- Alternatives Assessment Guide from the Interstate Chemicals Clearinghouse (IC2)

There is information on: Transparency, Stakeholder Involvement, Frameworks, Hazard, Performance, Economic Viability, Exposure, Materials Management, Social Impact, Life Cycle Thinking and Addressing Tradeoffs

Six General Steps of an Alternatives Assessment

- Identify Chemicals of Concern
- Initial Evaluation
- Scoping
- Identification of Alternatives
- Evaluation of Alternatives
- Identify Acceptable Alternatives or Innovate

Step 1: Identify Chemical(s) of Concern

Objective

To identify a chemical, product or process that is the subject of the Alternatives Assessment

Identify Chemical(s) of Concern

It is assumed that the chemical or chemicals of concern have been identified. It could be due to regulatory demands, market drivers or improving business operations/chemical management.

Chemicals of high concern include substances that are:

- persistent, bioaccumulative and toxic
- persistent, mobile and toxic
- very persistent and very bioaccumulative
- carcinogenic;
- mutagenic;
- reproductive or developmental toxicant;
- endocrine disruptor
- neurotoxicant.

"Toxic" includes both human toxicity and ecotoxicity

Some resources on how to screen for chemicals of concern will be shared in **Step 4.**

Step 2: Initial Evaluation

Objective

- To gather information on the chemical of concern
- To determine whether the chemical is truly needed in the product or process.

Is an Alternative Assessment Needed?

In order to understand if an alternative assessment is needed, one needs to understand why a chemical of concern is in a product in the first place.

If an alternative assessment is needed, this step is also helpful as one can better understand the function and related relevant requirements of both the chemical, material and product the chemical of concern is used in.

So, the first question to ask is:
Is the chemical intentionally* added to the product?

*intentionally added in this case is a chemical that is added to the formulation of the final product or added to a component or ingredient of that product.

If the chemical is intentionally added, ask "Is the Function Necessary?"

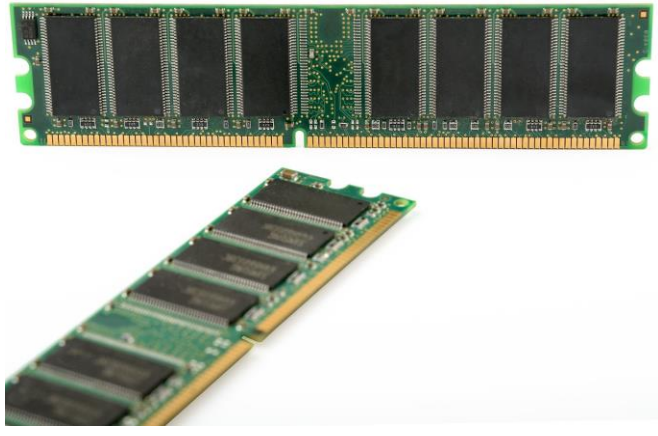
If it is not necessary, eliminate it. (and no assessment needed!)

Examples

- Triclosan (function is an **antimicrobial**) in hand soap. An antimicrobial is not necessary in hand soap as physical removal of germs suffice.
- PFAS (function is **water repellency**) on a water shoe. Water repellency is not needed on straps of a water shoe as ones feet will get wet.

If the chemical is intentionally added, ask "Is the Function Necessary?"

If the function is necessary, move forward with an alternatives assessment.



Examples

- N-Methyl-2-Pyrrolidone (NMP) (function is a **solvent**) in a photoresist stripper formulation. A solvent is needed.

- Diethyl phthalate (DEP) (functions as a **solvent and fixative**) in a fragrance oil used as an ingredient in scented shampoo. A solvent and fixative is needed in a fragrance oil.

You will also need to get a better understanding of the properties and performance needs of the chemical, material and product.

Chemical of Concern

If an Alternative Assessment is needed some information you might need to gather include:

- the human health and environmental effects of the chemical
- Specific function of functions the chemical serves in the product or process
- Performance requirements
- Relevant physical and chemical properties
- Potential exposure pathways

If the chemical is unintentionally added and it is a contaminant in a material or chemical impurity

No AA is needed if:

- The chemical or material containing the chemical of concern can be removed without impacting the product or
- One can purchase the material or chemical without the chemical of concern, for example, an alternative with a higher purity.

If these are not possible, an AA is needed.

Example

- 1,4 dioxane is a manufacturing impurity of Sodium Laureth Sulfate (SLES) (function is a **surfactant**) in some cleaning products. Surfactants are needed in those products so an AA is needed.

Step 3: Scoping

Objectives

- To determine your stakeholders and how they will be involved
- To identify goals, principles and decision rules
- To determine assessment methods

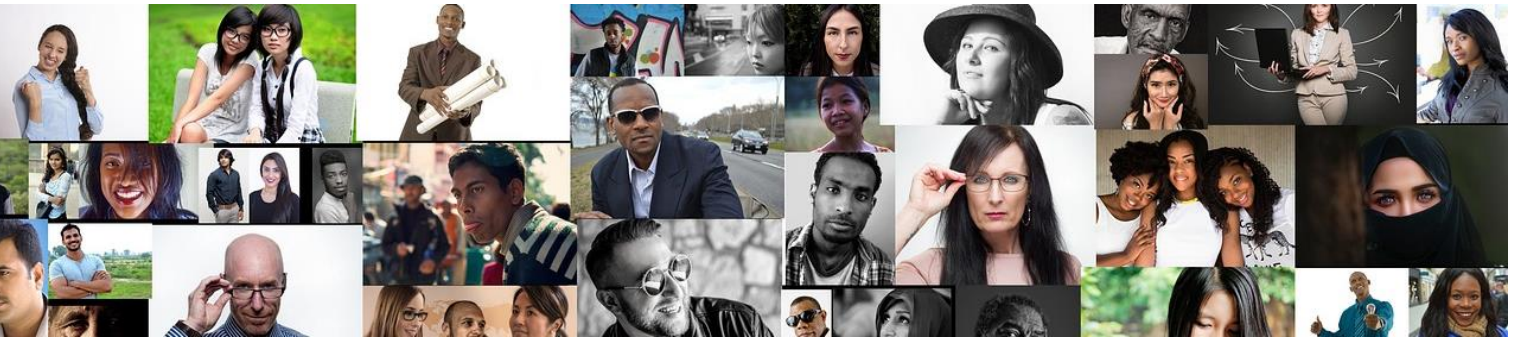
Stakeholders

Stakeholders- Individuals or groups that are impacted or can impact the transition.

Examples include chemical manufacturers, product designers, users of the product, fence line communities, researchers and others downstream of the product use.

Engaging stakeholders can lead to greater understanding and buy-in, provide broader perspectives, data and expertise that will improve the quality of the assessment.

The level of engagement will depend on factors such as who is conducting the assessment and the scale of the change.



Recommendation, Read p 35-45 **about Scoping** .

Stakeholders

Some questions that can help you identify stakeholders:

- Which stakeholders are critical to your success?
- Who is affected by the alternative assessment and decisions?
- Are there external stakeholders that are specifically affected?
- Are there external stakeholders who are potential collaborators for addressing all, or parts, of the assessment?
- What expertise is needed for this interdisciplinary project and are they on your team?
- Are there external stakeholders who could provide missing perspectives?



Reading on Stakeholder Engagement

Read p 37-38 of A Framework to Guide Selection of Chemical Alternatives from the National Academy of Science.

If you want to learn more, please read the section on stakeholder engagement in the IC2 Alternative Assessment Guide.

Establish Goals
(Desired Outcomes)

What is the main goal driving the substitution?

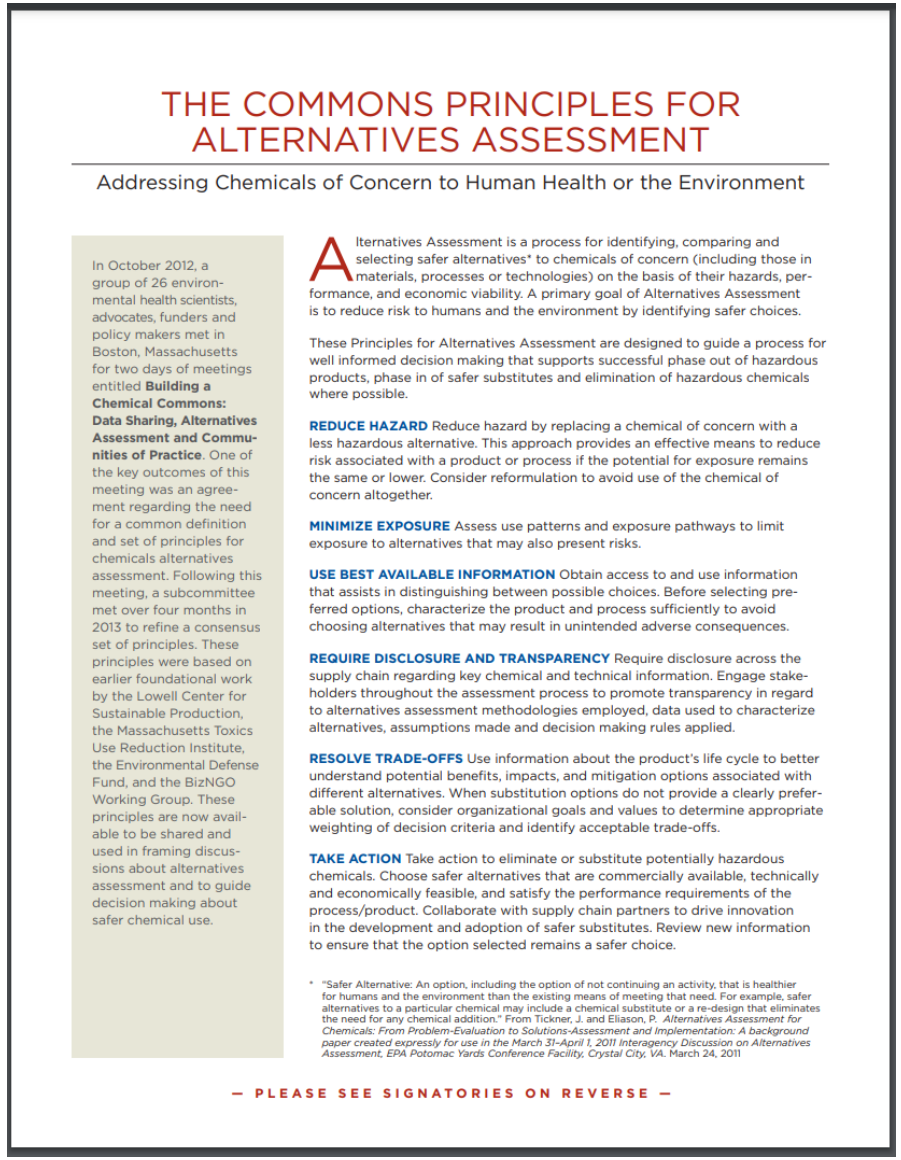
Are there overarching organizational goals?

Do you need to decide on one alternative for a specific application or identify a range of alternatives for a fairly broad application?

Example goals:
"To support the informed transition to functional, cost-effective and safer alternative."

"To use the highest percent biobased waste feedstock possible."

Establish Principles
(Values or Tenets of the organization)



THE COMMONS PRINCIPLES FOR ALTERNATIVES ASSESSMENT

Addressing Chemicals of Concern to Human Health or the Environment

In October 2012, a group of 26 environmental health scientists, advocates, funders and policy makers met in Boston, Massachusetts for two days of meetings entitled **Building a Chemical Commons: Data Sharing, Alternatives Assessment and Communities of Practice**. One of the key outcomes of this meeting was an agreement regarding the need for a common definition and set of principles for chemicals alternatives assessment. Following this meeting, a subcommittee met over four months in 2013 to refine a consensus set of principles. These principles were based on earlier foundational work by the Lowell Center for Sustainable Production, the Massachusetts Toxics Use Reduction Institute, the Environmental Defense Fund, and the BizNGO Working Group. These principles are now available to be shared and used in framing discussions about alternatives assessment and to guide decision making about safer chemical use.

Alternatives Assessment is a process for identifying, comparing and selecting safer alternatives* to chemicals of concern (including those in materials, processes or technologies) on the basis of their hazards, performance, and economic viability. A primary goal of Alternatives Assessment is to reduce risk to humans and the environment by identifying safer choices.

These Principles for Alternatives Assessment are designed to guide a process for well informed decision making that supports successful phase out of hazardous products, phase in of safer substitutes and elimination of hazardous chemicals where possible.

REDUCE HAZARD Reduce hazard by replacing a chemical of concern with a less hazardous alternative. This approach provides an effective means to reduce risk associated with a product or process if the potential for exposure remains the same or lower. Consider reformulation to avoid use of the chemical of concern altogether.

MINIMIZE EXPOSURE Assess use patterns and exposure pathways to limit exposure to alternatives that may also present risks.

USE BEST AVAILABLE INFORMATION Obtain access to and use information that assists in distinguishing between possible choices. Before selecting preferred options, characterize the product and process sufficiently to avoid choosing alternatives that may result in unintended adverse consequences.

REQUIRE DISCLOSURE AND TRANSPARENCY Require disclosure across the supply chain regarding key chemical and technical information. Engage stakeholders throughout the assessment process to promote transparency in regard to alternatives assessment methodologies employed, data used to characterize alternatives, assumptions made and decision making rules applied.

RESOLVE TRADE-OFFS Use information about the product's life cycle to better understand potential benefits, impacts, and mitigation options associated with different alternatives. When substitution options do not provide a clearly preferable solution, consider organizational goals and values to determine appropriate weighting of decision criteria and identify acceptable trade-offs.

TAKE ACTION Take action to eliminate or substitute potentially hazardous chemicals. Choose safer alternatives that are commercially available, technically and economically feasible, and satisfy the performance requirements of the process/product. Collaborate with supply chain partners to drive innovation in the development and adoption of safer substitutes. Review new information to ensure that the option selected remains a safer choice.

* "Safer Alternative: An option, including the option of not continuing an activity, that is healthier for humans and the environment than the existing means of meeting that need. For example, safer alternatives to a particular chemical may include a chemical substitute or a re-design that eliminates the need for any chemical addition." From Tickner, J. and Eliason, P. *Alternatives Assessment for Chemicals: From Problem-Evaluation to Solutions-Assessment and Implementation: A background paper created expressly for use in the March 31-April 1, 2011 Interagency Discussion on Alternatives Assessment, EPA Potomac Yards Conference Facility, Crystal City, VA.* March 24, 2011

— PLEASE SEE SIGNATORIES ON REVERSE —

Example Principles

- Ensure transparent information
- Take precautionary approach when there is uncertainty

Read "The Commons Principles for Alternatives Assessment" for more information on principles.

https://www.bizngo.org/images/ee_images/uploads/resources/commons_principles_AA_2013_10_14.pdf

Establish Decision Rules and Assessment Criteria

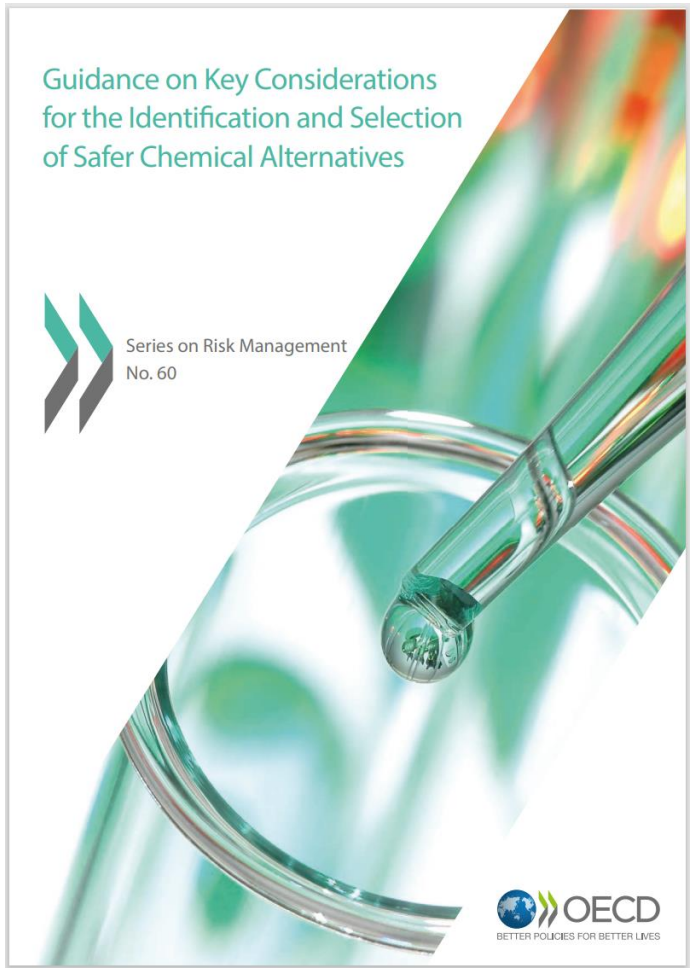
This step can address things such as:

- What modules will be used
- Are there minimum criteria?
- How will data gaps be handled? What about trade offs?
- Acceptable sources of info?

Examples:

- Avoid chemicals that are persistent, bioaccumulative and toxic
- Avoid chemicals that are highly toxic to aquatic organisms and persistent
- Avoid options that do not meet specific performance criteria.
- Certain data gaps are unacceptable for alternatives- data is required for carcinogenicity, Mutagenicity/Genotoxicity, Reproductive or Developmental Toxicity, Persistence.
- Evaluate only alternatives that are chemical alternatives (versus material, product or process change)

Example Criteria and Decision Rule for Alternatives



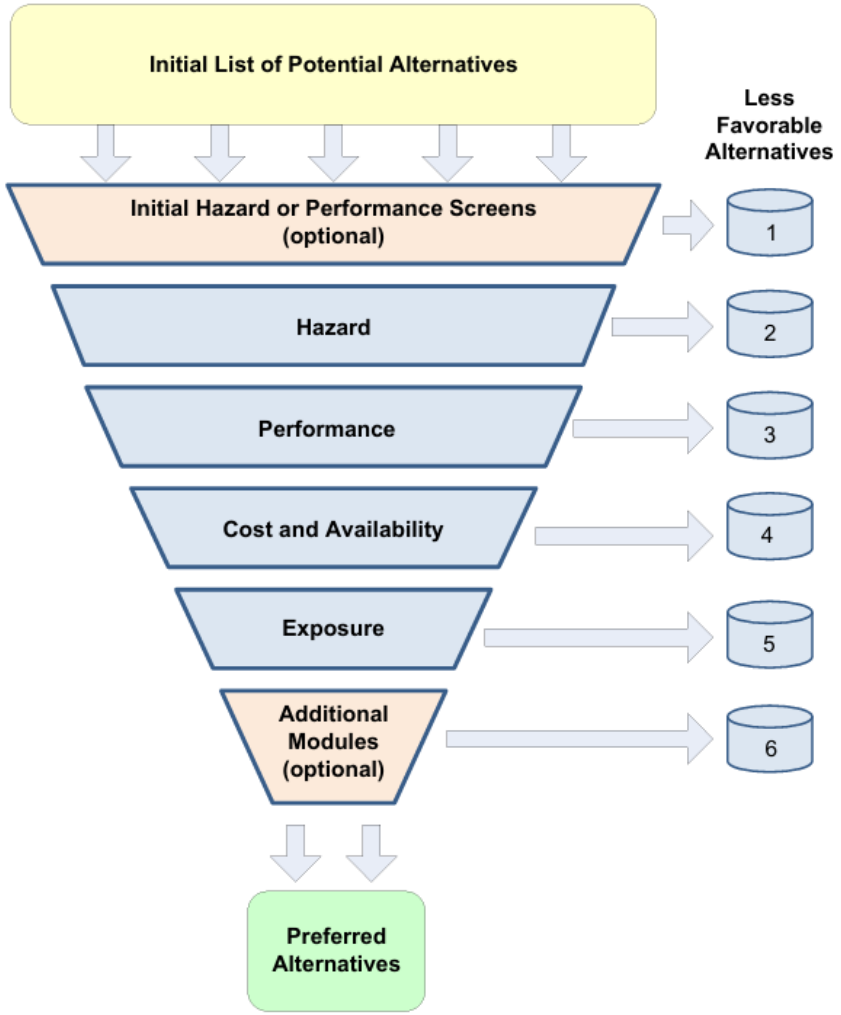
"This minimum set of criteria and practices should not preclude assessors from including more comprehensive approaches in their alternatives assessments. Assessments that go beyond these minimum requirements will reduce the likelihood of a substitution decision leading to unintended consequences to the environment, workers, and the public more broadly. "

"Avoiding CMRs, PBTs and vPvBs (very persistent, very bioaccumulative substances)" is **a decision rule** that is consistent with most regulatory program priorities, for example authorization under REACH (Article 57), whereby substances characterized by these hazard traits are prioritized for substitution."

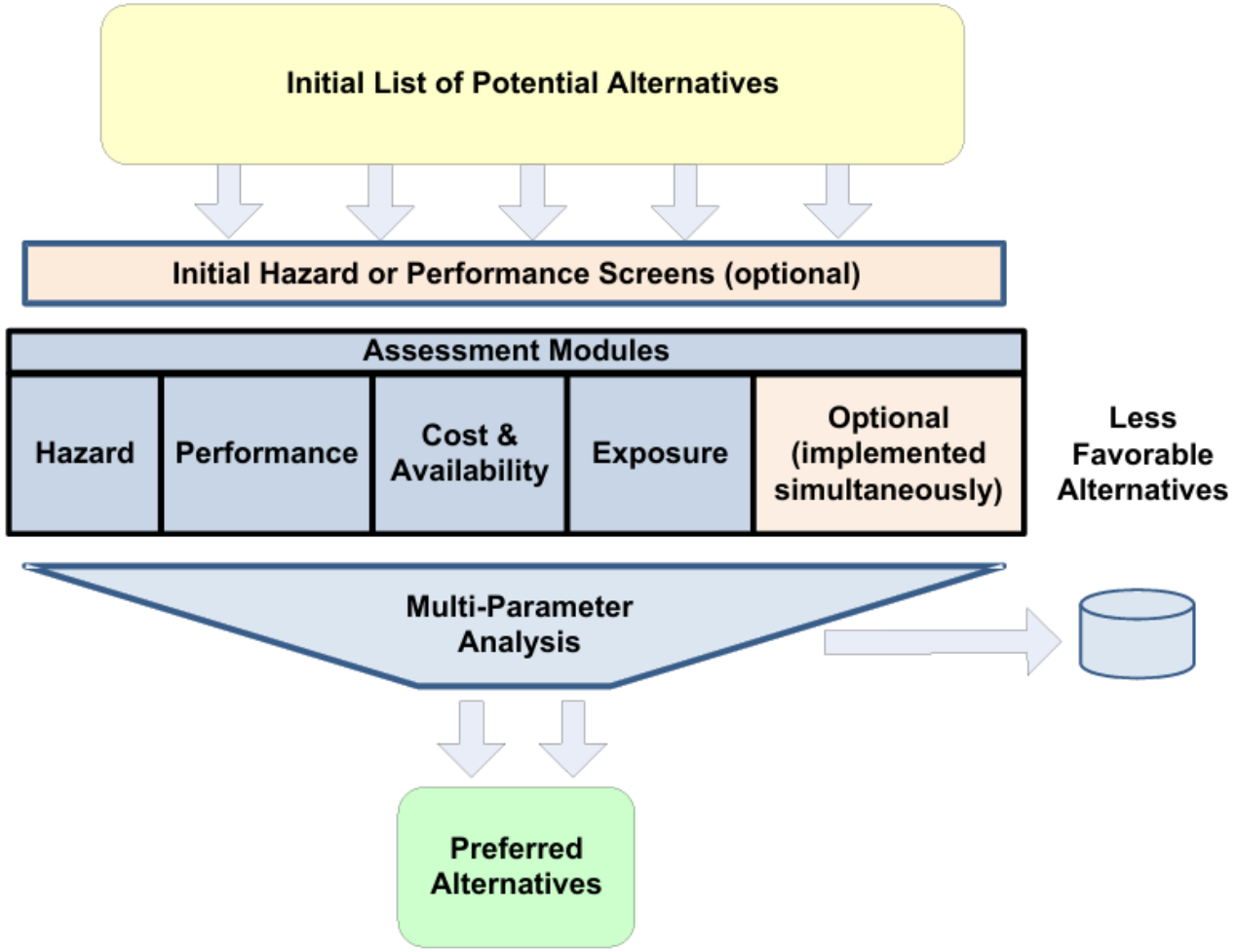
https://www.oecd-ilibrary.org/environment/guidance-on-key-considerations-for-the-identification-and-selection-of-safer-chemical-alternatives_a1309425-en

Example Decision Frameworks

Sequential



Simultaneous



Alternatives Assessment Guide - Interstate Chemicals Clearinghouse (IC2)

Types of alternatives

When looking for alternatives, you can decide on the types of alternatives to assess that may meet the chemical (or the products that it is in) function and performance requirements. Types include:

- A relatively simple **chemical substitute** that does not result in a substantial product or production process redesign (some are known as a “drop in substitute”)
- An **alternative material**
- A **product or process change** that eliminates the need for the chemical of concern
- **Re-design** of a product that eliminates the need for the chemicals of concern

Example of a Chemical Substitute

Seattle Bullitt Center: Air and Water Barrier Coating

Photo from https://prosoco.com/the-bullitt-center-and-prosoco/

The building designers specified that no phthalates could be used in materials selected for the project.

Phthalates function as plasticizers and, at the time, were used in the barrier as the plasticizer function is needed to prevent cracking of the material.

The company selected reformulated and used polypropylene glycol as the plasticizer so that they could meet the performance requirements without the hazard.

Reference for example HERE

Example of a Material Substitute

Urea Formaldehyde Adhesives can be used to bond plywood. An alternative material is a formaldehyde-free adhesive made of soy.

The adhesive can be used in the same application equipment.

Video with more info HERE

Example of an Alternative Process

Perchloroethylene (PERC) is a halogenated solvent that has frequently been used in the dry cleaning industry.

An alternative technology is professional wet cleaning. One needs different equipment and the cleaning process is different but is another way to clean clothes.

Case Study of a facility who substituted PERC dry cleaning with wet cleaning HERE

Example of a Redesign

Complete Elimination of a Chemical Developer

Bisphenol A (or Bisphenol S) functions as a developer, which reacts with white or colorless dyes (color formers) in the presence of heat, converting them to a dark color.

An alternative thermal printing paper was designed that does not need a chemical developer to create an image. This technology relies on air voids in the paper coating to develop an image. The heat melts the surface coating with the air voids turning it from opaque to clear letting a colored layer show through.

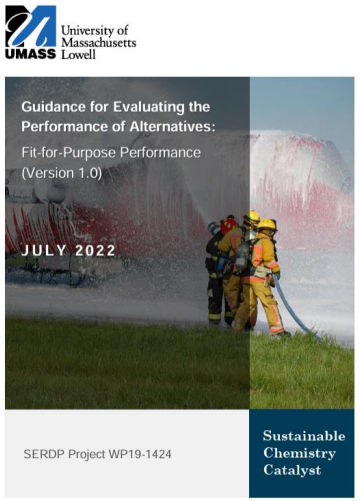
This thermal paper is compatible with commercial thermal printers that use the bisphenol thermal printing paper.

Methods

In this step, you will need to decide and document your intended process. It is important to be transparent about this step. This will help reduce bias while going through the process. Some of these methods may need to be modified during the assessment process as you gain more information from the process.

- Which assessment steps (examples- hazard, exposure, performance, cost) will be addressed? At what level and with what tools?
- How alternatives will be assessed or compared- for example do they have to meet a minimum criteria or be within a certain range for an assessment step?

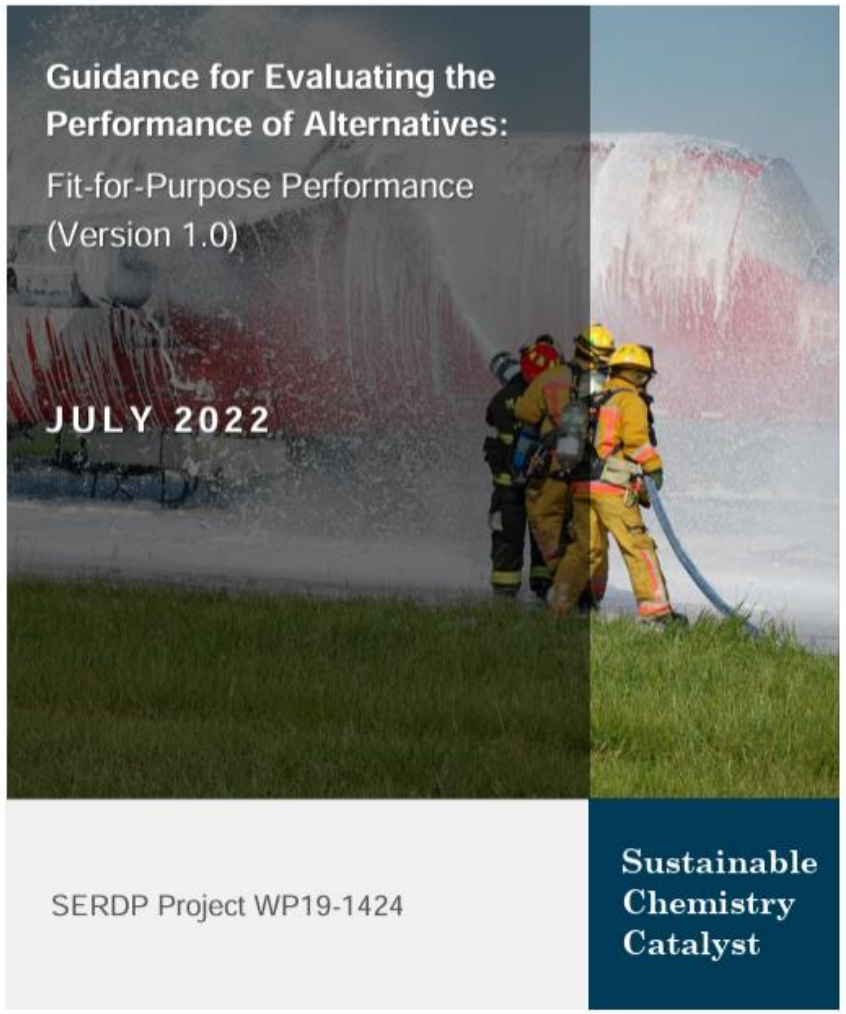
Performance
Fit-for-Purpose



Guidance considerations include:

- Determine the **function** of the chemical/material/product/process of concern for the specific application and understand this function within the production chain.
- Define the **application-specific scenario(s)** in which the substance of concern is used and identify alternatives that are suitable for that particular purpose.
- Establish and/or use performance standards that **have been developed independent of the existing chemicals/materials/products/processes of concern (as much as possible)** and adjust them based on available alternatives or alternatives on the horizon.
- Develop and use a **range of performance standard benchmarks**, from "inadequate" to "sufficient" to "best in class" to evaluate the alternative for the specific application(s).
- Consider **technical performance separately from technical feasibility** (feasibility of adoption) of potential alternatives.
- Consult **stakeholders to determine acceptable tradeoffs** between performance results and other elements such as environmental health and safety.

From HERE (recommended reading).



Performance

Fit-for-Purpose

Performance based on application-specific contexts

"A fit-for-purpose performance approach underscores the importance of evaluating whether the function of the chemical, material, product, or process of concern achieves sufficient performance, recommends using a range of acceptable thresholds, and acknowledges important considerations around tradeoffs with environmental health and safety performance. "

Guidance considerations include:

- Determine the function of the chemical/material/product/process for the specific application and understand this function within the production chain.
- Define the application-specific scenario(s) in which the substance of concern is used and identify alternatives that are suitable for that particular purpose.
- Establish performance standards that have been developed independent of the existing chemical of concern.
- Develop and use a range of performance benchmarks for the specific application(s).
- Consider technical performance separately from technical feasibility (feasibility of adoption)
- Consult stakeholders to determine acceptable

Step 4: Identification of Potential Alternatives

Objectives

- To identify potential alternatives within the scope of the assessment
- To screen out those that are easily identified as problematic

Looking for Potential Alternatives

Consider the range of alternatives you defined in your scope (i.e., chemical, material, alternative process, redesign)

Use as many resources as you can think of to find potential alternatives such as:

- your colleagues,
- databases,
- your suppliers,
- manufacturer/vendor information,
- organizations working on safer alternatives,
- government publications,
- trade association sites/journals and
- tailored internet searches

Note that just because an alternatives is marked as safer, doesn't mean that they meet <u>your</u> criteria of safer.

Is there a way to communicate your criteria?

Communicate what you want – compliance AND safer chemicals that serve the function you need

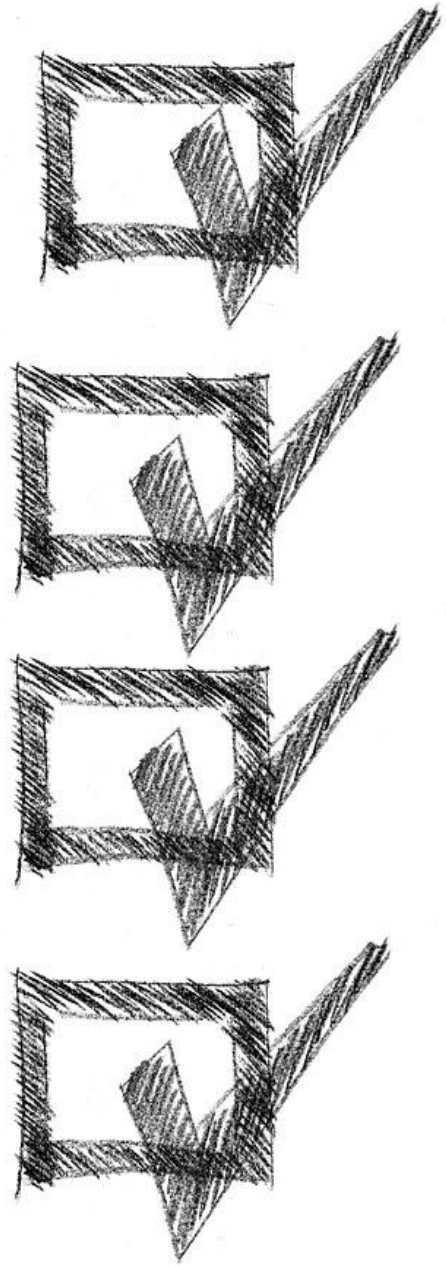
Example Request for Chemical Alternatives

Compatible with ABS/PC resin

Can Meet UL 94 V0 at specified target wall thickness.

No Brominated or Chlorinated compounds,
No chemicals with H340, H350 or H360 H-phrases

Preference for chemicals that are GreenScreen Benchmark 2,3 or 4, Enhesa Hazard Category Green, Green/Yellow or Yellow, ChemForward A,B or C, or listed on US EPA SCIL, CleanGredients, ChemForward SAFER or Cradle to Cradle Certified



In addition to specifying performance needs, quantities and a Restricted Substance List (RSL), **consider providing a list of hazard traits that are unacceptable or preferable chemical hazard assessment scores/material certifications**.

Activity

Go to the ACTIVITY SLIDES and select one or two of the resources.

Take 3-5 minutes to explore the resource making sure to look at what types of alternatives are mentioned as well as the information available.

When you are ready, share this information with a partner. Is there anything you found especially useful?

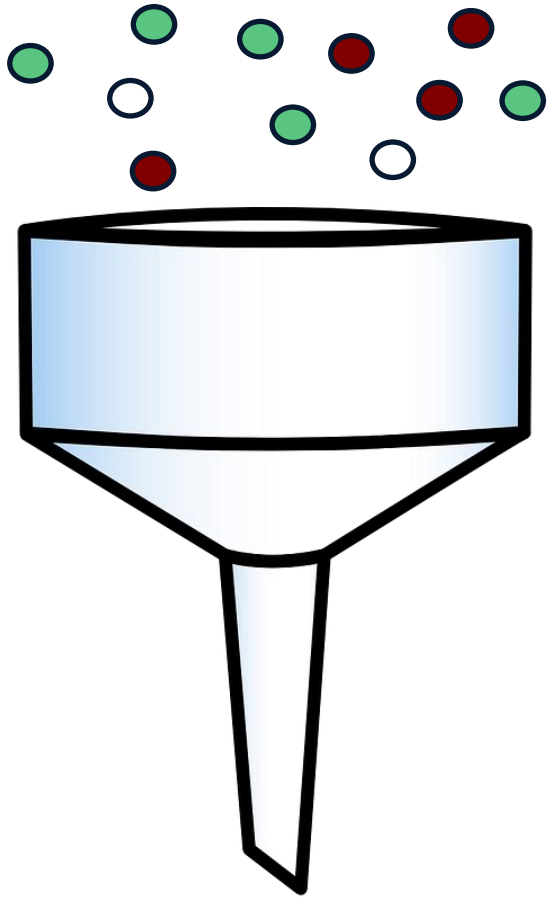
https://www.globalgreenchem.com/_files/ugd/c7d2f6_61227acf466141c289bd3091b4b1de58.pdf

Congrats!

You now have a list of potential alternatives.

The next step is to go through the list and **screen** out the least promising alternatives to get to an amount that one has the capacity to assess in more depth.

Screening



This step is to narrow down the number of alternatives that you will assess further.

One can screen out based on **hazard** or negative **performance**.

One can also screen out those that don't meet the decision rules that were developed in the scoping step.

Remember, that one needs to document all of ones decisions.

Transparency

In order to screen alternatives for hazard, one either needs:

- transparency of the ingredients of the alternatives (through disclosure) or
- a third-party certification that meets your hazard criteria.

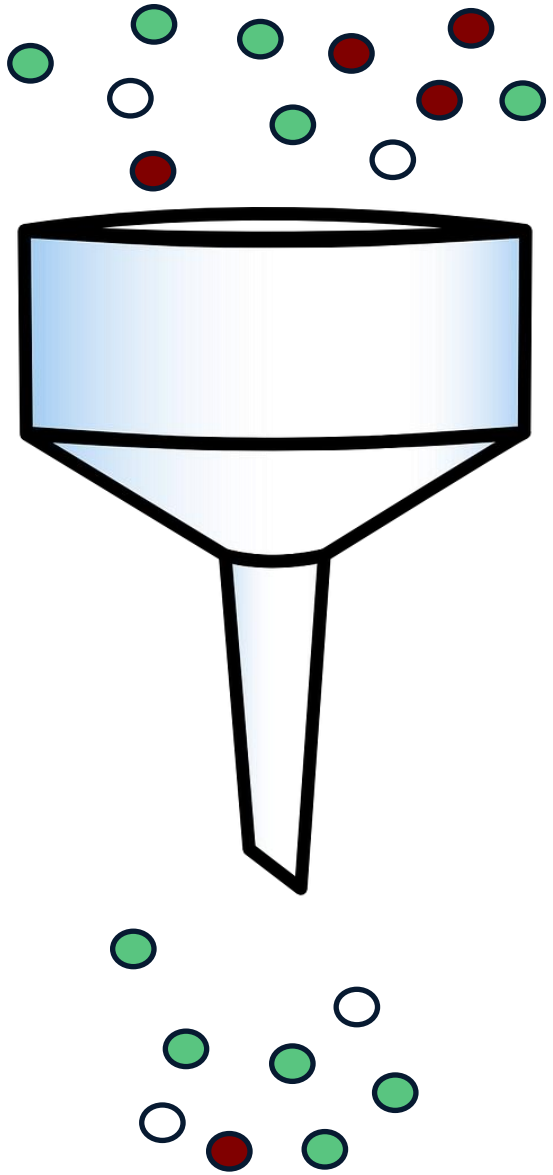
Learn more about the Principles of Chemical Ingredient Disclosure (website and webinar)

Screening for Hazard

Screen out chemicals that are identified to have hazard traits of high concern identified during scoping.

One can do this by:

- Scanning Safety Data Sheets (SDSs) for certain H-phrases and screening them out based on decision rules.
- Reviewing specified Hazard Authoritative lists.



SDSs

One can look at Section 2 of SDSs

Example:

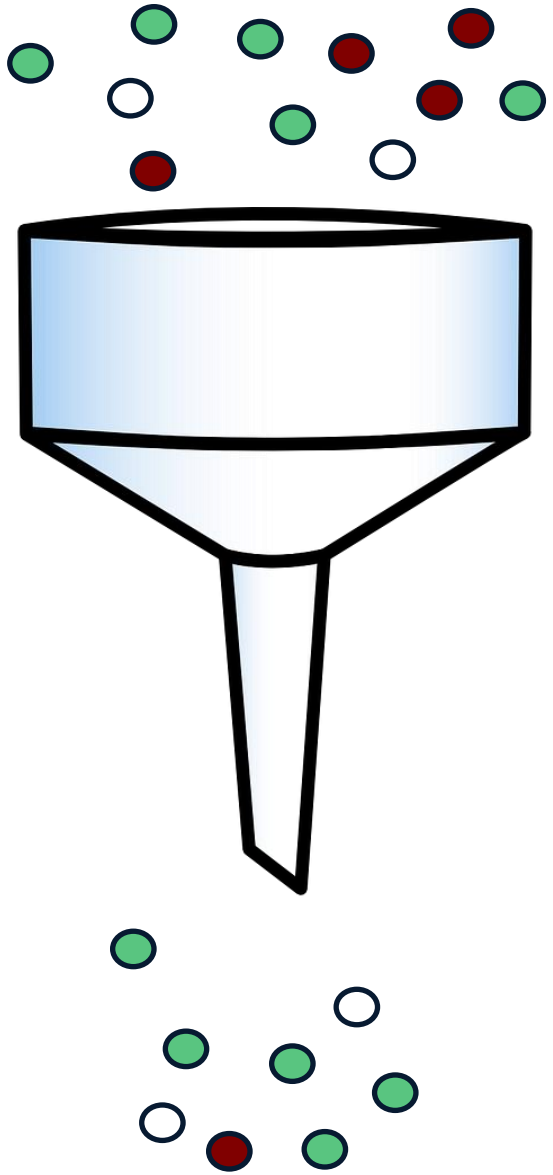
2.2 Label elements

Labelling according Regulation (EC) No 1272/2008

Pictogram

Signal Word	Warning
Hazard statement(s)	
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H336	May cause drowsiness or dizziness.
H351	Suspected of causing cancer.

Or on several databases to find Harmonized Classifications



Methodologies with Authoritative Lists

GreenScreen List Translator™

One way to screen chemicals is with existing resources such as the GreenScreen List Translator. A nonprofit, Clean Production Action, developed a methodology (GreenScreen - which will be discussed later) that allows one to assess, summarize and compare the hazards of chemicals. Based on this, the organizations developed a simpler tool that only pulls from authoritative lists to quickly identify chemicals of high concern. It cannot identify if a chemical is safer.

Uses Information from Hazard Authoritative Lists

Compares against the GreenScreen Hazard Endpoints and Hazard Criteria

Provides a hazard assessment level for each endpoint and a summary score and can flag if chemicals of concern

Lists → Criteria → Score

Useful for screening out hazardous alternatives and for prioritizing chemicals to try to replace.

https://www.greenscreenchemicals.org/assess/list-translator

GreenScreen List Translator™

Hazard Levels, Example List and Example Criteria

The GreenScreen List Translator™ allow one to quickly identify chemicals of high concern by compiling information from over 40 hazard lists developed by authoritative scientific bodies convened by international, national and state governmental agencies, intergovernmental agencies and NGOs and scoring the chemicals on a range of hazard endpoints based on the results. An example is EU-GHS H-statements.

TABLE 7. **Description of Hazard Levels for List Translator**

Hazard Level Classification*	
vH	Very High Concern
H	High Concern
M	Moderate Concern
L	Low Concern
vL	Very Low Concern
(BLANK)	The chemical was not found on any of the authoritative or screening lists associated with GreenScreen
Range	A range may be reported for chemicals found on "B" lists. B lists sometimes include a level of uncertainty and may benefit from additional research to confirm a more specific hazard classification level

* **Bold** font indicates result was derived from an Authoritative A list; *Italics* font indicates result was derived from Authoritative B, Screening A, or Screening B lists

GreenScreen Supporting List Information		GreenScreen List Translator				
List	Sublist Category	GreenScreen Hazard	List Type	A or B	Hazard Range	Display in Hazard Box
EU – GHS (H-Statements)	H318 – Causes serious eye damage	Eye Irritation/ Corrosivity	Authoritative	A	vH	**vH**
EU – GHS (H-Statements)	H319 – Causes serious eye irritation	Eye Irritation/ Corrosivity	Authoritative	A	H	**H**
EU – GHS (H-Statements)	H320 – Causes eye irritation	Eye Irritation/ Corrosivity	Authoritative	A	M	**M**
EU – GHS (H-Statements)	H330 – Fatal if inhaled	Acute Mammalian Toxicity	Authoritative	A	vH	**vH**
EU – GHS (H-Statements)	H331 – Toxic if inhaled	Acute Mammalian Toxicity	Authoritative	A	H	**H**
EU – GHS (H-Statements)	H332 – Harmful if inhaled	Acute Mammalian Toxicity	Authoritative	A	M	**M**
EU – GHS (H-Statements)	H334 – May cause allergy or asthma symptoms or breathing difficulties if inhaled	Respiratory Sensitization	Authoritative	B	H or M	*H or M*
EU – GHS (H-Statements)	H335 – May cause respiratory irritation	Systemic Toxicity/ Organ Effects (Single Exposure)	Authoritative	A	M	**M**
EU – GHS (H-Statements)	H336 – May cause drowsiness or dizziness	Neurotoxicity–Single Exposure	Authoritative	B	M or L	*M or L*
EU – GHS (H-Statements)	H340 – May cause genetic defects	Mutagenicity/ Genotoxicity	Authoritative	A	H	**H**
EU – GHS (H-Statements)	H341 – Suspected of causing genetic defects	Mutagenicity/ Genotoxicity	Authoritative	A	M	**M**
EU – GHS (H-Statements)	H350 – May cause cancer	Carcinogenicity	Authoritative	A	H	**H**
EU – GHS (H-Statements)	H350i – May cause cancer by inhalation	Carcinogenicity	Authoritative	A	H	**H**
EU – GHS (H-Statements)	H351 – Suspected of causing cancer	Carcinogenicity	Authoritative	A	M	**M**

https://www.greenscreenchemicals.org/assess/list-translator

Hazard Endpoints

Group I Human					Group II and II* Human								Ecotex		Fate		Physical		Multiple
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						SINGLE	REPEATED*	SINGLE	REPEATED*											

AA Acute Aquatic Toxicity
AT Acute Mammalian Toxicity
B Bioaccumulation
C Carcinogenicity
CA Chronic Aquatic Toxicity
D Developmental Toxicity
E Endocrine Activity
F Flammability
IrE Eye Irritation
IrS Skin Irritation
M Mutagenicity and Genotoxicity
N Neurotoxicity
P Persistence
R Reproductive Toxicity
Rx Reactivity
SnS Sensitization (Skin)
SnR Respiratory Sensitization
ST Systemic/Organ Toxicity

** Repeated exposure*

The results of those endpoints are then put into a summary score. For example, if a chemical is any of the following:

PBT = High P + High B + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]

vPvB = very High P + very High B

vPT = very High P + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]

vBT = very High B + [very High T (Ecotoxicity or Group II Human) or High T (Group I or II* Human)]

High T (Group I Human)

It would score as an LT-1

https://www.greenscreenchemicals.org/assess/list-translator

GreenScreen List Translator™

Scores:

NoGS, LT-UNK, LT-P1, LT-1

"**LT-1**" (**a known chemical of high concern**) -the hazard classifications for a given chemical meet one or more of the GreenScreen Benchmark-1 criteria and would most likely be a Benchmark-1 chemical.

"**LT-P1**" - the hazard classifications for a given chemical may meet one or more of the GreenScreen Benchmark-1 criteria but it is based on a screening list so more information is needed.

"**LT-UNK**" – the chemical is present on at least one of the GreenScreen specified Lists but none that would result in a score of LT-1 or LT-P1.

“**NoGS**" – the chemical is not found on any of the GreenScreen Specified Lists.

Consider Screening out chemicals that are LT-1s. One will need to assess the remaining chemicals more thoroughly to ensure that they are safer that the chemical of concern one is replacing.

https://www.greenscreenchemicals.org/assess/list-translator

GreenScreen List Translator™

2 Database Tools that have Automated GreenScreen List Translators:

3E Exchange

(**open access** for chemical comparisons- need to log in)
https://exchange.3eco.com/

Pharos

https://pharos.habitablefuture.org/

Example of
Using a GreenScreen List Translator

3E Exchange

Summary Score is here

[71-55-6] , [EC: 200-756-3] LT - 1

1,1,1-Trichloroethane

To look up what each of the endpoints are, go to the question marks.

Share Compare

GreenScreen List Translator™ Score - LT-1

Group I Human					Group II and II* Human									Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
H		M	M or L		M	M	M	M or L				H	H	vH	Mult	vH or H		M		Mult

The results for the individual endpoints based on Authoritative lists are here.

- General Information
- Transformation Products and Impurities
- Regulation and Hazard Lists
- Restricted Substance Lists
- Quick Chemical Assessment Tool (QCAT)
- GreenScreen® Assessment
- GreenScreen® Specified Lists

If one clicks on this row, one can see the lists and how that data is incorporated into the summary (example on next slide)

Example of
Using a GreenScreen List Translator

3E Exchange

GreenScreen® Specified Lists

GreenScreen List Translator™ Score - LT-1

Group I Human					Group II and II* Human								Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
H		M	M or L		M	M	M	M or L				H	H	vH	Mult	vH or H		M		Mult

Regulation	Chemical Family	Chemical Name	RN	Group ID	Reason for Inclusion	Hazard Type	Hazard Score	List Translator
GHS - Korea		1,1,1-Trichloroethane; Trichloroethane	71-55-6		H420			
GHS - Korea		1,1,1-Trichloroethane; Trichloroethane	71-55-6		Skin corrosion/irritation: Category 2			
GHS - Malaysia		1,1,1-trichloroethane; methyl chloroform	71-55-6		[Acute Tox. 4 (inh); H332]	Acute Mammalian Toxicity	M	LT - UNK
GHS - New Zealand		Ethane, 1,1,1-trichloro-	71-55-6		Acute Tox. 4 (inhalation); H332	Acute Mammalian Toxicity	M	LT - UNK
EU - GHS (H-Statements)		1,1,1-trichloroethanemethyl chloroform; 602-013-00-2	71-55-6		Acute Tox. 4	Acute Mammalian Toxicity	M	LT - UNK
CA Prop 65		1,1,1-Trichloroethane	71-55-6		cancer	Carcinogenicity	H	LT - 1
GHS - Japan		1,1,1-Trichloroethane	71-55-6		H350	Carcinogenicity	H	LT - P1
IARC		1,1,1-Trichloroethane	71-55-6		2A	Carcinogenicity	H	LT - 1
GHS - New Zealand		Ethane, 1,1,1-trichloro-	71-55-6		Aquatic Chronic 2; H411	Chronic Aquatic Toxicity	Mult	LT - P1
MAK Pregnancy Risk		1,1,1-Trichloroethane	71-55-6		C	Developmental Toxicity	M or L	LT - UNK

the lists and how that data is incorporated into the summary

GreenScreen List Translator™

If you are interested in learning more about GreenScreen List Translator:

- look at the methodology here or
- watch part of a webinar which gives a brief overview on GreenScreen and then more detail on the List Translator (4:15-21:55)

  Note- while the webinar is fairly old, versions have changed and the speakers have moved to different organizations the content still provides a useful overview.

https://vimeo.com/160264438

Example of Screening Alternatives
Using a GreenScreen List Translator

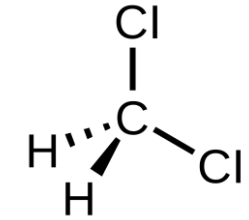
So, if one reviewed all of the solvents that were used in the furniture adhesives mentioned in the earlier example, one would have seen that they are all chemicals of concern that should be avoided.

3E Exchange

LT - 1 [75-09-2] , [EC: 200-838-9] Dichloromethane

GreenScreen List Translator™ Score - LT-1

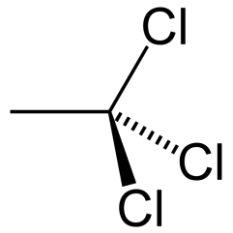
Group I Human					Group II and II* Human								Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
H	M	M	H or M	H or M	M	M	M	M or L				H	H	M		vH or H				Mult



LT - 1 [71-55-6] , [EC: 200-756-3] 1,1,1-Trichloroethane

GreenScreen List Translator™ Score - LT-1

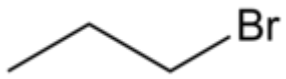
Group I Human					Group II and II* Human								Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
H		M	M or L		M	M	M	M or L				H	H	vH	Mult	vH or H		M		Mult



LT - 1 [106-94-5] , [EC: 203-445-0] 1-Bromopropane

GreenScreen List Translator™ Score - LT-1

Group I Human					Group II and II* Human								Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
H		H	H		M	M	M	M or L				H	H	M		vH or H			H	Mult



All LT-1s
HIGH for Carcinogenicity

Comparison Here

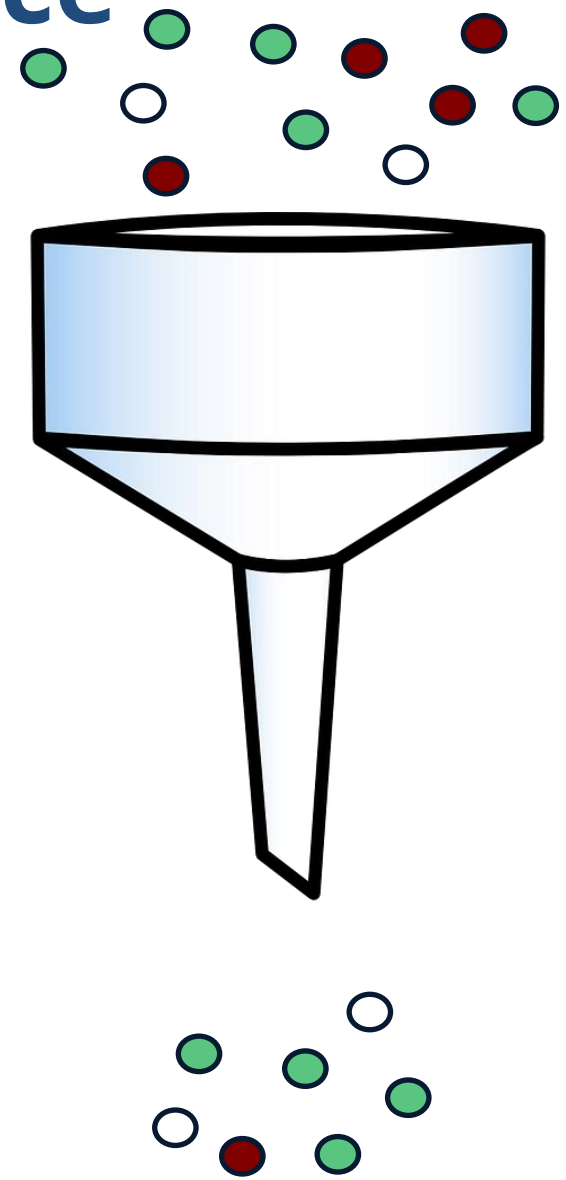
Activity

You are being asked to screen selected potential alternatives for hazards.

Please go to the "**Hazard Screening Activity**" for more information and for instructions on how to use the Automated GreenScreen List Translator.

https://www.globalgreenchem.com/_files/ugd/c7d2f6_f671bf894c454428bed70dee2b9a4282.pdf

Screening for Performance

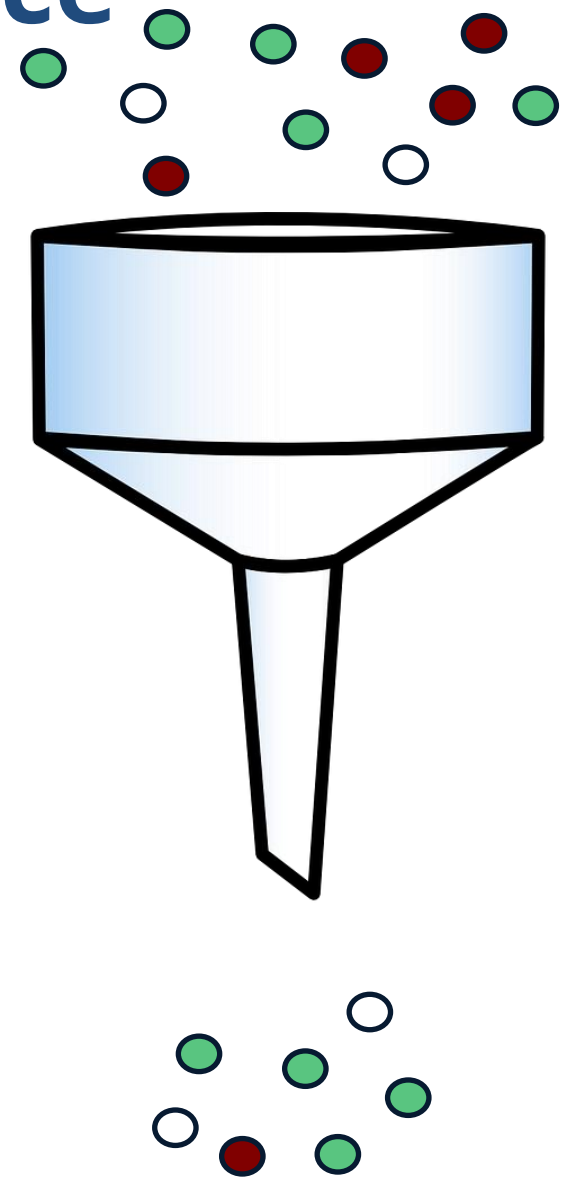


Screen out chemicals that are identified to not perform.

One can do this by:

- Assessing if the proposed alternative(s) have been identified by expert sources as unfavorable for the application based on performance.
- Implementing relevant decision rules that were defined during scoping

Screening for Performance



For example, Dipropylene Glycol functions as a solvent and fixative in fragrances.

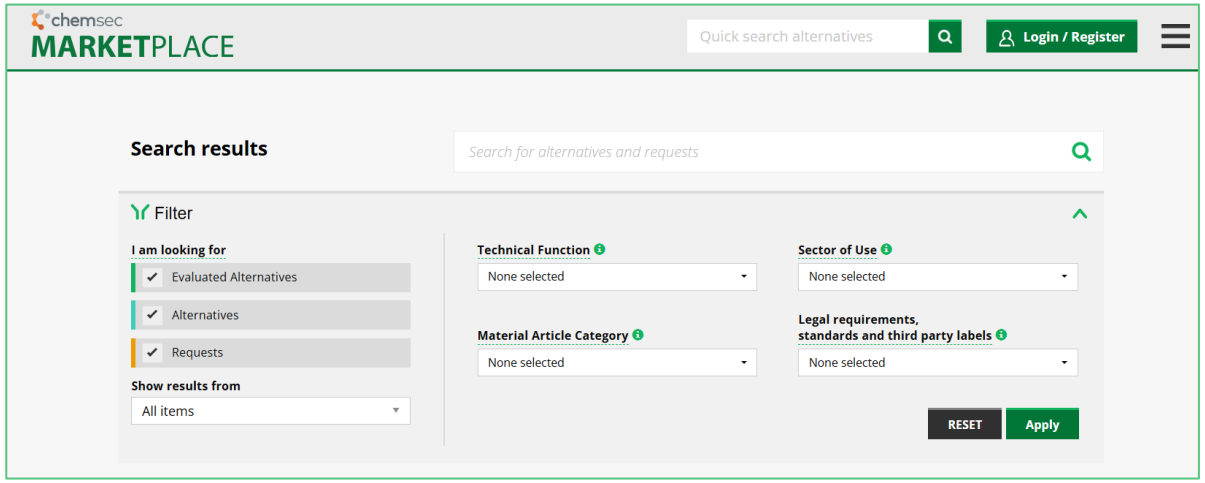
If one was looking for alternatives to Diethyl Phthalate (DEP) used in fragrances for the manufacturing of cold processed soaps, Dipropylene Glycol would be filtered out as it causes the soap batch to seize.

Another example would be eliminating alternatives that one doesn't have adequate space or infrastructure to implement.

What Does One Do if there are no potential alternatives?

One needs Green Chemistry innovation!

Post requests for alternatives and share information on the criteria.



Example is ChemSec Marketplace.

Communicate and collaborate on Innovation.

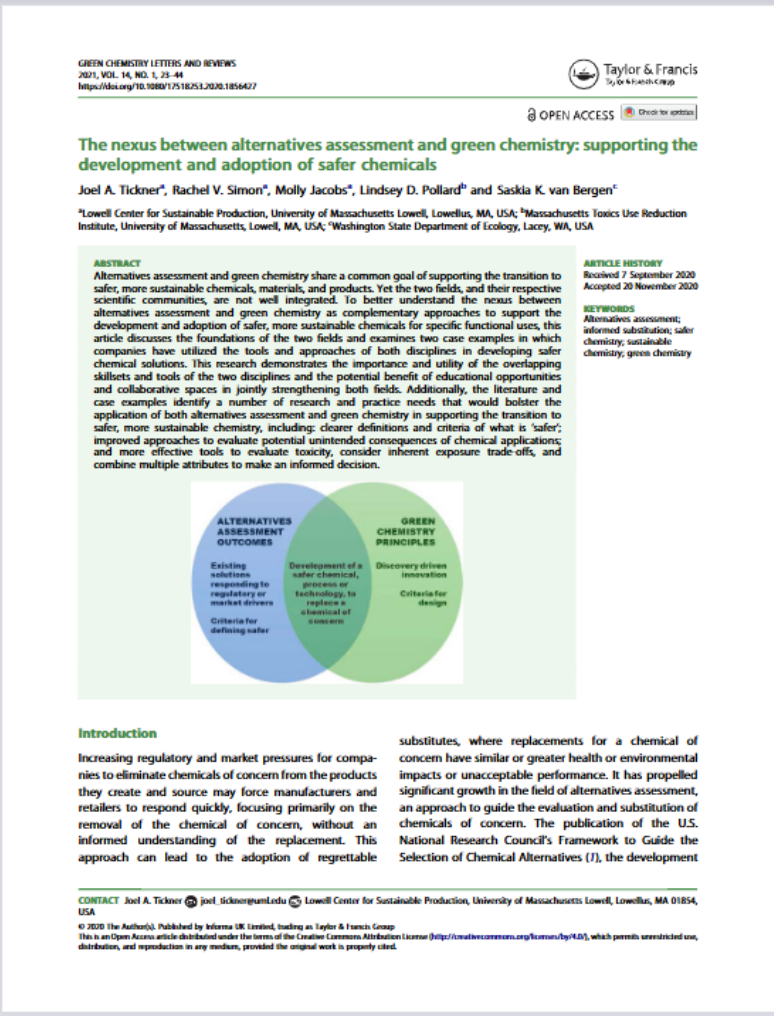
Green Chemistry Technology Needs

This list is developed and maintained by the GC3 Startup Network based on input provided by a selection of manufacturers, brands, and retailers comprising the GC3 membership. It is a living document subject to continued modification. There are no representations or warranties about the completeness, accuracy, or reliability of the information.

Chemical Function	Description	Identifier
Adhesives	Bonding agents without the use of methylene diphenyl diisocyanate (MDI) and toluene diisocyanate (TDI), generally used in paints, coatings, foams, glues, composite woods and flooring	1
	MEK-free primers/adhesives	2
	Reversible/switchable adhesives for applications including recycling/recovery, industrial electronics pick-and-place processes, short-term silicon wafer bonding, feet for climbing robots	3
	Solvent-free, water-based adhesives that do not rely on chloroprene monomer, including applications such as foam to foam, foam to polymer, foam to wood, and metal to metal capabilities in high humidity climate conditions, especially in healthcare	4
	Wood adhesives that do not contain added formaldehyde	5
Battery Technologies	Cobalt-free batteries that are environmentally (GreenScreen® Benchmark 2 or higher) and socially sustainable	6
	EGDME (1,2-dimethoxyethane)-free batteries that are GreenScreen® Benchmark 2 or higher	7
Blowing Agents	Blowing agents for wire and cable insulation without the use of azodicarbonamide (ADC)	8

Example is through communicating and collaborating with organizations like Change Chemistry (formerly GC3).

Nexus of Green Chemistry and Alternatives Assessment



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Taylor & Francis

OPEN ACCESS

The nexus between alternatives assessment and green chemistry: supporting the development and adoption of safer chemicals

Joel A. Tickner[a], Rachel V. Simon[a], Molly Jacobs[a], Lindsey D. Pollard[b] and Saskia K. van Bergen[c]

[a]Lowell Center for Sustainable Production, University of Massachusetts Lowell, Lowellus, MA, USA; [b]Massachusetts Toxics Use Reduction Institute, University of Massachusetts, Lowell, MA, USA; [c]Washington State Department of Ecology, Lacey, WA, USA

ABSTRACT

Alternatives assessment and green chemistry share a common goal of supporting the transition to safer, more sustainable chemicals, materials, and products. Yet the two fields, and their respective scientific communities, are not well integrated. To better understand the nexus between alternatives assessment and green chemistry as complementary approaches to support the development and adoption of safer, more sustainable chemicals for specific functional uses, this article discusses the foundations of the two fields and examines two case examples in which companies have utilized the tools and approaches of both disciplines in developing safer chemical solutions. This research demonstrates the importance and utility of the overlapping skillsets and tools of the two disciplines and the potential benefit of educational opportunities and collaborative spaces in jointly strengthening both fields. Additionally, the literature and case examples identify a number of research and practice needs that would bolster the application of both alternatives assessment and green chemistry in supporting the transition to safer, more sustainable chemistry, including: clearer definitions and criteria of what is 'safer'; improved approaches to evaluate potential unintended consequences of chemical applications; and more effective tools to evaluate toxicity, consider inherent exposure trade-offs, and combine multiple attributes to make an informed decision.

ARTICLE HISTORY
Received 7 September 2020
Accepted 20 November 2020

KEYWORDS
Alternatives assessment; informed substitution; safer chemistry; sustainable chemistry; green chemistry

Introduction

Increasing regulatory and market pressures for companies to eliminate chemicals of concern from the products they create and source may force manufacturers and retailers to respond quickly, focusing primarily on the removal of the chemical of concern, without an informed understanding of the replacement. This approach can lead to the adoption of regrettable substitutes, where replacements for a chemical of concern have similar or greater health or environmental impacts or unacceptable performance. It has propelled significant growth in the field of alternatives assessment, an approach to guide the evaluation and substitution of chemicals of concern. The publication of the U.S. National Research Council's Framework to Guide the Selection of Chemical Alternatives (1), the development

CONTACT Joel A. Tickner joel_tickner@uml.edu Lowell Center for Sustainable Production, University of Massachusetts Lowell, Lowellus, MA 01854, USA

Suggested Reading

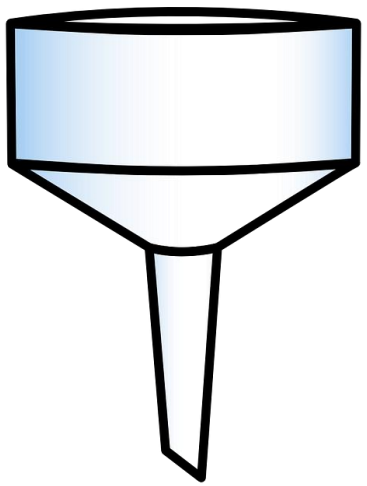
"To better understand the nexus between alternatives assessment and green chemistry as complementary approaches to support the development and adoption of safer, more sustainable chemicals for specific functional uses, this [open access] article discusses the foundations of the two fields and examines two case examples in which companies have utilized the tools and approaches of both disciplines in developing safer chemical solutions. "

Step 5: Evaluation of Alternatives

Objectives

- To Assess and Compare Alternatives against a number of modules (Hazard, relative Exposure, Performance, Economic viability)

Evaluation of Alternatives



Now that there is a narrower list, one needs to take the alternatives through more robust assessments based on what was decided in the **Scoping** step.

It is recommended that, at a minimum Hazard, relative Exposure, Performance and Economic viability are assessed.

Assessing Hazard and Exposure

The alternatives have already been screened and some of the regrettable substitutions have been phased out.

In order to ensure that the remaining alternatives are safer, one needs to use a more robust chemical hazard assessment methodology. **No data does not mean a chemical is safer.**

It also could be that a chemical or ingredient has been assessed and certified by a third-party assessor with a robust material health methodology that meets your criteria for safer.

With respect to exposure, one needs to use life cycle thinking when evaluating exposure potential to ensure that no significant exposure pathways are missed and one isn't shifting risk.

Also, what are the intrinsic hazards, while several alternatives might be identified as safer, do any have hazard traits that are categorized as high or very high and have exposure pathways connected to those traits?

Hazard

Broad Range of Hazard Endpoints to Consider

Human Health		Environmental Toxicity & Fate	Physical Hazards
Carcinogenicity	Acute Mammalian Toxicity	Acute Aquatic Toxicity	Reactivity
Mutagenicity & Genotoxicity	Systemic Toxicity & Organ Effects	Chronic Aquatic Toxicity	Flammability
Reproductive Toxicity	Neurotoxicity	Terrestrial Toxicity	Ozone Depleting Potential
Developmental Toxicity	Skin Sensitization	Bioaccumulation	
	Respiratory Sensitization	Mobility	
Endocrine Activity	Skin Irritation	Persistence/ Biodegradation	
	Eye Irritation		

A few of the fate and transport endpoints could be considered under exposure versus hazard but they are mentioned here as many of the tools that will be mentioned, consider these.

One can also consider environmental transformation products.

How to Assess and Compare Chemical Hazards
Example Criteria/Methods/Tools

- Safety Data Sheet (GHS H phrases)
- ChemHAT
- PRIO
- P2OASys
- GreenScreen® List Translator Tools
- **Safer Choice Master Criteria/Functional Criteria**
- **GreenScreen®**
- **Enhesa Chemical Assess**
- **Cradle to Cradle Certified and ChemForward**

Unbolded are useful screening tools. **Bolded are more robust assessments** that, depending on your requirements, can provide data to help one determine that the alternative safer (or not) than the chemical of concern.

How to Assess Screen and Compare Chemical Hazards Example Tools/Databases

- Safety Data Sheet (GHS H phrases) (Required)
- ChemHAT (**open access**)
- PRIO (**open access**)
- P2OASys (**open access**)
- GreenScreen® List Translator Tools **+**
  - Pharos
  - 3E Exchange (**open access** for chemical comparisons- need to log in)
- **Safer Choice Master Criteria/Functional Criteria**
  - Safer Chemical Ingredient List (**open access**)
  - Cleangredients
- **GreenScreen®**
  - IC2 Chemical Hazard Assessment Database (**open access**)
  - ToxFMD Screened Chemistry Library (Benchmark 1 summaries open access- **need to log in**)
- **Enhesa Chemical Assess**
- **Cradle to Cradle Certified** Product Registry (**open access**)
- **ChemForward** (**several open access assessments**)

Unbolded are useful screening tools. **Bolded are more robust assessments** that, depending on your requirements, can provide data to help one determine that the alternative safer (or not) than the chemical of concern.

The US EPA Safer Chemical Ingredient List (SCIL)

Chemicals on SCIL are listed by function and meet either the master criteria or the relevant functional criteria. These chemicals are assessed by a third party profiler and then EPA staff review the completed hazard profile and, if it meets the relevant criteria, it is approved for the list.

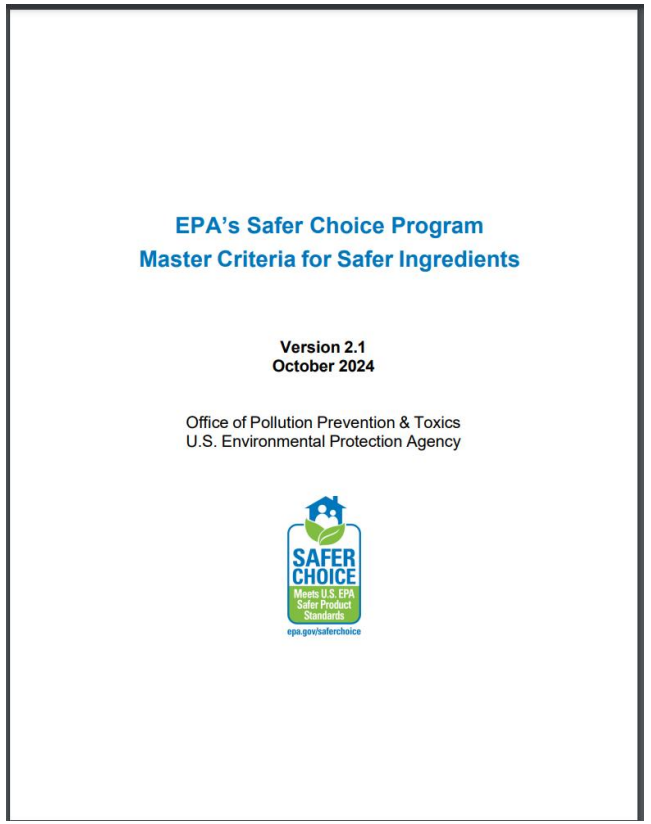
Criteria for Safer Chemical Ingredients

Each chemical ingredient in a formulation has a function in making a product work - whether it is to aid in cleaning by reducing surface tension (surfactants), dissolve or suspend materials (solvents), or reduce water hardness (chelating agents). Within these "functional classes," many ingredients share similar toxicological and environmental fate characteristics. As a result, Safer Choice focuses its review of formulation ingredients on the key (environmental and human health) characteristics of concern within a functional class. This approach allows formulators to use those ingredients with the lowest hazard in their functional class, while still formulating high-performing products.

The Safer Choice Program evaluates each ingredient in a formulation against the following Master and Functional-Class Criteria documents, as appropriate. These documents define the characteristics and toxicity thresholds for ingredients that are acceptable in Safer Choice products.

The criteria are based on EPA expertise in evaluating the physical and toxicological properties of chemicals, and while they incorporate authoritative lists of chemicals of concern, they go far beyond these lists. Safer Choice applies the criteria using EPA research and analytical methods to ensure that Safer Choice products contain only the safest possible ingredients. All criteria documents are part of the Safer Choice Standard.

- Master criteria
- Functional-class criteria
  - Chelating and sequestering agents
  - Colorants, polymers, preservatives, and related chemicals
  - Defoamers
  - Enzymes and enzyme stabilizers
  - Fragrances
  - Oxidants and oxidant stabilizers
  - Processing aids and additives
  - Solvents
  - Surfactants


EPA's Safer Choice Program
Master Criteria for Safer Ingredients

Version 2.1
October 2024

Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency

SAFER CHOICE
Meets U.S. EPA Safer Product Standards
epa.gov/saferchoice


Surfactants

Clear Options

Note: When a functional use category is selected, the search above will only apply to the chemicals assigned to this functional use. To select a different functional use, please scroll up.

Note for Surfactants: The hazard profile of a surfactant varies with its structure. Manufacturers using CAS numbers in this functional class may need to provide additional information for Safer Choice review. See the Safer Choice Safer Surfactant Criteria for more information.

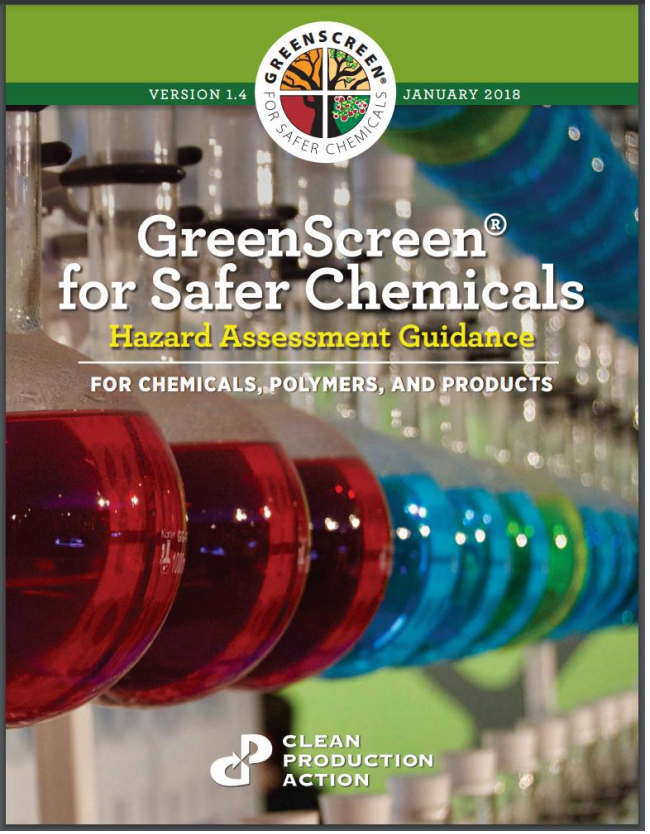
Show 25 entries

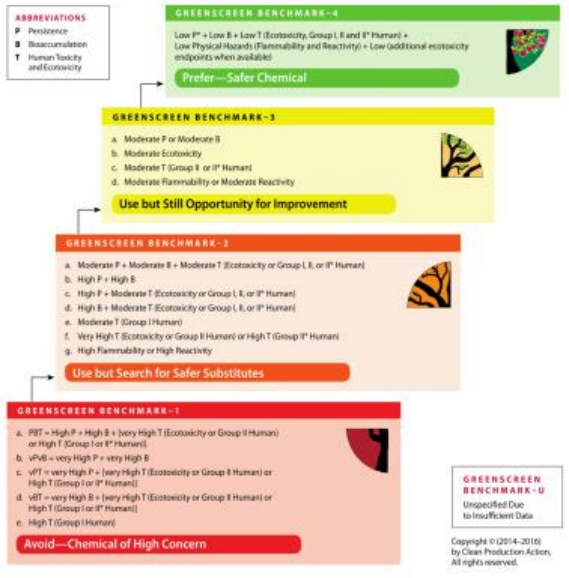
Code	Common Name	CAS Registry Number	Functional Use
	(Z)-7-Hexadecenoic acid	2416-19-5	Surfactants
	(Z)-9-Hexadecenoic acid	373-49-9	Surfactants
	.beta.-Alanine, N-(2-carboxyethyl)-N-[3-(decyloxy)propyl]-, sodium salt (1:1)	64972-19-6	Surfactants
	1-Dodecanesulfonic acid, hydroxy-, sodium salt	128824-30-6	Surfactants
	1-Hexadecanaminium, N-(carboxymethyl)-N,N-dimethyl-, inner salt	693-33-4	Surfactants
	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-(C8-18 and C18-unsatd. acyl) derivs., inner salts	147170-44-3	Surfactants
	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-C8-18 acyl derivs., inner salts	97862-59-4	Surfactants
	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-coco acyl derivs., chlorides, sodium salts	61789-39-7	Surfactants
	1-Propanaminium, 3-amino-N-(carboxymethyl)-N,N-dimethyl-, N-coco acyl derivs., inner salts	61789-40-0	Surfactants
	1-Propanaminium, N-[carboxymethyl]-N,N-dimethyl-3-[(1-oxodecyl)amino]-, inner salt	73772-45-9	Surfactants
	1-Propanaminium, N-[carboxymethyl]-N,N-dimethyl-3-[(1-oxohexadecyl)amino]-, inner salt	32954-43-1	Surfactants
	1-Propanaminium, N-[carboxymethyl]-N,N-dimethyl-3-[(1-oxooctyl)amino]-, inner salt	73772-46-0	Surfactants
	1H-Imidazole-1-propanoic acid, 2-heptyl-2,3-dihydro-3-(2-hydroxyethyl)-, monosodium salt	68630-95-5	Surfactants
	2-Ethylhexyl-alpha-D-glucoside	125590-73-0	Surfactants
	2-Ethylhexyl-poly-D-glucosides	161074-93-7	Surfactants
	2-O-Rhamnopyranosyl-rhamnopyranosyl-3-hydroxydecanoyl-3-hydroxydecanoate	4348-76-9	Surfactants
	9-Eicosenoic acid	506-31-0	Surfactants
	Acetic acid, 2-chloro-, reaction products with 2-heptyl-4,5-dihydro-1H-imidazole-1-ethanol and sodium hydroxide	68608-64-0	Surfactants
	Acetic acid, chloro-, sodium salt, reaction products with 4,5-dihydro-2-undecyl-1H-imidazole-1-ethanol and sodium hydroxide	68608-66-2	Surfactants
	Alcohols, C10-12, ethoxylated propoxylated	68154-97-2	Defoamers; Surfactants
	Alcohols, C10-14, ethoxylated	66455-15-0	Surfactants
	Alcohols, C10-16, ethoxylated	68002-97-1	Surfactants
	Alcohols, C10-16, ethoxylated propoxylated	69227-22-1	Surfactants
	Alcohols, C11-14-iso-, C13-rich, ethoxylated	78330-21-9	Surfactants
	Alcohols, C11-15-secondary, ethoxylated	68131-40-8	Surfactants

Showing 1 to 25 of 352 entries (filtered from 965 total entries)

Previous 1 2 3 4 5 ... 15 Next

https://www.epa.gov/saferchoice/safer-ingredients





GreenScreen® for Safer Chemicals

A nonprofit, Clean Production Action, developed the GreenScreen methodology so that one could assess, summarize and compare the hazards of chemicals. It builds off the Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

Technical experts assess and classify 18 human health and environmental endpoints using information such as authoritative lists, scientific literature, modeling tools and suitable chemical analogs. A summary and justification of each decision is documented in the assessment and the relevant literature is cited.

After the endpoints are assessed, a summary score is determined (Benchmark 1, 2, 3, 4 or U).

https://www.greenscreenchemicals.org/learn/guidance-and-method-documents-downloads

GreenScreen® for Safer Chemicals

Example of Summary for Cyrene

GreenScreen® Assessment View source View key

Group I Human					Group II Human									Ecotox			Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS	SnR	IrS	IrE	AA	CA	Eo	P	B	Rx	F
						single	repeat	single	repeat											
L	**L**	**L**	*L*	DG	**L**	**M**	**L**	*L*	**L**	**L**	DG	**L**	**M**	**L**	*L*		**vL**	**vL**	**L**	**L**

The full assessment is available as a PDF document

For the endpoint scores, **bold** is high confidence, *italicized* is lower confidence.

Benchmark 3
Slight Concern

AA Acute Aquatic Toxicity
AT Acute Mammalian Toxicity
B Bioaccumulation
C Carcinogenicity
CA Chronic Aquatic Toxicity
D Developmental Toxicity
E Endocrine Activity
F Flammability
IrE Eye Irritation
IrS Skin Irritation
M Mutagenicity and Genotoxicity
N Neurotoxicity
P Persistence
R Reproductive Toxicity
Rx Reactivity
SnS Sensitization (Skin)
SnR Respiratory Sensitization
ST Systemic/Organ Toxicity
* *Repeated exposure*

https://www.greenscreenchemicals.org/learn/guidance-and-method-documents-downloads

GreenScreen® for Safer Chemicals

Example Endpoint Summary and Supporting Data

Mutagenicity/Genotoxicity (M): L

Cyrene (53716-82-8) was assigned a hazard classification level of Low for Mutagenicity/Genotoxicity based on negative results reported from *in vitro* assays using the chemical of interest. The low hazard conclusion is based on high quality studies reported for the chemical of interest therefore reported with high confidence.

← **Summary**

Data

- Lists
  - *Authoritative: None*
  - *Screening: None*

← **Not on Relevant Hazard Lists**

- Measured Data

ECHA 2023a

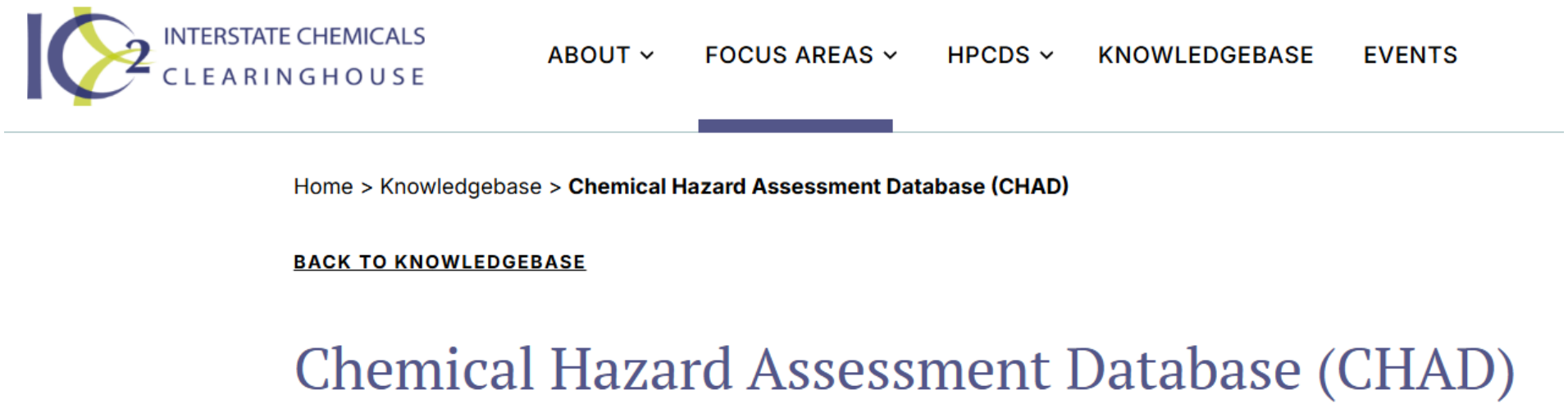
- Cyrene has been tested in a valid bacterial reverse mutation assay, conducted according to OECD Test Guideline 471 (1997) and in compliance with GLP, using Salmonella typhimurium strains S. typhimurium TA 1535, TA 1537, TA 98, TA 100, and TA 102. No increase in the number of revertants was observed in any test strain, with or without metabolic activation when tested up to limit concentration. Appropriate positive, negative, and solvent controls were added and gave expected results. It is concluded that the test substance is negative for mutagenicity to bacteria under the conditions of the test.
- Cyrene has been tested for ability to cause chromosome aberrations in cultured peripheral human lymphocytes in an in vitro cytogenicity study, conducted according to OECD Test Guideline 487 and in compliance with GLP. No increase in the number of cells with aberrations was observed either with or without metabolic activation in cultured peripheral human lymphocytes. Appropriate solvent and positive controls were included and gave expected results. It is concluded that the test substance is negative for the induction of chromosome aberrations under the conditions of this study.
- Cyrene has been tested in a valid in vitro mammalian mutagenicity study, conducted according to OECD Test Guideline 476 and in compliance with GLP, using mouse lymphoma L5178Y cells. Cyrene did not induce mutation at the HPRT locus of L5178Y mouse lymphoma cells when tested for 3 hours up to cytotoxic concentrations in the absence of a metabolic activation system (S9) and up to a concentration equivalent to 10 mM in the presence of metabolic activation system. Appropriate solvent, negative and positive controls were included and gave expected results. It is concluded that the test substance is negative for mutagenicity to mammalian cells under the conditions of this study.

← **Data**

- Estimated Data: None

Full Assessment for Cyrene is HERE.

IC2 Chemical Hazard Assessment Database

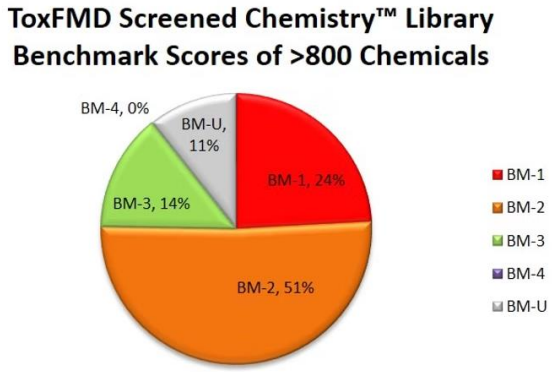


- Over 180 Open Access GreenScreen Assessments.
- No login needed.

https://www.theic2.org/hazard-assessment-database/

ToxFMD

- Online subscription-based service with GreenScreen assessments.
- Free access to over 200 Benchmark 1 Chemicals (need to set up an account).



TOX FMD SCREENED CHEMISTRY® LIBRARY

Enter CAS# or Chemical Name:

Clear | 80-09-1 | Go

	Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
	Carcinogenicity	Mutagenicity/ Genotoxicity	Reproductive Toxicity	Developmental Toxicity	Endocrine Activity	Acute Toxicity	Systemic Toxicity		Neurotoxicity		Skin Sensitization*	Respiratory Sensitization*	Skin Irritation	Eye Irritation	Acute Aquatic Toxicity	Chronic Aquatic Toxicity	Persistence	Bioaccumulation	Reactivity	Flammability
							S	R*	S	R*	*	*								
	C	M	R	D	E	AT	STs	STr	Ns	Nr	SNS*	SNR*	IrS	IrE	AA	CA	P	B	Rx	F
80-09-1 | Bisphenol S |	*M*	L	H	*L*	H	L	DG	*M*	DG	L	L	DG	L	L	M	vH	*M*	vL	L	L

S indicates single exposure, R or * indicates repeated exposure. Hazard levels in ITALICS reflect low confidence. Hazard levels in BOLD reflect values based on high confidence*

GreenScreen® Benchmark Summary:

Benchmark	a	b	c	d	e	f	g
1: Avoid—Chemical of High Concern	NO	NO	NO	NO	YES		
2: Use—but Search for Safer Substitute	STOP						
3: Use—but Opportunity for Improvement	STOP						
4: Prefer—Safer Chemical	STOP						

No: *Chemical is not captured by the hazard combinations addressed by this sub-benchmark. If all outputs for sub-benchmarks in a benchmark level are "No", the benchmarking process progresses to the next benchmark level.*

Yes: *Chemical is captured by the hazard combinations addressed by this sub-benchmark. If any output for a sub-benchmark in a benchmark level is "Yes", the benchmarking process does not progress to the next benchmark level.*

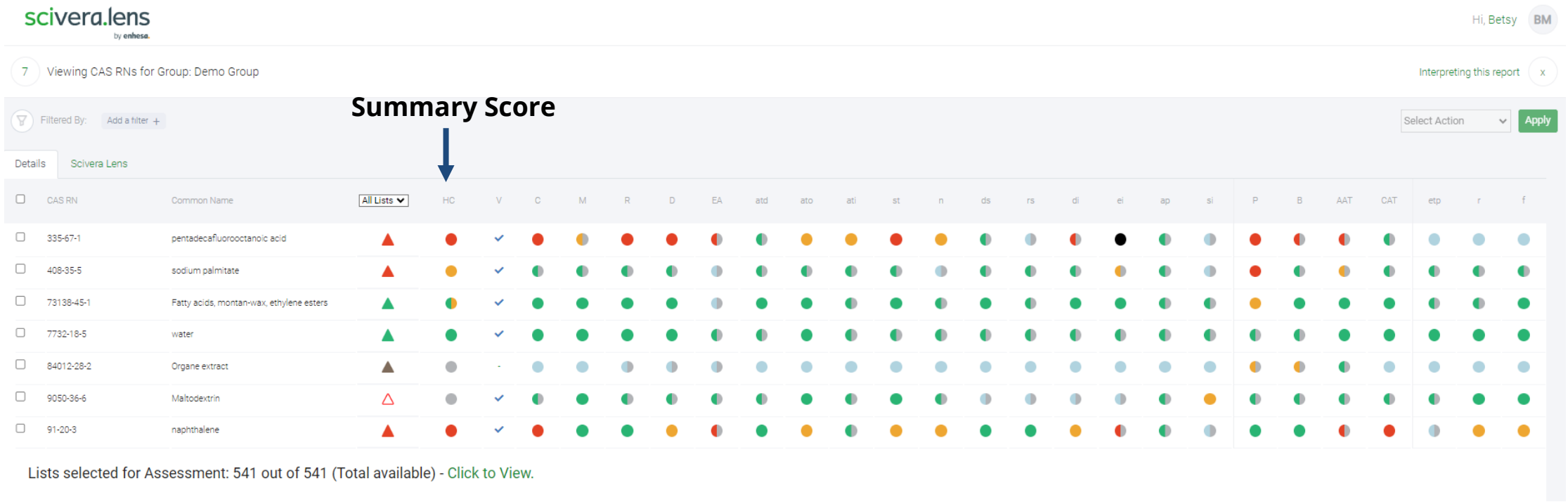
GreenScreen® Benchmark Score:

Full GreenScreen® Report

https://database.toxservices.com/FMD

Chemical Assess

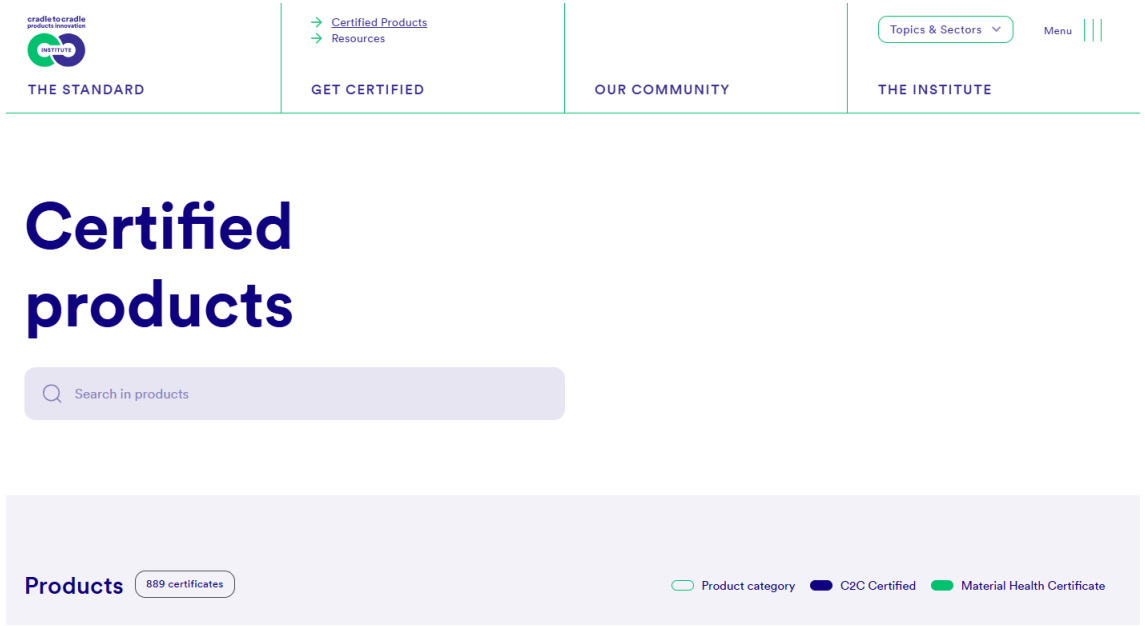
- Online subscription-based service of hazard assessments (over 5000 verified)
- 24 Human, Environmental and Physical endpoints.



https://www.enhesa.com/sustainablechemistry/our-solutions/chemical-assess/

Cradle to Cradle Certified

- Online open access
- No log in needed
- Uses Cradle to Cradle Methodology



https://c2ccertified.org/certified-products/

ChemFORWARD

Summary Score

Chemical Name	CAS #	Chemical Class	ChemForward Hazard Band
1-Butanol, 3-methoxy-, 1-acetate	4435-53-4	glycol ether	C

2 Hazard Summaries GHS and C2CC

- Online subscription-based service of assessments using 2 methodologies (GHS and C2CC).
- Free access to some assessments (need to set up an account).
- Includes routes of exposure.

GHS | C2C

How to read the GHS Hazard Summary Table

	Carcinogenicity	Mutagenicity	Reproductive Toxicity	Developmental Toxicity	Acute Toxicity	STOT-Single	STOT-Repeated	STOT- Neurotoxicity-Single	STOT- Neurotoxicity-Repeated	Skin Sensitizer	Respiratory Sensitizer	Skin Corrosion/Irritation	Serious Eye Damage/Eye Irritation	Acute Aquatic Toxicity	Chronic Aquatic Toxicity	Ozone Depletion
Oral	(NC)	NC	(NC)	NC	(NC)	CNP	NC	CNP	(NC)					(Cat 3)	(NC)	NC
Dermal	(NC)		CNP	CNP	CNP	CNP	CNP	CNP	CNP	(NC)		(NC)				
Inhalation	(NC)		CNP	CNP	CNP	CNP	CNP	CNP	CNP		(NC)		Cat 2B			

GHS | C2C

How to read the C2CC Hazard Summary Table

	Human Health										Environmental							Other			
	Carcinogenicity	Mutagenicity	Reproductive & Developmental Toxicity	Endocrine Activity / Disruption	Oral Toxicity	Dermal Toxicity	Inhalation Toxicity	Neurotoxicity	Skin, Eye, and Respiratory Corrosion/Irritation	Sensitization of Skin and Airways	Fish Toxicity	Daphnia Toxicity	Algae Toxicity	Terrestrial Toxicity	Persistence	Bioaccumulation	Climatic Relevance	Other (Human Health)	Organohalogens	Toxic Metals	Other (Environmental Health)
Oral	-	G	G	-	G			G			Y	G	Y	-	G	G	Y	G	G	G	G
Dermal	-		-			-		-	Y	G											
Inhalation	-		-				-	-													

https://alternatives.chemforward.org/preview/ojotns3e75gd/portfolios/38 – Free Assessments.
https://www.chemforward.org/plastic-additives – Free access to summary scores after registration.

Example of Using these Assessments

LT - 1 [80-05-7] , [EC: 201-245-8] Bisphenol A **Chemical of Concern**

GreenScreen List Translator™ Score - LT-1																			
Group I Human					Group II and II* Human									Ecotox		Fate		Physical		Mult*
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F	
						single	repeated*	single	repeated*											
		H	H	H		M		*M or L*		*H or M*			vH	vH	*Mult*					Mult

This is an example of a GreenScreen List Translator result of BPA, a chemical of concern. In the Screening activity, one chemical was screened out due to the decision rules that were stated. The remaining chemicals "passed" the screen but additional data is needed to for this current step. Frequently there can be a minimum requirement for the amount of data required.

Remember that no data does not mean that the chemical is less hazardous.

BPA Assessment is from 3E Exchange

Example of Using these Assessments

GreenScreen® Hazard Summary Table for Benzenesulfonamide, 4-Methyl-N-[[[3-[[(4-methylphenyl)sulfonyl]oxy]phenyl] Amino]carbonyl]-)

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeat*	single	repeat*										
M	L	*M*	*M*	DG	L	L	M	*L*	L	L	*L*	L	L	H	H	*H*	vL	L	L

= Benchmark 2

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect lower confidence in the hazard classification while hazard levels in **BOLD** font reflect higher confidence in the hazard classification. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Group II* Human Health endpoints are indicated by an * after the name of the hazard endpoint or after "repeat" for repeated exposure sub-endpoints. Please see Appendix A for a glossary of hazard acronyms.

This is an example of a GreenScreen assessment of one of the alternatives to BPA. If you completed the screening assignment, compare the results from 3E Exchange to this assessment.

Based on the decision rules in the screening activity, this alternative would not be deselected in the screening step and likely has adequate data to get it into the final comparisons with respect to hazard.

Example of Focusing on a Hazard Endpoint

A company was developing an BPA-free epoxy resin so wanted to identify a safer alternative.

They first screened out bisphenols based on regulatory compliance, then narrowed the selection based on structural elements of the molecule.

GreenScreen assessments were also used but since estrogenic activity was the main concern and there is usually limited data on this endpoint,
they emphasized this endpoint. They performed testing and supported additional independent researchers to try to demonstrate a lack of estrogenic activity.

More information HERE.

Exposure

Exposure

The basic exposure assessment asks questions about differences in exposure without the use of control measures between the chemical of concern and the alternatives and assesses if it is roughly equivalent, less than or potentially more. This can help deprioritize or eliminate an alternative.

One also uses life cycle thinking to avoid the potential of shifting the burden to another population. Were there any process changes that increase exposure to a certain population? What is the route of exposure and do the physical properties of the chemicals and hazard traits increase the chemical risk?

One can also decide if one should perform additional exposure considerations.

Table 8: Qualitative Questions to Identify Exposure Pathways.

Life Cycle Stage	Qualitative Inquiry
Manufacture	• Are workers prone to exposure (inhalation, ingestion, dermal, physical/chemical risk, etc.) during manufacture? • Does the manufacturing process lead to environmental exposure through leaching into air, water, or soil? If yes, what is the likely fate in the environment?
Transportation/Storage	• Is there risk of exposure from combustion, corrosivity, etc.?
Use	• Do the intended or foreseeable uses suggest an exposure pathway? • Is alternative prone to leaching, disassociation, degradation or other means of escape from product into the user or indoor or outdoor environments?
End-of-Life	• Does disposal/reclamation/recycling create potential environmental exposures from leaching into air, water, soil? • Does disposal/reclamation/recycling create potential exposures to workers from inhalation, ingestion, dermal?
All	• Do any physical or chemical properties, such as persistence or solubility, suggest likely exposure pathways?

From IC2 Alternative Assessment Guide Draft 1.2

Exposure

If one notices differences in exposure, one can perform a comparative exposure to the original chemical of concern.

Also, while several alternatives might be identified as safer and selected to move forward when looking at the hazards, one can ask if any have hazard traits that are categorized as high or very high and have exposure pathways connected to those traits?

> For example, if one of the alternatives is high for respiratory sensitization. Is inhalation an expected route of exposure given the expected conditions of use of the alternative? Is the alternative a volatile organic compound? If the answer is yes for either, it may be a reason to document the alternative as unfavorable or less favorable.

Here about what a practitioner considers HERE.
Related articles here and here.

Performance

Performance

How does one assess this? There is a balance. One doesn't want to overprescribe the performance needs but it obviously one needs the alternative to work. What performance attribute are critical? Which are desirable?
For this module, one needs to identify the functional requirements as well as the tolerance.

The level of detail of this module will vary depending on user and breadth of assessment.

If a standard was written around the chemical of concern and not the function, it is likely overly prescriptive and does not allow for innovation. It can also be that a standard would remove certain alternatives at the chemical level but, if they were still included, the performance of the product would have met the market need.

You might want to go back to the "Fit for Purpose" slides mentioned in the scoping section.

Performance- Basic Level

Some basic level questions include:

Has the alternative already been identified as a favorable alternative with respect to performance for the same or similar function as the chemical of concern? Is it already used in similar products available on the market? Do marketing materials for the alternative indicate that it will meet the function for the application of interest?

If the alternative has been found to perform but not as well as the chemical of concern can the process or product be modified to accommodate the alternative? If no, is the difference in performance critical to the product?

Has the alternative been identified by expert sources as unfavorable in the specific application being assessed?

Performance

In addition to the basic level questions, one might also ask questions at the product level such as:

Is durability affected?

Will worker require retraining? (this one might not change the assessment decisions but likely has a cost consideration and could help with the implementation.)

There are additional performance assessment levels that one can perform and that you can read more about in the recommended readings.

An example of performance testing is HERE.

Economic Feasibility

Economic Feasibility

Basic questions include:

- Is the alternative used in the application of interest? Is the alternative currently offered for sale for the application of interest?

Additional levels consider supply of alternative and comparative costs:

- Is the alternative currently being used for the application of interest? Is the price comparable to that of the chemical of concern? If not, is the price difference prohibitive?
- Is the alternative being produced in sufficient supply from several manufacturers?
- Can one demonstrate cost savings to your customers that would justify an increase in the unit cost?

Benefits might also be considered.

An example could be lower utility bills. Read about some examples of cost savings **HERE**.

Other Modules

Other Modules to Consider

This Training addresses some of the core modules to consider but there are others that one can consider.
For example, one can consider materials management, social impact and/or results of a life cycle assessment.

Information on these can be found in the IC2 Alternative Assessment guide.

Step 6: Identify Acceptable Alternatives or Innovate

Objectives

- To either identify acceptable alternatives based on the information compiled in Step 5 or communicate the need for innovation and
- To document conclusions.

Identifying Alternatives and the Process

Use information from the scoping section, decision rules, criteria and information compiled in Step 5 to conclude if there are favorable alternatives that could replace the chemical of concern of material or products that contain it.

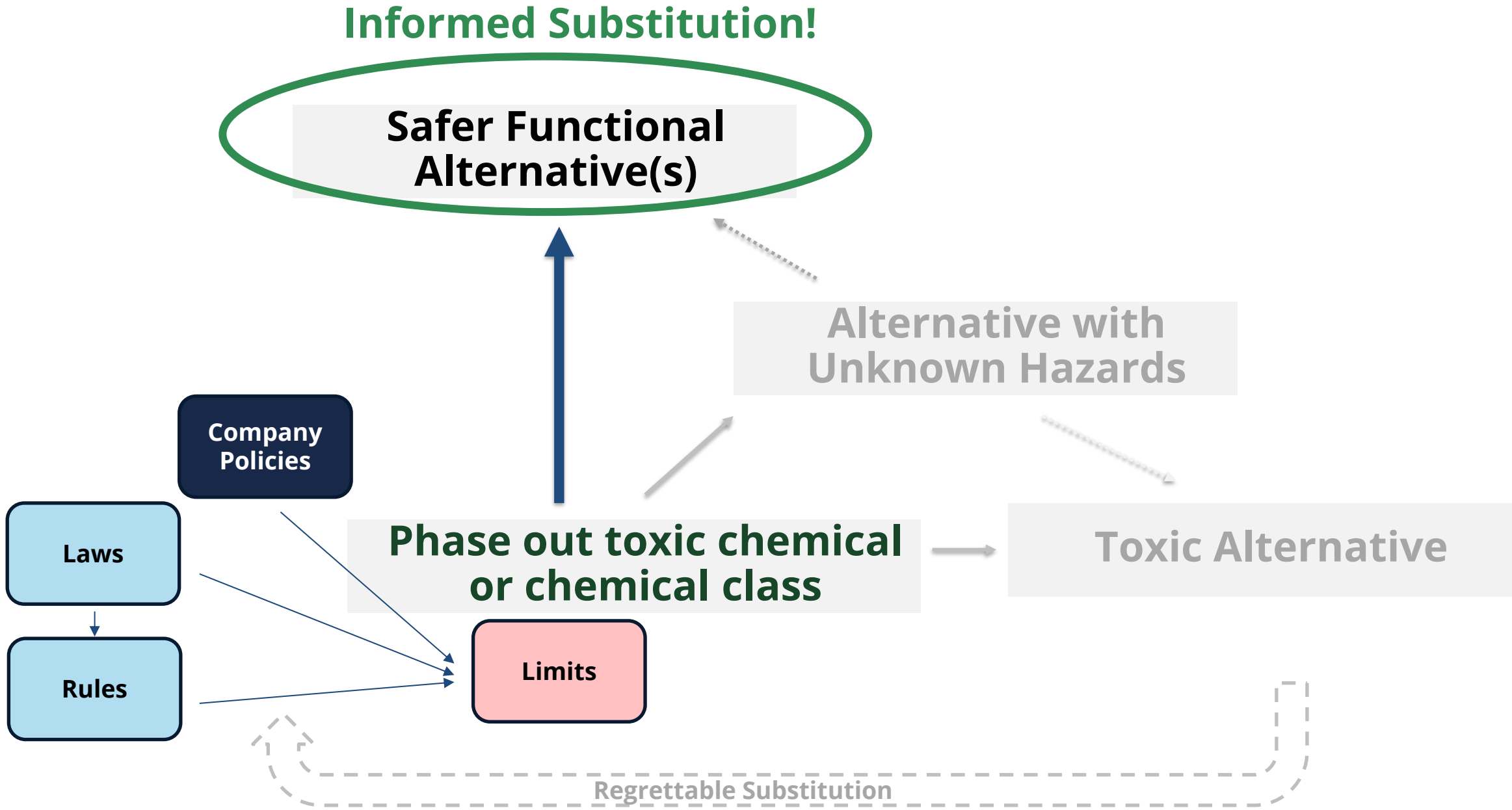
If no favorable alternatives remain, one might need to go back and reassess certain evaluation modules or communicate the need for innovation.

Documenting the Results

This section should include:

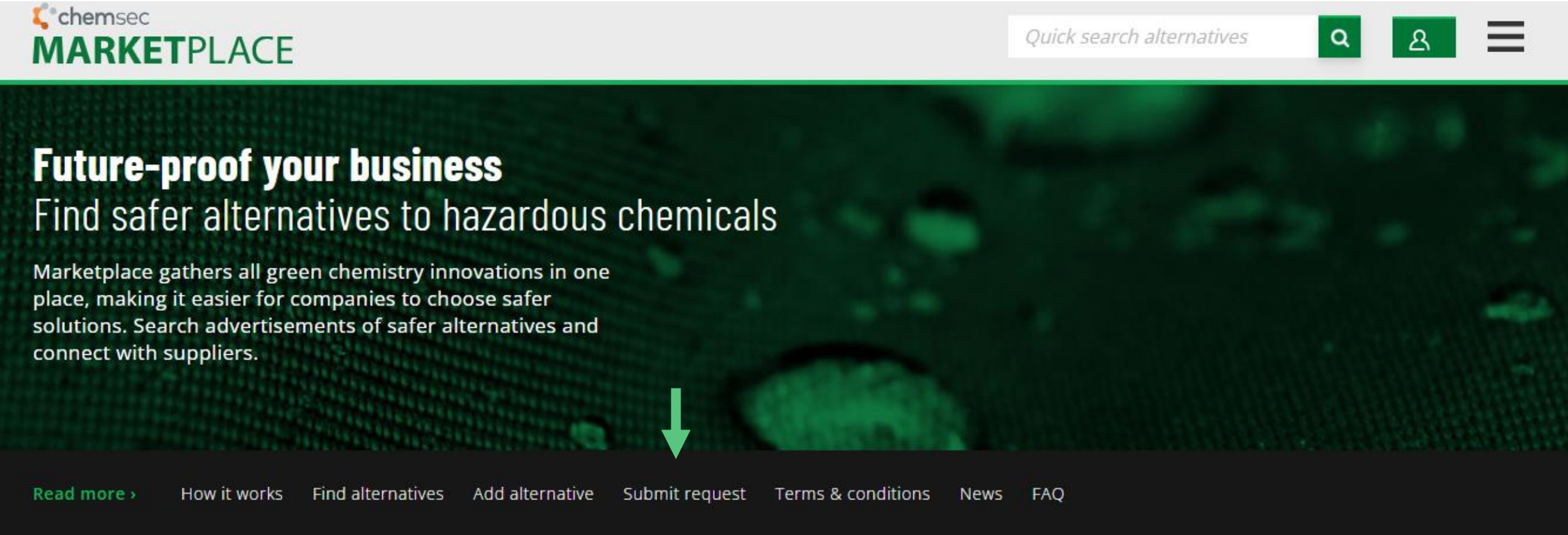
- Preferred alternatives along with the rationale.
- Key findings that can be shared to spur innovation and support the adoption of safer alternatives
- Challenges or limitations that influenced decision making.
- Research needs or recommendations for a follow-up assessment if needed to find preferrable alternatives.

The Results of an Alternatives Assessment



The Results of an Alternatives Assessment

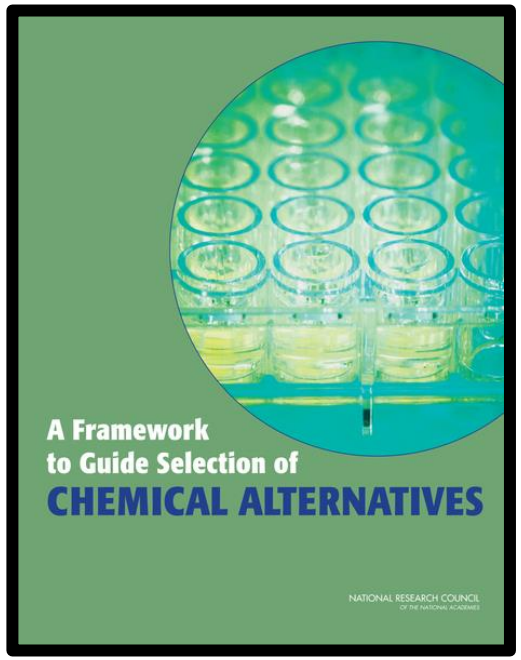
If safer viable alternatives are not identified, one can communicate criteria for a Green Chemistry Innovation. An example site is https://marketplace.chemsec.org/ .



Green Chemistry Innovation

The innovations can use design rules for safer chemicals as well as predictive tools and then once developed can be assessed against the existing alternatives using an alternatives assessment framework.

SSbD Safe & Sustainable by Design



https://www.jennystanford.com/9789814968591/first-do-no-harm/
https://www.parc-ssbd.eu/#
https://nap.nationalacademies.org/catalog/18872/a-framework-to-guide-selection-of-chemical-alternatives

Implementing Change

Watch a clip of this video on workers opinions of the implementation of a safer alternative.

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102- Łukasz Dudzic

Thank You!

For questions, please reach out:

This module was exclusively developed by Saskia van Bergen, H2L Consulting

saskiavb@usa.net

greenchemistry@yale.edu

https://www.globalgreenchem.com

https://www.chemistryforsustainability.org

https://greenchemistry.yale.edu/

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