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CURRENT LANDSCAPE OF ALTERNATIVES ASSESSMENT PRACTICE: A META-REVIEW

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IOMC
INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS
A cooperative agreement among **FAO, ILO, UNDP, UNEP, UNIDO, UNITAR, WHO, World Bank and OECD**

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FORWARD

As interest in the substitution of harmful chemicals continues to grow in industry, NGOs and the public sector, organizations are seeking guidance on the selection of appropriate methods and tools. OECD is responding to this need. The OECD's 49th Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides, and Biotechnology established an Ad Hoc Group on Substitution of Harmful Chemicals with the goal of furthering tools and approaches to support decision making for the substitution of chemicals of concern. As part of its work, the Joint Meeting requested that the Ad Hoc Group build on existing work to develop a toolbox to support the evaluation of alternatives when safer substitutes to chemicals of concern are sought.

This report is the first output from this work stream. It summarizes the literature on substitution of chemicals of concern (or alternatives assessment, which is the term in use in Northern America), with a focus on the current landscape of substitution practice in OECD member countries. It discusses definitions, principles, frameworks and tools for alternatives assessment, as well as the key drivers and audiences, and it identifies the contribution that OECD can make in this space.

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I. INTRODUCTION

A. Substitution and the Growing Role of Alternatives Assessment

This meta-review summarizes the literature on substitution of chemicals of concern, with a focus on the current landscape of substitution practice in OECD member countries. Substitution can be defined as "the replacement or reduction of hazardous substances in products and processes by less hazardous or non-hazardous substances, or by achieving an equivalent functionality via technological or organisational measures" [1]. If substitution is the act of replacing or reducing a hazardous substance, then alternatives assessment is the approach by which potential alternatives are evaluated. The goal of alternatives assessment is "informed substitution," defined as "the considered transition from a chemical of particular concern to safer chemicals or non-chemical alternatives" [2].

The practice of alternatives assessment to inform the replacement of chemicals of concern with safer substitutes is increasing in OECD member countries. Organizations are seeking alternatives assessment guidance and tools they can use to implement and comply with regulations, particularly in the European Union (EU) and at the state level in the United States. Alternatives assessments are used to respond to government regulation and/or industry, retailer, and consumer demand for products that do not contain chemicals of concern.

Several government initiatives over the last 20 years illustrate the growing role of alternatives assessments in informing substitution. The Massachusetts Toxics Use Reduction Act of 1989 (TURA) served as a catalyst to pollution prevention planning and substitution of harmful chemicals [3], with the Toxics Use Reduction Institute (TURI) at the University of Massachusetts at Lowell playing an important role in developing and applying alternative assessment approaches to chemicals of concern, such as the 2006 Five Chemicals Study [4]. In 2005, the U.S. Environmental Protection Agency's (EPA) Design for the Environment (DfE) Program published results of its first alternatives assessment to evaluate flame retardants alternatives to pentabromodiphenyl ether used in furniture foam [5]. The European Chemicals Agency (ECHA) issued guidance in 2007 to assist EU member states in evaluating alternatives to substances proposed for restriction under the REACH regulation [6]; in 2011, ECHA issued guidance for completing a mandatory "analysis of alternatives," a requirement for companies seeking authorisation to use a substance of very high concern (SVHC) under REACH [7]. In 2011, the United Nations Environment Programme (UNEP) Persistent Organic Pollutants (POP) Review Committee published its assessment of chemical and non-chemical alternatives to endosulfan [8]. Also in 2011, U.S. EPA's DfE Program published an updated version of its chemical alternatives assessment criteria to enable decisions that consider the potential human health and environmental hazards of alternatives [9]. In 2013, the California Safer Consumer Products Regulation codified a green chemistry approach that requires alternatives assessment and, where deemed necessary to manage risk, end-of-life product management [10]. Efforts in Asia include a five-year research project initiated in 2007 by the Japanese Ministry of Economy, Trade and Industry (METI) on the development of methodologies for risk tradeoff analysis and the optimization of chemical management [11].

Among industry and NGO initiatives, the Zero Discharge of Hazardous Chemicals (ZDHC) group of apparel companies developed a hazard assessment guidance document to identify and prioritize chemicals in their supply chains that require substitution with safer alternatives [12]. Retailers such as Boots and B&Q in the United Kingdom have developed tools to screen and evaluate chemicals used in the products they sell and advance adoption of alternatives [13, 14]. In the United States, Clean Production Action created the GreenScreen®, in complement to the U.S. EPA's DfE alternatives assessment criteria, for the purposes of comparing chemical alternatives [15]. Various industry sectors are using alternatives assessment tools during product development [16]. For example, Hewlett Packard uses GreenScreen® to assess the human health and environmental impacts of alternatives to chemicals restricted in the electronics industry [17].

B. The Ad Hoc Group on Substitution of Harmful Chemicals

The OECD's 49th Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides, and Biotechnology established the Ad Hoc Group on Substitution of Harmful Chemicals with the goal of furthering tools and approaches to support decision making for the substitution of chemicals of concern. As part of its work, the Joint Meeting requested that the Ad Hoc Group build on existing work to develop a toolbox to support the evaluation of alternatives when safer substitutes to chemicals of concern are sought.

The contents and structure of a toolbox will depend on the number and diversity of alternatives assessment frameworks, tools, and methods, as well as gaps and opportunities for improvement identified by the Ad Hoc Group. Surveys of the growing number of alternatives assessment tools and methods have been attempted by various NGOs, academic organizations, and businesses. This meta-review takes advantage of existing surveys and compilations and serves as a first step toward structuring the development of a substitution toolbox that will prove useful to a variety of audiences. This meta-review is not intended to provide in-depth information on individual frameworks, tools, and methods, or to assess their quality. Rather, this review is intended to give a broad overview of the current state of substitution practice within the OECD member countries, highlight gaps and needs within the field of alternatives assessment, and identify possible contributions of the Ad Hoc Group.

C. Meta-Review Methodology

To conduct this meta-review, we identified sources on alternatives assessment, with a focus on the substitution of chemicals of concern with safer alternatives. These sources included government, industry and non-governmental documents, reports, presentations, and Web sites, as well as the published literature. We focused our search on sources from the last 15 years, from OECD member countries. We polled committee members at the beginning of the meta-review process to identify relevant sources, and we shared the list of sources with committee members before starting our review. Our primary goal was to be comprehensive, not exhaustive, in the sources that we identified and reviewed. The list of all sources reviewed throughout this meta-review process is available in Appendix A, and the list of sources cited in this meta-review is available in the References section. Not all of the reviewed sources are cited in this report.

II. CURRENT PRACTICE OF ALTERNATIVES ASSESSMENT

A. Definitions and Principles of Alternatives Assessments

Definitions

A review of the literature shows a range of definitions for the term "alternatives assessment." This review finds that the definitions of alternatives assessment have changed over time to reflect an expanding view of scope (as illustrated by this sampling of definitions):

- Edwards et al., 2005 [18]: The process whereby a chemical, material, or product that has been identified as toxic is compared with alternatives to find a substitute that is safer for workers, communities, and ecosystems.

- Geiser [n.d., as cited by 19]: Alternatives assessment is a process for identifying and comparing potential chemical and non-chemical alternatives that can be used as substitutes to replace chemicals or technologies of high concern.

- Toxics Use Reduction Institute (TURI), 2011 [20]: An alternatives assessment looks comprehensively at the uses of chemicals of concern, and the availability of safer, technically feasible, and affordable alternatives. These alternatives may be chemical substitutions, but may also be modifications to processes or product redesigns that facilitate the shift to safer processes and products.

- Winnebeck, 2011 [21]: Alternatives assessment is a tool used to compare the environmental, human health, and performance attributes of a set of products that perform the same function to ensure potential replacements are indeed less impactful and that the replacement does not have an unforeseen side effect.

- Design for the Environment (DfE), 2013 [22]: Alternatives assessments provide a basis for informed decision making by developing an in-depth comparison of potential human health and environmental impacts.

- Interstate Chemicals Clearinghouse (IC2), 2012 [23]: The "Golden Rule" of alternatives assessments is replacing chemicals of concern in products or processes with inherently safer alternatives, thereby protecting and enhancing human health and the environment.

- Whittaker and Heine, 2013 [24]: Chemicals Alternatives Assessment (CAA) is a form of alternatives assessment that focuses on finding alternative chemicals, materials, or product designs to substitute for the use of chemicals of concern.

- Lowell Center/BizNGO/BlueGreen Alliance, 2013 [25]: 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 review of these definitions shows more commonalities than differences. The definitions are similar in their focus on hazard, and taking action to replace chemicals of concern with safer alternatives. This meta-review found a general recognition that alternatives assessments can encompass a broad set of attributes, including but not limited to hazard, fate, physical-chemical properties, functional use approach, technical feasibility / product performance, use-based exposure and risk, cost and availability, life-cycle impacts, social impacts, stakeholder input, and comparison of materials and/or processes. Depending upon the product type and alternatives assessment context, some attributes may be of higher priority than others.

It should be noted that an alternatives assessment may include an exposure and/or risk assessment, but they are distinct in their steps and scope. As discussed in Section II.B, some alternatives assessment frameworks call for an assessment of exposure or risk, while others do not.

Alternatives assessment may refer to the assessment of chemical, material, and/or process alternatives. The majority of the literature, however, focuses on chemical substances and discusses tools and methods for chemical substitution. There is relatively less discussion or in-depth guidance in the literature on the replacement of chemicals of concern with alternative materials or processes.

Alternatives Assessment Principles

One of the earliest mentions of a substitution principle comes from Sweden. As reported in Mont [26], the 1990 Swedish Act on Chemical Products reads “anyone handling or importing a chemical product must take such steps and otherwise observe such precautions as are needed to prevent or minimise harm to man or the environment. This includes avoiding chemical products for which less hazardous substitutes are available.” The focus of this Act on replacement of hazardous substances with less hazardous alternatives is similar to the definition of substitution given in the introduction of this meta-review. More recently, the substitution principle was defined as “a policy principle that requires the replacement of hazardous (or potentially hazardous) chemical substances by less hazardous alternatives” by the Swedish Chemicals Agency (KemI) [27]. The substitution principle is a central element of the Stockholm Convention on POPs, and the European REACH regulation [28].

Kuczenski and Geyer [29] identify the following common elements of alternatives assessment frameworks based on their review of frameworks and KemI’s report on the substitution principle [27]:

- Use of qualitative and quantitative information
- A diminished reliance on the results of risk assessment
- A description of the functional use of a chemical as the basis for developing alternatives
- An iterative process of continuous improvement

A group led by the Lowell Center for Sustainable Production (LCSP), along with the BizNGO Working Group (BizNGO) and BlueGreen Alliance (BGA), drafted a set of principles for alternatives assessments (see Figure 1). In addition, the Interstate Chemicals Clearinghouse (IC2) Technical Alternatives Assessment Guidance Team drafted principles for alternatives assessments to accompany its Alternatives Assessment Guidance Document (see Figure 2).

Figure 1: Principles for Alternatives Assessments from LCSP/BizNGO/BGA [25]

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.

Figure 2: Principles of Alternatives Assessments from IC2 Working Group [23]

REDUCING RISK BY REDUCING HAZARD Chemical hazard should be emphasized. When an exposure assessment is part of an alternatives assessment, it should not be used to justify the continued use of chemicals of concern. Exposure reduction should be used to reduce risk by improving a product only after selecting the least hazardous option(s).

TRANSPARENCY All assumptions, data sources and quality, decisions, etc., should be documented and explained. For example, decision methods require establishing weighting criteria and the values selected to establish the relative weightings should be communicated and justified. It is also good practice to document search and study selection, including which studies are and are not used to inform decision making and why.

FLEXIBILITY Four modules should be included in all analyses, specifically performance, cost and availability, hazard, and exposure. The remaining modules should be considered by the user if relevant to the particular chemical, product, or process under assessment.

LIFE-CYCLE THINKING All decisions made should reflect a broad perspective and include consideration of the full life cycle of the product. Impacts to workers, consumers, and to the environment across the life cycle and the supply chain should all be considered.

OPPORTUNITIES FOR GREEN CHEMISTRY AND CONTINUOUS IMPROVEMENT Distinguish between results that provide clear benefits and ones that afford marginal improvements or important trade-offs. Identify all opportunities for continuous improvement and set goals for meeting them, which may include a longer-term Green Chemistry design challenge.

CONSIDER UNCERTAINTIES While in general, data from peer-reviewed scientific studies are preferred over assumptions, estimates, and unpublished data, even well-performed studies may not provide full information about a substance. For example, there may be cases where certain animals may not be good models for toxicity, or where other adverse effects are not captured by the analytical requirements of the test method. As part of the data review, it's important to capture these uncertainties and factor them into decision making.

While the name of each principle and its wording varies, a comparison of the LCSP/BizNGO/BGA and IC2 principles shows more similarities than differences.

Similarities between LCSP/BizNGO/BGA and IC2 Principles:

- Reducing risk by reducing hazard as a first principle
    - Both lists of principles emphasize an initial focus on reducing hazard to reduce risk. Reducing exposure is noted as a secondary method of reducing risk.
- Transparency
    - Transparency of data, assumptions, and decision-making criteria are mentioned. Transparency of information about methodologies, data, and assumptions communicated through the supply chain is included in the LCSP/BizNGO/BGA list.
- Data quality
    - The quality of data applied in alternatives assessments is highlighted as a critical consideration in both sets of principles.
- Exposure
    - The role of exposure in reducing overall risk is noted in both lists.
- Promoting innovation and continuous improvement
    - Both sets of principles encourage future thinking that drives the development of safer alternatives and promotes continuous improvement to reduce environmental and human health impacts. Both lists stress that an alternatives assessment is action-oriented (i.e., it is about making decisions and taking action, not just analysis), and that the starting point is the substitution of a chemical of concern.
- Trade-offs
    - Both sets of principles highlight the possibility of trade-offs among alternatives.

Main differences between LCSP/BizNGO/BGA and IC2 Principles:

- IC2 includes 'flexibility' as a principle and cites four modules (or attributes) that alternatives assessments should include at a minimum. LCSP/BizNGO/BGA does not include a similar principle or minimum set of attributes that alternatives assessment should address.

- The role of green chemistry as an approach for designing safer alternatives is mentioned only in the IC2 principles.

B. Frameworks for Alternatives Assessment

As discussed in this meta-review, alternatives assessment refers broadly to the process of assessing alternatives to a chemical of concern. Numerous organizations have described a set of steps for conducting alternatives assessments. Those steps vary in response to the specific context and objectives of the potential substitution. Over time, a number of *alternatives assessment frameworks* – defined as the arrangement of analyses and decisions that can be used to assess alternatives – have emerged in response to drivers such as regulation of chemical substances and stakeholder interest in consistent approaches to evaluating alternatives.

THE NINE ALTERNATIVES ASSESSMENT FRAMEWORKS IDENTIFIED IN THIS META-REVIEW

- BizNGO Alternatives Assessment Protocol
- California Safer Consumer Products Regulation
- DfE Chemical Alternatives Assessments
- German Guide on Sustainable Chemicals
- Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guidance (draft)
- Lowell Center Alternatives Assessment Framework
- REACH Authorisation Analysis of Alternatives
- TURI Alternatives Assessment Process Guidance
- UCLA Multi-Criteria Decision Analysis
- UNEP Persistent Organic Pollutants Review Committee General Guidance on Alternatives

All alternatives assessment frameworks identified in this meta-review originate from the same question, that is, how should one assess potential alternatives to a chemical (or material or product) of concern?[1] The nine frameworks highlighted in this meta-review have a number of commonalities, such as the assessment of intrinsic hazard, fate, physical-chemical properties, functional use approach, technical feasibility, and product performance. (Refer to the Glossary at the end of this meta-review for definitions of each attribute.)

ALTERNATIVES ASSESSMENT FRAMEWORK COMMONALITIES

Intrinsic Properties:
- Hazard
- Fate
- Physical-Chemical Properties

Functional Use Approach
Technical Feasibility
Product Performance

Variation exists among attributes in each framework (see Table 1), as does the level of detail. For example, the Lowell Center Framework does not specify how to evaluate intrinsic hazard; rather, it points practitioners to various tools and methods for assessing and comparing hazards. In contrast, specific guidance for assessing intrinsic hazard exists under the German Guide on Sustainable Chemicals and U.S. EPA's DfE Chemical Alternatives Assessment Steps. Each of these frameworks uses a different set of criteria to assess intrinsic hazards. Similarly, while all of the frameworks may address cost and availability to some extent, specific requirements for this attribute are detailed under the REACH tiered approach and the IC2 guidance, and are only given a general mention in the BizNGO Alternatives Assessment Protocol and other frameworks.

Similarly, frameworks differ in the way they specify steps to conduct an alternatives assessment. The IC2 Alternatives Assessment Guide, for example, presents three types of decision-making frameworks—

[1] For example, the BizNGO Alternatives Assessment Protocol [35] states "Step 1. Chemicals of concern are the entry point into the alternatives assessment protocol." The goal of the Lowell Center Framework [37] is to create "an open source framework for the relatively quick assessment of safer and more socially just alternatives to chemicals, materials, and products of concern."

sequential, simultaneous, and hybrid—and includes 11 scoping and assessment modules (e.g., life-cycle thinking, exposure, cost and availability assessment, social impact, and performance) that users can choose among to conduct an assessment [30]. IC2 also hosts a wiki site, developed collaboratively by representatives from ten states, as a way to lay out basic steps of conducting an alternatives assessment and to share resources and approaches [31]. The BizNGO Alternatives Assessment Protocol and TURI's Alternatives Assessment Process Guidance (developed as part of its Five Chemicals Study) [32] recommend steps to conduct an alternatives assessment without prescribing how to carry out each step.

Variations in alternatives assessment frameworks arise naturally from the specific requirements and context surrounding the authoring organization's needs, goals, and legal requirements. The REACH regulation calls for comparison of risks, economic feasibility, and technical feasibility when determining if alternatives are suitable. Consideration of other life-cycle impacts is not required, but LCA methodologies may be applied to get an idea of potential impacts. The REACH regulation may also require an assessment of social impacts. California's regulation on safer consumer products requires an assessment of relevant life-cycle impacts and other attributes when comparing alternatives. The BizNGO Chemical Alternatives Assessment Protocol includes life-cycle assessment and risk assessment as two separate steps, noting that they are not always necessary or appropriate for selecting an alternative. The German Guide on Sustainable Chemicals [33] includes an analysis of social impacts, while the BizNGO Protocol does not mention them. As Rossi [34] wrote, "There is no single alternatives assessment method or tool available to meet all needs, to fit all applications. Alternatives assessment methods and tools need to be flexible, adaptive, and probably modularized. The appropriate methods and tools will vary depending on goal…, audience…, and level of assessment."

Just as there is no single tool available to conduct an alternatives assessment, there is no single framework available to fit all applications. As the comparison of alternatives assessment frameworks suggests, the appropriate framework to apply in the substitution process will vary depending on the context, including the goal, audience, resources, and other factors.

Table 1: Attributes that vary among alternatives assessment frameworks

Attributes / Framework	Use-Based Exposure/ Risk	Cost & Availability	Other Life-cycle Impacts	Social Impacts	Stakeholders	Includes Comparison of Materials and/or Processes
BizNGO Alternatives Assessment Protocol [35]	As needed	Yes	As needed	Not mentioned	Not mentioned	Yes
California Safer Consumer Products Regulation [36]	Yes	Yes	Yes	Yes	Yes	Yes
DfE Chemical Alternatives Assessment Steps [22]	As needed	As needed	As needed	As needed	Yes	Can be added
German Guide on Sustainable Chemicals [33]	Yes	Yes	Yes	Yes	Not mentioned	No
Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guidance (draft) [30]	Yes	Yes	As needed	As needed	As needed	As needed
Lowell Center Alternatives Assessment Framework [37]	Not mentioned	Yes	Not mentioned	Yes	Yes	Yes
UNEP Persistent Organic Pollutants Review Committee General Guidance on Alternatives [38]	Yes	Yes	As needed	Yes	As needed	As needed
REACH Authorisation Analysis of Alternatives [7]	Yes	Yes	As needed	Yes (but in the Socio-Economic Analysis)	Yes	Yes
TURI Alternatives Assessment Process Guidance (also referred to as “Five Chemicals Guidance”) [32]	Yes	Yes	Yes	Yes	Yes	Yes
UCLA Multi-Criteria Decision Analysis [39]	Yes	Yes	Yes	Not mentioned	Can be added	Can be added

C. Tools and Repositories for Alternatives Assessment

Many tools and repositories have been developed over the last decade to assist interested users in conducting alternatives assessments. For purposes of this meta-review, the Ad Hoc Group defines tools and repositories as follows:

- **Tool:** An approach for evaluating a chemical, material, process, product, and/or technology for the purpose of attribute analysis within an alternatives assessment; these may include open source tools, fee-source tools, computer-based tools, and paper-based methods.

- **Repository:** A collection of the results of an assessment made available to others beyond the entity who conducted the assessment. Repositories may include government, business, non-profit or consultant-developed databases, websites, or software tools that provide information on potential alternatives.

Several organizations have surveyed the literature and other sources in recent years to catalogue the growing number of tools and create inventories or compendiums of tools (Appendix B).

Tools, which may address one or more of the attributes in Tables 1 and 2, vary in complexity and the degree of subject matter expertise needed to apply them. In general, a large number of tools are available to define and compare intrinsic chemical properties such as hazard and fate [40]. In contrast, this review finds there is not the same breadth of tools that address attributes such as **cost and availability, use-based exposure/risk, technical feasibility, and product performance.**

This meta-review also found variation among tools in how attributes are addressed, level of comprehensiveness, and their overall objectives. For example, the GreenScreen® [15] and the SIN (Substitute It Now) List [41] vary in their hazard criteria and overall purpose. In GreenScreen®, hazard criteria are based on the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), U.S. EPA's DfE alternatives assessment criteria, and other international precedents. It assists companies in conducting a comparative hazard assessment and identifying safer alternatives to chemicals of concern. The SIN List includes chemicals that meet EU criteria for being 'Substances of Very High Concern' under Article 57 of REACH. It is intended to complement REACH regulation and provide easy-to-use guidance to companies on chemicals to avoid; it is not designed to identify safer alternatives. For use-based exposure/risk, the Column Model [42] considers a number of factors that increase or decrease potential exposure. BASF's Eco-efficiency Analysis evaluates exposure according to the way that substances are handled rather than determining actual exposure concentrations [40].

Examples of Tools to Aid in Alternatives Assessment

RISCTOX
- Developed by the Spanish Trade Union Institute for Health, Work, and Environment
- Provides information about risks to human health and environment posed by chemicals in the workplace
- Includes how to address the substance if it occurs in the workplace, written practice guidelines, how the substance is classified, and current regulations

GreenScreen®
- Developed by Clean Production Action
- Ranks chemicals and materials based on their human health and environmental hazards
- Includes a set of four benchmarks that provide a decision framework for screening out chemicals that are associated with adverse health and environmental impacts

Column Model
- Developed by the Institute for Occupational Safety of the German Federation of Institutions for Statutory Accident Insurance, and Prevention
- Evaluates acute and chronic health hazards and environmental concerns. Hazards are classified into five categories based on R-phrases (or H-statements in the draft GHS Column Model

Lists that Identify Chemicals of Concerns
The SIN (Substitute It Now) List
- Developed by International Chemical Secretariat
- Includes chemicals that meet EU criteria for being 'Substances of Very High Concern' under Article 57 of REACH

National Toxicology Program (NTP) Carcinogen List
- Prepared by U.S. Department of Health and Human Services National Toxicology Program
- Identifies agents, substances, mixtures, and exposure circumstances that are *known or reasonably anticipated* to cause cancer in humans

Two inventories of tools covered in this meta-review, the Lowell Center Compendium [40] and SUBSPORT [43], summarize tools according to a common set of descriptors, allowing more direct comparison among tools. Several descriptors in these two inventories are similar (e.g., “ease of use” (Lowell Center) and “user friendliness” (SUBSPORT)). Other descriptors are slightly different. For example, SUBSPORT uses the term “reliability” to refer to data inputs while the Lowell Center uses “limitations” to describe a similar concept. (SUBSPORT also uses “limitations,” but in this case discusses the number of chemicals that the tool addresses.) Figure 3 compares the descriptors and narrative summaries used by Lowell Center Compendium and SUBSPORT for an example tool, the Column Model.

Figure 3: Comparison of Descriptors and Narrative Summaries for an Example Tool – Column Model

Column Model (Summarized by Lowell Center):	Column Model (Summarized by SUBSPORT):
Developed by: Institute of Occupational Safety of the German Federation of Institutions for Statutory Accident Insurance and Prevention **Fee for use:** No **Main purpose:** Provide a practical tool for industry to compare chemicals currently in use and proposed alternatives. **Ease of use:** Easy to moderate **Hazards evaluated:** Acute toxicity, reactivity, corrosivity, skin sensitization, ocular hazards, and irritants. Carcinogenic, mutagenic and reprotoxic substances (CMRs), bio-accumulation, water pollution, flammability, and explosivity. **How hazards are classified:** Hazard rankings based on EU R- phrases and GHS H- statements. 5 risk categories: very high; high; medium; low; and negligible. **Weighting of hazard categories:** Hazard categories are not weighted. **Exposure consideration:** Exposure potential from vapor pressure, and chemical processing taken into account. **Strengths:** Tool uses a streamlined approach to array data and compare chemical alternatives, including exposure potential. **Limitations:** Data derived primarily from MSDS or SDS, which may not provide sufficient information.	**Elaborated by**: IFA, Institute for Occupational Safety and Health of the German Social Accident Insurance **Description**: The model is based on 6 columns in which the following hazard categories are described: • Acute health hazards • Chronic health hazards • Fire and explosion hazards • Environmental hazards • Exposure potential • Process hazards **Reliability**: The main sources of information for this method are Chemical Safety Data Sheets. Several studies conducted in Europe have shown important shortcomings of these sheets, especially regarding classification. **Applicability**: Restricted to single cases of substitution of one product or chemical by another. It is not possible to compare products with alternative procedures or technologies. This method is aimed at SME’s and non-specialized users. It is applicable only to chemical hazards and risks. **User friendliness**: Easy to handle by non-professional users and does not require special expertise if Chemical Safety Data Sheets are available. **Limitations**: Since the method is based on R phrases, it covers 7000 chemicals classified with such phrases, included in Regulation (EC) 1272/2008 CLP. **Availability**: The method (in German or English) can be downloaded free of charge at IFA’s website. There is a Spanish version published by INSHT (Spanish Occupational Health and Safety Institute).

Data availability, quality, and interpretation

One of the commonalities across alternatives assessment tools is the need for data and the importance of data quality and reliability. In 1998, the U.S. EPA conducted a study of chemical hazard data availability and concluded that 43% of high production volume chemicals lacked basic toxicity information [44]. Since that time, government agencies, such as the U.S. EPA, and the OECD and its stakeholders, have launched high production challenge programs designed to gather and make public data on these chemicals [45]. Over 2,200 chemicals have been assessed collectively through the OECD HPV Program, International Council of Chemical Associations (ICCA) Initiative, and U.S. EPA HPV Challenge Program [46]. Other data sources include U.S. EPA’s ChemView Portal [47], which aggregates health and safety data for specific chemicals under the Toxic Substances Control Act, and the OECD’s eChem Portal, which aggregates data on chemicals from 28 governmental sources. Though data access has improved in the past couple of decades, there are still significant gaps in data availability that impede the ability to understand and compare chemical hazards [40, 48].

When data are available, quality and completeness are important considerations, and challenges may include how to interpret a large volume of data and reconcile conflicting information. The U.S. EPA's DfE Program has developed a generalized preference for data as follows: 1) measured data on the chemical being evaluated, 2) measured data from a suitable analog, and 3) estimated data from appropriate models [9]. Common sources for measured data are toxicological study reports or authoritative body reviews. (Authoritative body reviews are typically government agency-developed evaluations of published data for certain chemicals.) Acknowledging that all studies have limitations, even measured data should be evaluated for quality and completeness. In the DfE program, safety data sheets (SDSs) are not considered reliable sources of data, because they often contain limited to no data on ingredients in products, and may also vary in their accuracy due to the lack of common standards in preparing them [49].

When data are not available or lacking in quality, key challenges include how to convey uncertainty with regard to the evidence, and how to best fill data gaps. Data gaps can often be addressed through the use of relevant models or analogs, but identifying the most appropriate ones is often difficult and requires specialized technical expertise.

This central issue of data quality and reliability is handled differently across tools. Edwards et al. [40] provide a high-level summary of the varying ways in which tools address data gaps. For example, some tools provide a score for data quality, while others rate chemicals with no data as a high hazard. Some rely on authoritative chemical hazard lists developed by government agencies to screen chemicals. Others use authoritative lists of chemicals as a starting point to assess chemical hazard and also include a variety of other data, such as the results of quantitative-structure activity relationship (QSAR) models or experimental studies from the scientific literature.

Finally, data interpretation is a key challenge in alternatives assessments. For some chemicals, there may be multiple studies that require a weight-of-evidence approach implemented by experts to determine how to include such data in a tool. The same may be true when there is only a single toxicological study. Uncertainties associated with the data can be difficult to communicate and add complexity to decision making. One approach is to weigh hazard data based on whether they are estimated or measured. For example, the GreenScreen® [15] and DfE [9] program both make use of italics to communicate instances where data inputs are derived from models or analogs.

Comparing tools
Table 2 shows a potential approach for building on existing surveys of tools. It includes a list of descriptors developed by the OECD Ad Hoc Group grouped into the categories of applicability, goal, comparative attributes, user friendliness, transparency, and budget. The category "goal" draws upon the summary of tools developed by the Lowell Center. For illustrative purposes, four tools are included in Table 2 – RISCTOX [50], GreenScreen® [15], Column Model [42], and the SIN (Substitute It Now) List [41]; brief descriptions of each can be found in the previous sidebar. Note that this meta-review found descriptors or narrative summaries for only a relatively small subset (<50) of tools. Characterizing tools based on the descriptors in Table 2, or a similar set of descriptors, could serve as the foundation of an online tool selector or comparison feature, as discussed further in Section III.

Table 2: Example approach for characterizing tools, building upon the literature

Descriptors	Tools			
	RISCTOX	GreenScreen®	Column Model	SIN List
Applicability				
Chemical substitution	✓	✓	✓	✓
Material substitution				
Product substitution				
Process modification				
Goal				
Identification of hazardous substances/properties	✓	✓	✓	✓
Prioritization of substances for substitution	✓	✓	✓	✓
Compare alternatives	✓	✓	✓	
Identify assessed alternatives				
Comparative Attributes				
Hazard	✓	✓	✓	✓
Use-based exposure/ risk	✓		✓	
Technical feasibility/performance				
Cost & availability				
Life-cycle impacts				
Social impacts				
User friendliness				
Automated (e.g., computer-based rather than paper-based)?	✓	partial	✓	✓
Available in more than one language?	✓		✓	✓
Guidance available?	✓	✓	✓	✓
Support/training available?		✓		
Transparency				
Criteria	✓	✓	✓	✓
Weighting & decision making (if applicable)	n/a	✓	n/a	n/a
Budget				
Free of charge to access?	✓	✓	✓	✓

Alternatives Assessment Repositories

Four examples of repositories for sharing alternatives assessment results identified through this meta-review include SUBSPORT's Case Story Database [43], CleanGredients® [51], the IC2 Chemical Hazard Assessment Database [52], and the U.S. EPA's DfE Safer Chemical Ingredients List [53]; each is explained in greater detail in the adjacent sidebar. Repositories range from those that report on the conclusions of alternatives assessments (e.g., CleanGredients®) to those in which a user can find entire assessments (e.g., SUBSPORT). The SUBSPORT Case Study Database includes completed reports on select substances of high concern, and general information on alternatives compiled from industry and the literature, which the user can search by text or filter by industry sector. CleanGredients® and DfE's Safer Chemical Ingredient List provide listings of cleaning and related chemical product ingredients that have met criteria for environmental and human health performance. All of these repositories provide information on how they are compiled and updated.

Examples of Alternatives Assessment Repositories

SUBSPORT's Case Story Database
- Developed by KOOP Hamburg in collaboration with ISTAS Madrid; ChemSec, Gothenburg; and Grontmij A/S, Copenhagen
- Compiled from companies and the literature with general information on alternatives to substances of concern, with detailed alternatives assessment reports for select substances of high concern

CleanGredients®
- Developed by GreenBlue
- Lists cleaning product ingredients that meet consensus-based requirements for environmental and human health performance
- These ingredients can be used to formulate products eligible for the U.S. EPA's Design for the Environment (DfE) Program eco-label

IC2 Chemical Hazard Assessment Database
- Developed by Interstate Chemicals Clearinghouse (IC2)
- Enables users to search for GreenScreen™ and Quick Chemical Assessment Tool (QCAT) assessments
- Intended to promote awareness of assessments conducted on chemicals of high concern as well as reduce duplication of effort

Safer Chemical Ingredient List (SCIL)
- Developed by the U.S. EPA DfE Program
- Provides listing of cleaning and related chemical product ingredients (including functionality, CAS number, and chemical name) that meet EPA criteria for environmental and human health performance
- Assists product manufacturers in identifying chemicals that the DfE Program has already evaluated and identified as safer

D. Key Drivers and Audiences for Alternatives Assessment

The drivers for alternatives assessment have been well documented and described in the literature. Edwards et al. [40] provides a detailed description of regulatory and business drivers (both in the U.S. and the European Union), as well as "other drivers" including pressure from consumers, workers, and environmental advocates to eliminate chemicals of concern in a wide array of products. To best respond to these drivers facing their organizations, many governments, businesses, and NGOs developed decision-making frameworks and other guidance for conducting alternatives assessments, as previously discussed.

This meta-review also considered key audiences of alternatives assessment. Having an understanding of different audience groups and their needs will be important when shaping the development of an alternatives assessment toolbox. This meta-review found little discussion of audiences for alternatives assessments in the literature; audiences are often discussed implicitly rather than explicitly. The key audiences identified by this meta-review include manufacturers conducting alternatives assessments to inform chemical, material, or product substitution, consumers seeking simple product level information to inform their purchasing decisions, and government agencies conducting alternatives assessments to aid businesses or as a complement to regulation. Given this potentially broad interest in alternatives assessments, this meta-review attempts to group these audiences based on their needs and technical capabilities into four groups: non-technical decision makers, influencers, technical decision makers, and practitioners. Figure 4 presents general characteristics of each group. These groupings are not mutually exclusive.

Figure 4: Audiences for Alternatives Assessments Grouped by Needs and Technical Capabilities

Non-Technical Decision Makers	Influencers	Technical Decision Makers	Practitioners
• May include small and medium enterprises, retailers, workers, and product designers • Little to basic knowledge of alternatives assessments • Seek information on how different approaches/tools meet their needs and goals • Seek simple, easily digestible information to aid decision making • Example: A product designer who is selecting among alternative chemicals based on cost and environmental preferability; a retailer who specifies use of an appropriate tool by suppliers	• May include NGOs, academics, and governments • Basic to in-depth understanding of alternatives assessments • Seek information on how different approaches/tools meet their needs and goals • Use the concept and results of alternatives assessment to promote chemical safety and/or inform product selection and purchasing • Example: An NGO, trade union, or EH&S practitioner who advocates for use of alternatives assessments in the selection of chemicals to make products	• May include corporate materials managers and EH&S specialists • In-depth understanding of alternatives assessments • Seek detailed information on how different approaches/tools meet their needs and goals • Seek assistance in making trade-offs • Example: A corporate materials selection manager who specifies use of an appropriate tool by suppliers	• May include consultants, businesses, and governments • In-depth expertise in alternatives assessment and experience in a relevant technical field • Seek detailed guidance and in-depth training on how to apply tools • Seek access to robust technical data sources • Seek assistance in making trade-offs • Example: A consultant who applies tools to evaluate potential alternatives; a chemical supplier who assesses its portfolio at a customer's request

Given their technical capabilities and understanding of alternatives assessment, each of these audiences may come to a toolbox with different questions in mind. The Ad Hoc Group will take these needs into consideration when developing a toolbox that could support one or more of these audiences. This toolbox may include a feature to help each of these audiences identify the most appropriate tools, based on their needs.

III. OPPORTUNITIES TO ADVANCE ALTERNATIVES ASSESSMENT PRACTICE AND UNDERSTANDING

A. Summary of Gaps Identified Through Meta-Review

This meta-review found the following gaps and opportunities to advance alternatives assessment practice and understanding.

Harmonization of approaches

- Common definition, principles, and language (identified by multiple sources)
- Streamlined approach to evaluating life-cycle impacts and exposure [54]
- An alternatives assessment approach with clear triggers and checklists for exposure and LCA, and a harmonized approach among local jurisdictions to meet regulatory requirements [17]
- Need for more models and case studies for alternatives assessment; for example, case studies that describe the use of tools and lessons learned (identified by multiple sources)

Better data gathering and quality

- Common set of data sources, including toxicity data and hazard information (identified by multiple sources)
- Publicly available toxicity data for the thousands of chemicals in commerce [40]
- Better data sources on other attributes of alternatives, such as cost and availability, social impacts, and other life-cycle impacts (identified by multiple sources)

Heightened transparency and sharing of information

- Increased transparency in tools; for example, need for transparent hazard criteria and other background information on how a tool evaluates chemicals and materials (identified by multiple sources)
- Libraries or repositories to share evaluations for chemicals and materials to encourage the adoption of better materials and reduce the redundancy of assessing the same chemical/material multiple times [17]

Improved accessibility to tools and guidance

- Automated tools and methods to reduce hours of highly technical work [24]

- Guidance and tools for evaluating and comparing alternatives, including materials (identified by multiple sources)

- Easy-to-use guidance for new practitioners, including a step-by-step process, for chemical substitution scenarios [55]

- Practical tools that address regulatory questions or eco-label criteria (identified by multiple sources)

- Tools and guidance on assessing overall costs and benefits, and relating these to chemical functionality, performance requirements, and risk [55]

- Decision-making frameworks to perform hazard assessments of inorganic chemicals [17]

- Development of consistent guidance and follow-up in the context of regulatory monitoring and enforcement to enhance the substitution of harmful chemicals [55]

In Figure 5 below, these identified gaps and opportunities are related to the needs of alternatives assessment audiences identified earlier.

Figure 5: Needs of Alternatives Assessment Audiences and Gaps Identified in the Meta-Review

Needs	Gaps Identified in Meta-Review
Information on how different approaches/tools meet needs and goals	• Easy-to-use guidance for new practitioners, including a step-by-step process, for chemical substitution scenarios • Tools and guidance on assessing overall costs and benefits, and relating these to chemical functionality and performance requirements and risk • Common definition, principles, and language • Libraries or repositories to share assessments of chemicals and materials—to encourage the adoption of better materials and reduce the redundancy of assessing the same chemical/material multiple times
Access to robust technical data sources	• Common set of data sources, including toxicity data and hazard information • Publicly available toxicity data for the thousands of chemicals in commerce • Libraries or repositories to share assessments of chemicals and materials—to encourage the adoption of better materials and reduce the redundancy of assessing the same chemical/material multiple times • Better data sources on other attributes of alternatives, such as cost and availability, social impacts, and other life-cycle impacts • Decision-making frameworks to perform hazard assessments of inorganic chemicals
Simple, easily digestible information to aid decision making	• Libraries or repositories to share assessments of chemicals and materials—to encourage the adoption of better materials and reduce the redundancy of assessing the same chemical/material multiple times • Common definition, principles, and language • Availability of good models or case studies for alternatives assessment – case studies of tools being used and application of their lessons learned • Automated tools and methods to reduce hours of highly technical work • Easy-to-use guidance for new practitioners, including a step-by-step process, for chemical substitution scenarios • Practical tools that meet regulatory or eco-label requirements
Detailed guidance and in-depth training on how to apply assessment tools	• An alternatives assessment approach with clear triggers and checklists for LCA and exposure assessments, and a harmonized approach among local jurisdictions required to meet regulatory requirements • Increased transparency in tools/methods)e.g., need for publicly available hazard criteria and background materials) • Guidance and tools for evaluating and comparing alternatives, including materials
Assistance in making trade-offs	• Streamlined approach to evaluating life-cycle concerns and exposure • Availability of good models or case studies for alternatives assessment – case studies of tools being used and application of their lessons learned

B. Possible OECD contribution

Based on the number of gaps, including harmonized approaches, transparency and sharing of information, and access to high-quality data, there are significant opportunities for advancing the practice of alternatives assessment. The OECD could contribute by increasing and making more harmonized, where appropriate, the use of alternatives assessments by those not yet familiar with the field, and in making tools and methods more useful and relevant to existing audiences.

The Ad Hoc Group intends to use the knowledge gained through this meta-review to inform the development of an alternatives assessment toolbox, as described below. Of the needs and gaps identified in the literature, the Ad Hoc Group may be best positioned to make the greatest contribution towards advancing harmonization of approaches (acknowledging that full harmonization is not feasible given various legal requirements and market considerations), as well as improving accessibility to tools, methods, and guidance. It will be important to capitalize on existing work and insights gained through recent efforts to integrate and harmonize alternatives assessment approaches.

The Ad Hoc Group proposes the following activities to advance the harmonization of approaches and improve accessibility of tools, frameworks, and guidance:

- Develop an inventory of tools and methods

An inventory of tools and methods would be developed by leveraging and building upon existing inventories and compendiums to include a more comprehensive set of tools and descriptors. This inventory could provide the basis for a dynamic, online tool selector (described in more detail below).

- Link alternatives assessment frameworks to tools and existing data resources

Information on individual decision frameworks, tools, and data resources can be found in the literature, but this meta-review found few resources that help a user to understand linkages among them. For example, for a given alternatives assessment framework, it can be difficult to determine which tools are relevant to that framework. Similarly, if interested in a given tool, it can be challenging to determine the appropriate data resources to use. This type of linkage would be a critical element of building a robust, dynamic toolbox that would allow a user to select a framework based on which attributes they would like to address, and then choose tools that are suitable for implementing that framework.

- Build an online tool selector that could include a number of features geared towards different audiences.

While current inventories and compilations of tools are valuable, they are static in nature and require appreciable time to review. An online tool selector could synthesize disparate efforts into a dynamic toolbox. The tool selector could include the following features: (1) a series of structured questions that lead a user to a list of tools ranked by their applicability, (2) a 'browse tools' feature that would allow a user to read summaries of tools, with links to case studies and lessons learned, (3) the ability to compare and contrast tools, based on select attributes, to allow a user to select the best one for a particular question or context, and (4) a repository that shares the results of alternatives assessments.

- Develop an online toolbox that includes the inventory of tools and tool selector; allow for content or features appropriate for the different audiences.

As mentioned above, there are several audiences for alternatives assessments, all of whom could benefit, in varying ways, from an assessment toolbox. When developing the toolbox, a good design will be important to ensure usability and uptake. Educational materials, pointers to relevant data sources, and guidance on applying the tools in the toolbox are also features that could be included to improve a toolbox's value to multiple audiences.

- Identify potential areas for harmonization of approaches and focus on the common core elements (e.g., steps, terminology, case studies, and lessons learned) of alternatives assessment

In recent years, the field of alternatives assessment has grown tremendously, encompassing more organizations and a greater variety of approaches, including the introduction of regulatory use of alternatives assessment. While flexibility and pragmatism are critical in alternatives assessment, the increasingly global and cross-sector nature of the development and application of alternatives assessment means a common language and shared understanding of the field can reduce duplication of efforts and aid in harmonization of approaches.

GLOSSARY

Cost/Benefits and Availability: The negative (cost) and positive (benefit) implications, both direct and indirect, resulting from some action. This includes both financial and non-financial information [56]. Availability refers to the production of an alternative and its market accessibility.

Functional Use Approach: This approach starts with identifying the function that is desired. The concept is applied in two ways: first and foremost, to characterize the purpose a chemical or mixture serves, or the properties it imparts in a product or process (functional use), and second, to evaluate the whole product and how its use may influence the assessment of alternatives [57, 58].

Hazard: Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or population is exposed to that agent, based on its chemical, physical, or biological characteristics [59].

Intrinsic Property (of a Substance): An intrinsic property of a chemical substance is a characteristic of the substance, which can be used to determine its fate or to identify potential hazards. For example, in order to register a substance under REACH, the registrant must submit specific information about the intrinsic properties of the substance in each of the following areas:

- **physical/chemical properties**
- **human toxicological information**
- **ecotoxicological information**

Data on the intrinsic properties of a substance are categorised into endpoints. For instance, “carcinogenicity” is a human toxicological endpoint [60].

In the meta-review, “Intrinsic properties: hazard” refers specifically to the human and ecological hazard endpoints. “Intrinsic properties: fate” refers to biodegradation and bioaccumulation potential, in addition to any other fate endpoints. “Intrinsic properties: physical-chemical” refers to physical-chemical properties of the chemical substance.

Life-Cycle Impacts, Other: The impacts of using a chemical during its life cycle besides hazard, fate and use-based exposure/risk. Other life-cycle impacts may include global warming, water consumption, resource depletion, and social impacts.

Product Performance: The ability of a product to meet the performance requirements identified. The boundaries of performance characteristics are defined by the user.

Repository: A collection of the results of an assessment made available to others beyond the entity who conducted the assessment. Repositories may include government, business, non-profit or consultant-developed databases, websites, or software tools that provide information on potential alternatives.

Risk: The probability of harm to human health or the environment posed by exposure to a substance or material of concern. Risk is a function of hazard and exposure, and as the severity of the hazard and/or exposure increases, risk increases.

Social Impacts: All relevant impacts, which may affect workers, consumers and the general public and are not covered under health, environmental or economic impacts (e.g. employment, working conditions, job satisfaction, education of workers and social security) [56].

Stakeholders: Any entity (individual, population or facility) that is involved in or impacted by the extraction, synthesis, use or disposal/recovery of a chemical, material or product, or process modification under consideration.

Technical Feasibility: The determination as to whether the performance or functional requirements of a chemical, material or product could be fulfilled or replaced by eliminating or using an alternative chemical, material, product, process or technology, while considering any need for process adaptations and changes.

Tools/Methods: Approaches for assessing a substance, material, and/or process for the purpose of attribute analysis within an alternatives assessment; these may include computer-based screening tools, paper-based methods, etc.

Use-Based Exposure/Risk: Physical contact, inhalation, or ingestion of a chemical, which is determined by the anticipated handling, usage, and disposal of that chemical, including its use in a material or product.

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APPENDIX B: SAMPLING OF INVENTORIES AND COMPENDIUMS OF ALTERNATIVES ASSESSMENT TOOLS

Substitution of Hazardous Chemicals in Products and Processes [1]

- This report aimed "to identify, describe, and analyse relevant activities towards substitution of hazardous chemicals." Summaries of various assessment tools and methods, as well as substitution "case studies," are provided within the report.

Alternatives Assessment for Toxics Use Reduction: A Survey of Methods and Tools [18]

- The purpose of this report was "to provide to Massachusetts industry a compilation of tools for alternatives assessment of chemicals" that have been developed by government and private organizations in the United States and Europe. It provides a summary of over 100 various methods and tools that are available as of 2004, with an in-depth focus on nine tools.

A Compendium of Methods and Tools for Chemical Hazard Assessment [40]

- This compendium summarizes 18 hazard-based tools and methods in three categories: those that identify and screen out chemicals of concern, those that compare alternatives, and those that identify preferred chemicals and products.

Chemicals Alternatives Assessment (CAA): Tools for Selecting Less Hazardous Chemicals [24]

- This report provides a critical evaluation of 12 chemical alternatives assessment methods, including a comparison of human health and environmental hazard evaluation criteria.

Substitution Support Portal (SUBSPORT) [43]

- A collaboration in Europe by the organizations ChemSec (Sweden), ISTAS (Spain), Kooperationsstelle (Germany), and Grontmij (Denmark), SUBSPORT is an online resource on safer alternatives to the use of harmful chemicals, including a listing of tools and methods and a database of substitution case studies.

Alternatives Analysis Workshop: Tools, Methodologies and Frameworks [61]

This report summarizes hazard, exposure, life-cycle and other tools as well as alternatives assessment frameworks. This is the result of a two-day workshop on alternatives assessments hosted by the California Department of Toxic Substances Control.