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Alternatives Assessment Framework

of the Lowell Center for Sustainable Production

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This paper was produced by the Lowell Center's Chemicals Policy Initiative, whose objectives are to significantly advance policy dialogue on reforming chemicals policy in the United States; assist in the development of sustainable chemicals management outside the US; encourage the development and use of safer alternatives by creating and promoting a comprehensive framework for alternatives assessment; and identify tools and appropriate ways of assisting green chemistry innovation and safer supply chain management of chemicals .

Glossary of Terms

Chemical	Any "element, chemical compound or mixture of elements and/or compounds."[2] A chemical "mixture," also known as a chemical "preparation," includes multiple chemicals.
Hazard	"Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system or (sub) population is exposed to that agent."[3]
Material	The "basic matter (as metal, wood, plastic, fiber) from which the whole or the greater part of something physical (as a machine, tool, building, fabric) is made."[4] Human-made materials like petroleum-based plastics are synthesized from specific chemicals.
Material economy	The physical matter upon which we base our lives.
Product	Something "produced by physical labor or intellectual effort."[5] Products made from physical matter (as opposed to intellectual products) are made of chemicals and/or materials. The terms "products" and "articles" are often used interchangeably.
Risk	"The probability of an adverse effect in an organism, system or (sub) population caused under specified circumstances by exposure to an agent."[6]
Safer Alternative	An option, including the option of not doing something, that is healthier for humans and the environment than the existing means for meeting that need. For example, safer alternatives to the use of a hazardous chemicals include: replacing the chemical with an inherently less hazardous chemical; eliminating the need for the chemical through material change, product re-design, or product replacement; or eliminating the chemical by altering the functional demands for the product through changes in consumer demand, workplace organization, or product use.

Preface

To create an economy that sustains life, we need to develop a materials economy that protects ecosystems and human health. We need products made from non-toxic materials that are biodegradable, materials that can be closed loop recycled, and production processes powered by renewable energy. We need material systems that sustain life, where the outputs from extracting or growing raw materials, manufacturing chemicals and materials, and manufacturing products are ultimately benign inputs into ecological cycles. Reconfiguring our material economy will require changes in the design of chemicals, materials, products (including services), and economic systems (e.g., transportation systems, building systems, production systems, etc.) and changes in our culture.

If we want to transition our current economic and materials systems towards a more sustainable economy, we need to learn how to make decisions that move us towards more sustainable materials. How do we distinguish and define the specific properties of safer and cleaner, and, ultimately, truly sustainable products and services? How do we know whether one alternative chemical, material, or product is superior from an environment, health and safety perspective from another?

The Lowell Center for Sustainable Production Alternatives Assessment Framework represents a small, first step towards creating an approach that allows us to answer these questions. In recent years, various research projects have been undertaken to develop frameworks, approaches, and tools for assessment of substitutes at the chemical, material, and product levels. However, no consistent framework or methodology has been developed and widely adopted that guides the process of alternatives assessment. This is a problem because many governments and firms, even when they want to move towards safer materials, often lack tools or guidance on how and what they should look at in assessing alternatives – the process of alternatives assessment.

We do not see this framework as a static process but rather one that is continuously being revised and updated. We look forward to engaging with others on how to make alternatives assessment a robust yet practical framework for evaluating and identifying safer chemicals, materials, and products.

"Can one distinguish and define the specific properties of a technics directed toward the service of life: properties that distinguish it morally, socially, politically, esthetically from the cruder forms that preceded it? Let us make the attempt."

LEWIS MUMFORD,
TECHNICS AND CIVILIZATION, 1934

Alternatives Assessment Framework

INTRODUCTION

The Lowell Center for Sustainable Production has developed the Alternatives Assessment Framework with the goal of:

> **Creating an open source framework for the relatively quick assessment of safer and more socially just alternatives to chemicals, materials, and products of concern. "Open source" means the collaborative development, sharing, and growth of methods, tools, and databases that facilitate decision making. "Relatively quick assessment" means that the process results in robust decisions informed by the best available science, while avoiding paralysis by analysis.**

Safer alternatives are options that are healthier for humans and the environment than the existing means of meeting needs, including the option of not undertaking an activity. For example, safer alternatives to the use of a hazardous chemical include replacing the chemical with an inherently less hazardous chemical; eliminating the need for the chemical through material change, product re-design, or product replacement; or eliminating the chemical by altering the functional demands for the product through changes in consumer demand, workplace organization or product use.[7]

Why Alternatives Assessment?[8]

The vast majority of environmental science has focused on understanding and characterizing environmental and public health problems. Millions of dollars are invested annually in investigating issues ranging from the mechanism of action of a small number of toxic compounds and the fate and transport of substances in environmental media to the effects of contaminants on environmental resources and the technologies for measuring, monitoring, and managing those pollutants. While much of this work is important and valuable, the focus on problems is often at the expense of investigations that focus on solutions. To define problems without a comparable effort at finding solutions greatly diminishes the value of environmental science.

Given the many gaps in scientific knowledge and the many uncertainties surrounding environmental risks and the reality that risk assessments are slow, resource intensive, and result in attention to only a small universe of risks, alternatives assessment provides an efficient and effective route to positive solutions. An alternatives assessment approach offers several direct benefits for environmental policy including:[9]

Focusing on solutions rather than problems. The most important aspect of alternatives assessment is that it reorients environmental protection discussions from problems to solutions. For example, chlorinated solvents provide a service of degreasing and cleaning. Once we understand this service, it is possible to think of a range of alternatives, such as ultrasonic cleaning or less toxic aqueous cleaners or even redesigning a metal part so that the need for cleaning is eliminated altogether.

Stimulating innovation and prevention. Alternatives assessment processes can lead to innovation and produce substantial cost savings for firms as well as health and environmental benefits for society. Alternatives assessment calls attention to current and "on-the-horizon" alternatives. Resources that might otherwise be directed solely to the expensive and time-consuming process of characterizing problems can then focus on solutions.

Multi-risk reduction. Alternatives assessment can be a more efficient means of reducing multiple risks in the long term. Problem-based approaches generally examine one risk or problem at a time and are met with one solution at a time. These solutions are often inflexible (e.g., pollution control equipment) and require successive investments of technology to meet each new problem and standard. Alternatives assessments can examine a broader range of factors and options. For example, a traditional risk-based approach might narrowly examine the risks of a particular agricultural pesticide while an alternatives assessment would examine the availability of safer pesticides, alternatives to pesticides altogether (organic agriculture), or alternative structures such as smaller farms that might reduce dependence on pesticides. In a specific firm, an alternatives assessment might examine technology options that would benefit both worker and environmental health or ways to reduce toxic substance, energy, and water use simultaneously.

Alternatives assessment forms an essential component of a necessary shift from primarily problem-based environmental policy to solutions-based policy. We define solutions-based policy as holistic, integrated policy designed to prevent risks at their source, avoid risk shifting, establish far-reaching, long-term environmental goals, and stimulate innovation in safer and cleaner forms of production, products, and activities. We will only reach the goal of sustainable production and consumption if we change our environmental protection focus from figuring out how bad the situation will be to seeking alternatives to problematic activities and designing the conditions for a more sustainable future.

To achieve this shift in focus towards safer alternatives and solutions, government agencies, companies, and other stakeholders need tools and approaches to guide the development, assessment, and comparison of options. The Lowell Center Alternatives Assessment Framework provides a guide for conducting alternatives assessments. The Framework establishes the fundamental processes in any alternatives assessment but the actual tools and criteria for doing the assessment will vary across chemicals, materials, and products. Flexible yet robust methods of assessing alternatives are critical if we are to move beyond analysis to action.

The Lowell Center Alternatives Assessment Framework

The Lowell Center Alternatives Assessment Framework is designed to evaluate and identify environmentally[10] and socially preferable alternatives. "Alternatives" encompass production processes, chemicals, materials, products,[11] economic systems (such as transportation systems), and functions, as well as eliminating the need for a current activity or the function of a product. The Lowell Center Alternatives Assessment Framework consists of three core elements:

1. Alternatives Assessment **Foundation**
2. Alternatives Assessment **Processes**
3. Alternatives Assessment **Evaluation Modules**

We believe that any comprehensive alternatives assessment must include each of these core elements. Figure 1 illustrates the core elements of the Framework and how they overlap.

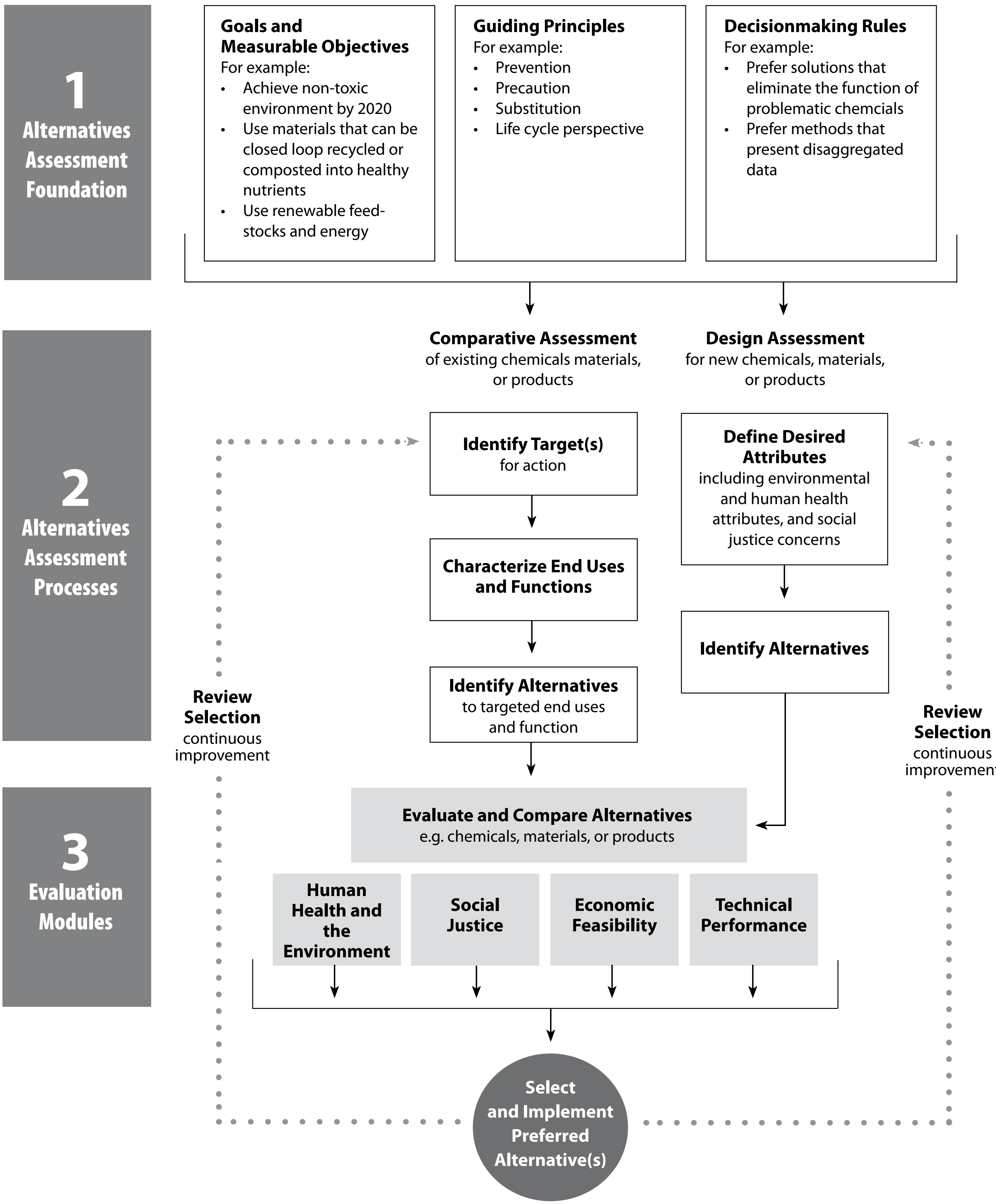
At the base of the Framework is the **Foundation**, where values are made explicit by clearly articulating the Principles, Goals, and Rules that guide decisions made during the assessment of alternatives. At the center of the Framework is the **Assessment Processes**—the methods, tools, and criteria used to evaluate which chemicals, materials, or products are safer and socially preferable. The Comparative Assessment Process and the Design Assessment Process are two separate yet overlapping tracks, depending on whether the subject of evaluation is an existing product or a product under development. Necessary to the Assessment Process are the **Evaluation Modules**, which evaluate the economic feasibility, technical performance, human health and environment impacts, and social justice impacts of alternatives.

These Evaluation Modules consist of methods, tools, and databases that facilitate relatively quick yet scientifically robust decisions. The modules are open source in that they are transparent and publicly available for the development, improvement, and/or use of all potential users. The Lowell Center envisions the Alternatives Assessment Framework as supporting the open and dynamic development of goals, methods, tools, and databases that lead to environmentally and socially preferable products, materials, and chemicals.

Defining the Terrain of Chemicals, Materials, and Products[12]

Throughout the Alternatives Assessment Framework we use the terms, "chemicals," "materials," and "products" as core areas of alternatives assessment work. As physical matter in our economy, chemicals, materials, and products are interrelated (for definitions of these terms see Glossary). Typical solid consumer products, such as the chairs we sit upon, are manufactured from materials, which in turn are constituted from chemicals. However, in other cases, chemical manufacturing processes generate chemicals as products.[13] Thus, products consist of materials and/or chemicals, materials consist of chemicals, and chemicals are constituents of materials or products. Figure 2 below illustrates the nested relationships between these types of matter.

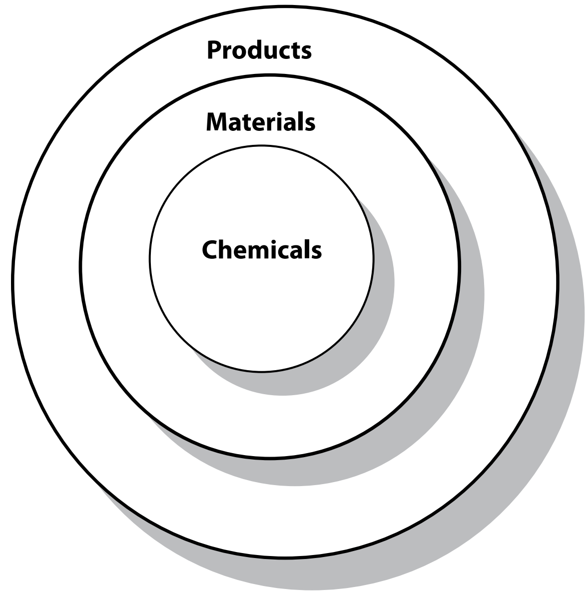
Figure 1 **Alternatives Framework: Detailed Summary**



Most products have this nested relationship. Consider carpet tiles as an example. Carpet tiles are made from a combination of backing and face materials. The face material is typically a nylon, either nylon 6 or nylon 6,6. Common backing materials include polypropylene, styrene butadiene rubber (SBR) and polyvinyl chloride (PVC). Nylon 6 is made from the chemical caprolactum; SBR is made from a mixture of chemicals styrene and butadiene, and the material natural rubber; polypropylene is made from the chemical propylene; and PVC is made from the chemicals ethylene and chlorine.

The distinction between chemicals, materials, and products emerges as most significant when evaluating and selecting solutions. For example, a solution to the substitution of a chemical of concern in a product, such as pentabrominated diphenyl ether (pentaBDE) in the foam cushions of a chair may be another chemical, or it may be a different material (e.g. metal or wood) that does not require a flame retardant. Similarly, post-consumer recycling systems are primarily developed around the material constituents of products rather than the individual chemicals.

Figure 2 **Nested Relationship Among Chemicals, Materials, and Products**



ALTERNATIVES ASSESSMENT FOUNDATION

Values are inherent in any technology assessment or comparison—be it a production process, chemical, material, product, or service. Personal and social values enter into the design and use of all decision-making methods and tools. The question is not how to design out values but rather how to make them explicit. Thus, any comprehensive Framework must define the Guiding Principles that inform the analysis, the Goals that the analysis process is designed to achieve, and Decision Making-Rules (see Figure 3 for an overview of this foundation and examples of Principles, Goals, and Decision-Making Rules).

Guiding Principles

When developing and using methodologies for informing decisions, practitioners make decisions. They make assumptions; create formulas; choose which formula(s) to use; and create new formulas even when others exist. Embedded in these decisions are values. These value-based decisions are often grounded in guiding principles and decision-making rules.

Guiding Principles for making environmental choices are common. Sometimes they are profession specific. Notable examples include The 12 Principles of Green Chemistry and The 12 Principles of Green Engineering (see *www.ChemicalsPolicy.org/organizations.shtml*). In industrial hygiene there is the hierarchy of controls.[14] In waste management there is the hierarchy of waste management.[15]

Figure 3 Alternatives Assesment Foundation

Goals and Measurable Objectives	Guiding Principles	Decisionmaking Rules
For example: • Achieve non-toxic environment by 2020 • Use materials that can be closed loop recycled or composted into healthy nutrients • Use renewable feed-stocks and energy	For example: • Prevention • Precaution • Substitution • Life cycle perspective	For example: • Prefer solutions that eliminate the function of problematic chemicals • Prefer methods that present disaggregated data

Other times these principles are firm specific, driven by a particular firm's mission. In all cases, they provide the foundations of the analyses and implementation that follow.

The Guiding Principles that inform the Lowell Center's design and application of the Alternatives Assessment Framework are:

- **Prevention:** any change to a chemical, material, or product that reduces, avoids, or eliminates the use of hazardous substances or generation of hazardous byproducts across its life cycle, so as to reduce risks to the health of workers, consumers, or the environment, without shifting risks between workers, consumers, or parts of the environment.[16]

- **Precaution:** preventive action to reduce threats of harm to human health or the environment, even if the exact nature and magnitude of the harm are not fully understood.[17]

- **Substitution:** "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 organizational measures."[18]

- **Life cycle perspective:** broad consideration (qualitative or quantitative) of environmental, social and/or economic issues across the life cycle of a chemical, material, or product.[19]

- **Transparency.** Openness and explicitness regarding methods, tools, and data sources. Transparency requires:
  - Publicly available data, including full disclosure of chemicals and materials in products to the fullest extent possible.
  - Clearly stated methodological steps, scope of analysis, data sources, assumptions, value judgments, and comprehensive discussion of uncertainty factors and missing data.

- **Stakeholder Participation.** Appropriate involvement of stakeholders in defining goals, developing methods, and selecting tools for implementing alternatives assessment.

- **Open Source.** A decision-making framework that is open, flexible, and easily adapted to meet evolving needs. The scope of work that needs to be completed to create a comprehensive Alternatives Assessment Framework is larger than any one single effort.

- **Enhancing, not delaying, decisions.** Methods and tools that facilitate making relatively quick decisions based upon robust data. These should be solutions based, identifying and leading to options that stimulate innovation.

- **Continuous improvement.** Successful implementation through continuous improvement and planning. Alternatives decisions are not final. They are steps along the path to sustainability. This means "don't let the perfect be the enemy of the good."

- **Values matter.** Explicitness about values, including the methods developed, tools used, and how data are analyzed. Examples of value judgments that emerge in alternative assessments include:
  - whether to use conservative, most likely case or worst case assumptions in analyses.
  - whether to emphasize the hazards or the risks of chemicals.
  - whether to emphasize pollution prevention or pollution control measures to manage toxic chemicals.
  - long-term goals and steps necessary to achieve them.
  - threshold of harm needed to trigger action.
  - priority action areas.
  - whether to use aggregated or disaggregated data.
  - how to aggregate data.

Goals and Measurable Objectives

Organizations and institutions perform alternatives assessments for a reason. They may want to inform the choices they make regarding chemicals, materials, products, suppliers, or production processes or to support the superiority of existing products. Once goals are agreed upon, the appropriate methods and tools for achieving the goals become clearer.

The process for defining goals differs widely depending upon whether it is a government entity, business, or non-governmental organization that is defining the goals. The Guiding Principles section above identifies principles critical to how goals should be developed, including transparency and collaboration with diverse stakeholders.

Examples of clearly articulated goals include:

Sweden. In 1999 the Swedish Parliament adopted fifteen national environmental quality objectives, the majority of which are to be attained by the year 2020.[20] Among the objectives are:

- "A Non-Toxic Environment" "The environment must be free from man-made or extracted compounds and metals that represent a threat to human health or biological diversity"[21] and

- "Reduced Climate Impact," which calls for achieving the goals of the UN Framework Convention on Climate Change.[22]

Herman Miller. The office furniture maker Herman Miller has committed to using the cradle-to-cradle protocol[23] in the design of all future products. President and CEO Brian Walker has established a Design for Environment goal that by 2010, 50 percent of all sales of products must meet the cradle-to-cradle protocol goals of:

- eliminating very problematic materials.
- designing for disassembly.
- maximizing recycled content and recyclability.
- eliminating PVC plastic.

Ecology Center of Ann Arbor. In its report on sustainable plastics in the automotive sector, this environmental group defined environmentally sustainable plastics as:

- having no hazardous chemicals associated with the life cycle of the material.
- being capable of either a) closed-loop recycling (recycled into the same product) or b) degrading into healthy nutrients for the soil.
- being manufactured from renewable raw materials and energy (without the use of genetically modified organisms—GMOs).[24]

Setting goals often involves setting interim measurable objectives to achieve those goals. For example, Sweden set the following measurable objectives to achieve the goal of A Non-Toxic Environment:[25]

- "By 2010, data will be available on the properties of all deliberately manufactured or extracted chemical substances handled on the market."
- "By 2010, finished products will carry health and environmental information on any dangerous substances they contain."
- Phase-out substances of very high concern, including: carcinogens, mutagens, and reproductive toxicants by 2007; cadmium by 2010; and very persistent and very bioaccumulative organic substances by 2010.

In setting measurable objectives—or benchmarks—organizations define priorities for identifying safer alternatives. Metrics or indicators are critical to understanding whether certain options and activities move the organization towards its ultimate goals and provide a means of measuring progress.

Decision-making Rules

Decision-making rules are typically derived from the Guiding Principles and Goals and are implemented during the Assessment Processes and in the Evaluation Modules. Some decision-making rules will be universal across Assessment Processes, while others will be specific to certain cases. Examples of decision-making rules include:

- Treat all chemicals lacking data as if they were chemicals of moderately high concern.
- Prefer solutions that eliminate the function of a problematic chemical, material, or product.
- Prefer methods that present disaggregated data. Such methods would present data across evaluation categories or hazards in their actual value terms—rather than creating a single number to compare across options—allowing a more transparent evaluation of trade-offs between options.
- Accept hazard assessment data as sufficient for determining whether to avoid a chemical.
- Avoid alternatives that are the direct source of persistent, bioaccumulative toxics (PBTs) across their lifecycle.
- Brainstorm a wide range of alternatives based on a detailed understanding of the function or service that the chemical, material, or product provides, the need it fills, and how that function can be achieved in a sustainable manner. Such an analysis should consider not only those alternatives that are available but those that may be on the horizon.
- When data are not available on chemical hazards, use modeling results from structural activity relationships in the short term, paired with a commitment from stakeholders, including chemical manufacturers, to develop additional data in the longer term.

Each organization needs to develop decision rules that provide the foundation for first narrowing the range of alternatives to be compared and then evaluating those alternatives.

ALTERNATIVES ASSESSMENT PROCESSES

The Lowell Center's Alternatives Assessment Framework has been designed to assist both in the selection and in the design of chemicals and technologies. The process used to evaluate alternatives will vary depending upon whether the assessment begins as a comparison of existing alternatives— "the Comparative Assessment Process"—or begins from the design of a new technology—"the Design Assessment Process." Figure 4 illustrates the stages of these two alternatives assessment processes.

THE COMPARATIVE ASSESSMENT PROCESS

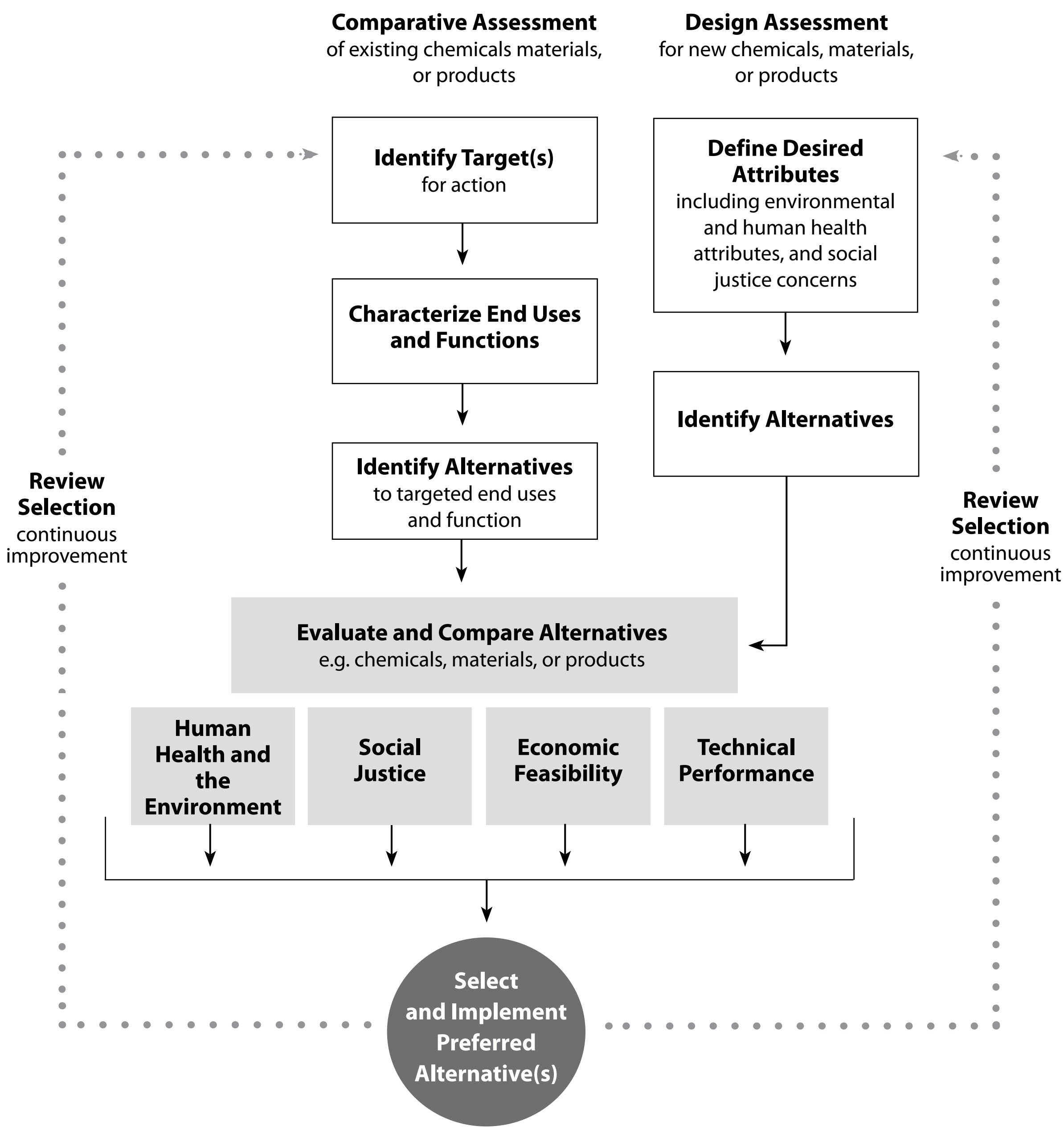
The Comparative Assessment Process involves six steps:

1) Identify Target(s) for Action
2) Characterize and Prioritize End Uses
3) Identify Alternatives
4) Evaluate and Compare Alternatives
5) Select Preferred Alternative(s)
6) Review Selection

The first step, **Identify Targets for Action**, can be a chemical, material, product, system, production process, or function. Of particular interest to the Lowell Center are assessments that begin with chemicals as targets for action—e.g., trichloroethylene—and then seek out safer alternatives that may include alternative chemistries, production processes, or product re-design. Chemicals as initial targets for action are of particular interest because there is increasing professional and public interest in performing comparative assessments of alternatives to hazardous chemicals—especially persistent, bioaccumulative, and toxic chemicals.[26]

The second step is **Characterize and Prioritize End Uses and/or Functions** of the technology for assessment. Often a particular chemical or material may be used in many end uses. For example, the primary end use and function of di-2-ethylhexyl phthalate (DEHP) is as a plasticizer (softening

Figure 4 Alternatives Assessment Processes



agent) for polyvinyl chloride (PVC) plastic. In this stage the user should understand the function of the chemical and how it flows through a facility or product supply chain.

Because most analyses cannot address every end use, specific end uses of high interest need to be prioritized for assessment. While a chemical such as DEHP may have hundreds of end uses, a single or a small number of end uses may constitute up to 80 percent or more of the total chemical use. In the case of DEHP, plasticizer use in PVC accounts for 90 percent of its end uses.

The third step is **Identify Alternatives** to the priority end uses that are on the market or in development (also referred to as "on the horizon"). This may involve a broad market survey and literature review as well as interviews with appropriate experts who have a broad perspective. To achieve the greatest environmental and social improvement, it is important to view a wide range of alternatives. For instance, alternatives need to be considered that include: drop-in replacements, eliminating the function or need entirely, changing systems, and replacing products with services. Alternatives that are not yet readily available but may be available in the foreseeable future (or have technical or cost issues) should not be eliminated at this point.

The fourth step, **Evaluate and Compare Alternatives**, is the most complex and challenging part of the Alternatives Assessment Framework. The Framework is designed to encourage the selection and use of a series of different "evaluation modules" that can be used to compare alternatives. These include modules for evaluating and comparing human health and the environment impacts, social justice impacts, economic feasibility, and technical performance. These are described below in Section 3.

It is here that the creation of an open source system for filling in the necessary methods, tools, and databases is critical. In Figure 4, the "Evaluate and Compare Alternatives" box—as well as the specific evaluation factors below it—are shaded to emphasize that further module development needs to be done in each of these areas. Especially challenging is defining the criteria for comparing chemicals, materials, or products across multiple attributes (toxicity, biological degradation, eutrophication, global warming, etc.) and across lifecycles. Also challenging is the development of economic analysis tools that do not discourage longer term investments in safer materials by focusing primarily on short-term costs.

In the fifth step, the decision maker will **Select Preferred Alternative(s)**. The preferred solution may be a single technology or there may be multiple acceptable technologies. For example, there may be many preferred options to the use of DEHP as a plasticizer in PVC plastics.

In selecting the preferred alternative, decision makers often need to prioritize among attributes. This is because there are few cases when an alternative is superior for all attributes: technical, social, economic, and environmental performance.

There is no generally agreed on way to compare technical, health and safety, and economic trade-offs. However, companies and public institutions use a variety of approaches to integrate environmental and/or social performance attributes into their selection of chemicals, materials, and products. Most large organizations have established procedures for comparing products based on economic and technical performance. In many cases, these procedures prioritize technical performance and sometimes cost above other considerations.

Such comparisons will likely involve qualitative and/or quantitative comparisons. An example of a quantitative comparison is to assign each performance attribute a ranking (e.g., on a scale of 1-4) and assign a weight to each attribute depending on its importance to the organization. Each alternative receives a total numeric score that allows cross comparisons. Another way may be a +/- or pro/con system. A hybrid of these as well as group/stakeholder deliberations may be the best approach.

Approaches to integrating environmental and social attributes into alternative selection processes include:

- using the evaluation modules discussed below to assess both social and environmental attributes.
- creating summary tables from the evaluation modules to support the selection process (see for example, the US EPA's Cleaner Technologies Substitute Assessment selection chapter).[27]
- inserting additional line items for environmental/social attributes into the organization's existing matrix for alternatives selection.
- using environmental/social attributes as "pre-screens" for alternatives. "Pre-screens" means the alternative must meet certain threshold(s) of environmental/social attributes to even be considered as a viable alternative.
- designing an iterative comparison and selection process whereby all attributes are optimized over time. In this approach, while trade-offs among attributes are accepted in the present, the goal is to optimize all performance attributes (environment, social, economic, and technical) over time. In this process the decision may mean selecting a firm which has the less preferred product today because it is more likely to produce the most optimal product for all attributes tomorrow. In this approach organizations are building continuous improvement and innovative capacity of product manufacturers into the selection process.

In many cases firms are using a combination of these approaches depending on the product in question, their goals, and their approaches to selecting products. In all cases, the selection process should include an implementation planning process, whereby details of process and product changes, research needs, communications needs, investments, training, and other administrative and organizational changes needed to implement the selected alternative as well as timelines and processes are clearly outlined. This step should include a discussion of the stakeholders within and outside of the firm or agency that should be involved in the implementation process.

The final step, **Review Selection**, reflects the fact that no technology—be it a chemical, material, or product—is typically perfect in terms of environment and social acceptability. Over time, specific chemical, material, and product selections will need to be re-visited and re-evaluated based upon emerging science and changing social expectations. Alternatives assessment is part of the journey towards sustainable technologies, and as such, will always be an iterative process.

THE DESIGN ASSESSMENT PROCESS

The **Design Assessment Process** differs from the Comparative Assessment Process because it begins with the intention to develop new chemicals, materials, products, or systems. This evaluation focuses on the positive attributes that designers want rather than selecting among options that are currently available on the market. The Design Assessment Process involves five steps:

1) Define Desired Attributes
2) Identify Alternatives
3) Evaluate and Compare Alternatives
4) Select Preferred Alternative(s)
5) Review Selection

The first step in the Design Assessment Process is to **Define Desired Attributes** that are wanted in the physical matter being designed, be it a chemical, material, product, or system. Examples include: the 12 Principles of Green Chemistry;[28] the 12 Principles of Green Engineering;[29] materials/products that can either be closed loop recycled or composted at the end of their use life; products that are durable, easily repaired/upgraded, or disassembled; and products/materials with high recycled content.

An important consideration in this step is consideration of necessity. Products are frequently designed without considering their necessity for society (whether they provide a benefit or fulfill an important human need) and whether the potential risks associated with the manufacture of that product should be incurred by society. An example is the use of antimicrobials in handsoaps, where research has indicated that they may not provide added protection over normal soap and water, but may actually contribute to antimicrobial resistance when widely distributed in the environment.[31] Another example is the use of mercury switches in children's disposable cereal box toys. The toys are not necessary for meeting an important human need but yet may contribute to mercury contamination and waste problems.

In the second step, **Identify Alternatives**, alternatives are identified that meet the desired attributes. The final three steps—Evaluate and Compare Alternatives and Select Preferred Alternative(s)—are the same as in the Comparative Assessment Process.

EVALUATION MODULES

The comparison of alternative solutions is a critical component of the Alternatives Assessment Framework. Further development of the Framework will require creating new and refining existing modules that facilitate the evaluation and comparison of alternatives. These modules will be combinations of methods, tools, and databases.

We use the "module" concept to emphasize that the components of alternatives assessments need to be designed to allow for flexibility, adaptability, appropriate use, and continuous improvement. We want modules that users can plug in to meet their specific needs.

While there may be other areas of interest in evaluating alternatives, the Lowell Center Alternatives Assessment Framework identifies the need for evaluation modules in four areas:

- Impacts on human health and the environment
- Social justice impacts
- Technical performance
- Economic feasibility

This section differs from the preceding sections in that it outlines a sketch of possible directions for action rather than a proposed set of actions because at this moment in time there are no clear choices as to which methods and tools are most appropriate (for given applications) for each of the evaluation modules. This is especially true for the Human Health and the Environment module and the Social Justice module, where methods and tools are more novel and less widely used than the methods/tools available for evaluating Technical Performance and Economic Feasibility. We emphasize the open source nature of this framework because we recognize that significant research and development is needed to create the tools needed for performing comprehensive Human Health and the Environment and Social Justice evaluations.

Human Health and the Environment

No dominant method has emerged for evaluating and comparing chemical or material hazards. Rather there are many assessment methods and tools that are available for defining and comparing the hazards associated with chemicals including:

- The "Evaluation Matrix" developed for the German Federal Environmental Agency.
- "Quick Scan" developed by The Netherlands.
- "PRIO" developed by the Swedish Chemicals Inspectorate (KemI).
- "The Column Model" developed by the German Institute for Occupational Safety (BIA).
- The "Pollution Prevention Options Analysis System" (P2OASys) developed by the Massachusetts Toxics Use Reduction Institute.
- The "Cradle to Cradle Design Protocol" developed by McDonough Braungart Design Chemistry (MBDC). The MBDC Cradle to Cradle Design Protocol also encompasses material and product assessment.
- The "Chemicals Assessment and Ranking System (CARS) designed by the Zero Waste Alliance.
- The "P2 Framework Models" developed by the US Environmental Protection Agency, which includes "EPI Suite," ECOSAR Aquatic Toxicity," "OncoLogic," and the "PBT Profiler."
- The Cleaner Technologies Substitutes Assessment (CTSA) method developed by the US EPA DfE Program and the University of Tennessee Center for Clean Products and Clean Technologies.
- The US EPA's chemical alternatives assessment developed in *Furniture Flame Retardancy Partnership: Environmental Profiles of Chemical Flame-Retardant Alternatives for Low-Density Polyurethane Foam* (2005).
- The "GreenList" Process developed by the SC Johnson Company.

Some of these tools are proprietary—CARS, MBDC Protocol, and P2OASys—while others are publicly available.

A significant challenge to the evaluation of alternatives is that the hazards posed by many chemicals have never been comprehensively tested. The US Environmental Protection Agency's (US EPA) High Production Volume (HPV) Challenge Program is a start in the direction of compiling better test data on roughly 2,000 chemicals used or imported into the United States in quantities equal to or greater than one million pounds per year. In addition, the US EPA has developed a set of tools—the "P2 Framework Models"—for predicting the likely hazards of a chemical based upon structure activity relationships. These tools and the HPV data, while imperfect, represent an important step towards developing more comprehensive hazard data on chemicals.

For product assessment the dominant method is life cycle assessment or LCA. The strengths of LCA include that it is a well-defined method, applies a life cycle perspective to a defined functional unit, and can be quite effective in assessing attributes for which there is readily available and quantifiable data that can be translated into common units (e.g., climate change gases). The weaknesses of LCA include: lack of transparency (a single number answer can hide the values, assumptions inherent in the analysis and trade-offs between options), difficulty in establishing boundaries for analysis, orientation towards the hazards of pollutants rather than the hazards of chemicals in production (which fosters a pollution control rather pollution prevention mindset), generally poor handling of recycling issues, and significant costs.

The shortcomings of LCA highlight the need to clearly define the applications for which LCAs are most appropriate (e.g., evaluating impacts of energy use) and for developing methods that are better suited to evaluating hazards of chemicals, materials, and products.

Social Performance

Social performance assessments over the past 15 years have focused on corporate behavior. For example, the Global Reporting Initiative (GRI) has developed social (as well as economic and environmental) performance indicators for individual corporations. The social indicators encompass four broad areas of concern: a) labor practices and decent work; b) human rights; c) society; and d) product responsibility. "Labor practices and decent work" covers employment, labor/management relations, health and safety, training and education, and diversity and opportunity. "Human rights" covers strategy and management, non-discrimination, freedom of association and collective bargaining, child labor, forced and compulsory labor, disciplinary practices, security practices, and indigenous rights. "Society" covers community, bribery and corruption, political contributions, competition, and pricing. "Product responsibility" covers customer health and safety, products and services, advertising, and respect for privacy. [31]

Prior to the emergence of social performance indicators for corporations, the trend in social performance assessments in the material economy focused on technology assessments, especially of technological systems with broad societal significance like nuclear power.[32] These technology assessments focused on how technologies affect communities, social interactions, and political institutions. The current debates over the use of genetically modified organisms (GMOs) and nanotechnology follow in this tradition of broad technology assessment.

An important next task in the development of this Alternatives Assessment Framework is to develop a social justice module that builds from the work on social performance indictors and technology assessments and applies it to the assessment of alternative chemicals, materials, and products.

Technical Performance

Technical performance assessments are essential to ensuring that alternative solutions meet or exceed the performance of existing products. An alternative is not viable if it does not achieve this end. The depth of technical performance assessment needed will vary with the end user, the degree to which readily available and tested products are already on the market, and the availability of technical data. Exhaustive technical assessments are not needed or useful in every situation.

Market Assessments seek to determine if alternatives exist on the market. At the most basic level, the mere presence of an alternative on the market and in competition with the product, chemical, or material of concern for exactly the same end use can be sufficient to state that technically viable alternatives exist. For some government decisions, market assessments are sufficient for their needs.

Research and Development (R&D) Assessments assess the likelihood that a technically viable alternative is in the R&D pipeline. R&D assessments are similar to market assessments in that they seek to identify the availability of products, although in the R&D pipeline rather than already on the market. The need for R&D assessments emerges when alternatives to products of concern either do not exist on the market or exist but are unacceptable due to cost, technical performance, social justice impacts, or environmental/human health impacts.

Detailed Technical Assessments by Product End Users are often required to determine if the product meets the needs of the end user. As noted above, the need for exhaustive technical assessments will vary depending on market adoption of an alternative and the availability of relevant technical data. The US EPA in its performance assessment module (of the Cleaner Technologies Substitute Assessment methodology) developed a 17-step process for evaluating technical performance that consisted of: 1) developing a performance protocol for evaluating products (11 steps); 2) developing supplier and observer data sheets for collecting consistent data across suppliers and products; and 3) testing and comparing performance results (4 steps).[33]

Technical Assessments for Regulatory Decisions. What is the technical and environmental performance of alternatives for an entire industry sector? When writing regulations the US EPA performs exhaustive assessments of technologies that are available or in development for meeting specific environmental performance goals within an industry sector. For example, when developing water effluent regulations for the pulp and paper industry in the 1990s, the US EPA produced a 200 page report on the availability, technical performance, cost, and environmental performance of pollution prevention technologies for the pulp and paper industry.[34]

Economic Feasibility

The level of economic assessment needed for informing alternatives selection will vary with end users—including regulators, institutional/business, consumers, and technology change advocates (such as non-governmental organizations). Economic feasibility assessments are performed at a variety of levels, ranging from quick market assessments to detailed industry-wide cost/benefit analyses:

Market Assessment. Does the alternative exist on the market? At the most basic level the mere presence of a product on the market means it is economically viable for some segment(s) of the economy. The market viability of an alternative will range from niche premium markets to direct price competition with the product of concern.

Cost Assessment. How much does the alternative cost relative to the chemical, material, or product of concern? Cost assessments will range from direct price comparisons to life cycle cost assessments (also known as "environmental cost accounting" or "total cost accounting"). A direct price comparison assesses the economic viability of an alternative simply in terms of product price—more, less, or the same -- relative to the product of concern. Life cycle costing is a holistic assessment of the comparative cost of alternatives to products of concern, including: product price; operation, maintenance, and repair costs over the life of the product; cost of regulatory compliance, disposal and other potential liabilities; and the use of long-term financial indicators (e.g., net present value, internal rate of return, and profitability index). The US EPA promotes the development and use of environmental accounting tools through its Environmental Accounting Project and developed a module for performing cost assessments as part of its Cleaner Technologies Substitute Assessment methodology.[35]

Cost/Benefit Analysis. What are the costs and benefits of technology change (often defined in terms of regulatory compliance) for an entire industry sector? Regulatory agencies, especially environmental regulatory agencies like the US EPA, frequently perform detailed analyses of the costs of technology change to comply with a new regulation as well as the environmental benefits of implementing the regulation. The US EPA refers to these as "regulatory impact analyses." These cost/benefit analyses forecast industry-wide impacts for a handful of regulatory scenarios based upon the level of pollution allowed.

Compliance cost variables may include industry-wide (i.e., across an entire industry sector such as pulp and paper manufacturing) capital costs, operations and maintenance costs, annualized costs, plant closing, and job loss for each regulatory alternative. As an example, the monetized compliance benefits when the US EPA calculated the benefits of updated water effluent regulations for the pulp and paper industry included human cancer risk reductions, acute health benefits, agricultural benefits, aquatic health benefits, and avoided costs for sludge disposal. In the monetization of benefits, many benefits remain unquantified due to lack of data. For example in the case of the pulp and paper analysis the following benefits were not quantified: non-carcinogenic effects of exposure to hazardous air pollutants and water pollutants other than dioxin; chronic effects of exposure to volatile organic compounds; effects of exposure to sulfur emissions; as well as the many intangibles including benefits of in-stream uses like swimming; near-stream uses like picnicking and wildlife observation; aesthetic benefits of residing, working, or traveling near water; and intergenerational equity benefits.

Notes on Economic Assessments

A challenge in performing economic assessments is that the price of alternatives is not static. As demand grows and manufacturers achieve economies of scale, prices decline. Additionally, institutional consumers that purchase in large volumes receive volume purchasing discounts and can also drive firms to innovate—developing new price competitive products—to capture new market share. If a large institutional consumer has a strong interest in a particular alternative—for example detergents made without nonylphenol ethoxalates—they are likely to receive them at a reasonable cost if they can ensure a large and regular purchase. Similarly in the case of regulatory compliance, regulatory agency forecasts of cost compliance may often be inflated in comparison to actual costs of compliance as implementing firms innovate and suppliers drop the prices of their products.

Limitations of the cost-benefit analysis appear when the methods ignore the reality that the cost of replacing a high hazard chemical may serve as insurance against a company's brand being scandalized in the public because of the use of a hazardous chemical. In the auto industry some producers follow a "zero faults approach"—i.e., avoid chemical scandal—because the costs of tarnishing brand image are in the long term much higher than eliminating the use of the high hazardous chemical. Thus the choice between a cost-benefit analysis or a zero (chemical) faults approach is a strategic decision. It might be that in the long term the zero faults approach is more economically beneficial to a firm than a cost-benefit approach.

SUMMARY

The Lowell Center Alternatives Assessment Framework is an effort to bring the disparate elements of alternatives assessment efforts under a single open-source umbrella. Values, long-term vision and goals, toxicity concerns, and social justice impacts have often been ignored in current efforts to identify and compare safer alternatives. The Lowell Center Alternatives Asssessment Framework is an initial step at defining a comprehensive approach for creating more environmentally appropriate and socially just products.

The Lowell Center considers this publication of the Alternatives Assessment Framework a first edition. As an open source tool we encourage people in firms, organizations, and governments to use it, adapt it, and expand on it. The Lowell Center is following up this publication with projects to more fully develop several of the evaluation modules and to apply the Framework. As we begin to apply this framework and work with others, we hope to develop and deepen the approaches. We hope that as others use this or similar frameworks, they will share their expansions and alternations. At some future date, the Lowell Center will reissue this document, more fully developed by further experience.

ENDNOTES

1 The outcomes of that meeting as well as the background research that informs this Alternatives Assessment Framework can be found at: *http://chemicalspolicy.org/downloads/alternativesassessmentfinalreport_000.pdf*.
2 OSHA Hazard Communication Standard (HCS), Subpart Z, Toxic and Hazardous Substances, 29 CFR 1910.1200, Section "c", "Definitions."
3 Organisation for Economic Co-operation and Development (OECD), 2003, *Descriptions of selected key generic terms used in chemical hazard/risk assessment* (Paris: OECD).
4 G&C Merriam Company, 1976, *Webster's Third New International Dictionary* (Springfield, MA: G&C Merriam Company).
5 Ibid.
6 Op cit., OECD, 2003.
7 For example, see the definition of "substitution" in: J. Lohse, et al., 2003, *Substitution of hazardous chemicals in products and processes*, compiled by Ökopol GmbH and Kooperationsstelle Hamburg for the European Union Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities (Hamburg: Ökopol GmbH), p. i.
8 See J. Tickner and K. Geiser, 2004, The precautionary principle – stimulus for solutions and alternatives-based environmental policy. *Environmental Impact Assessment Reviews*. Vol. 24. pp. 801-824.
9 Mary O'Brien, 2000, *Making better environmental decisions: an alternative to risk assessment* (Cambridge: MIT Press).
10 "Environmental" is broadly construed here to include human health and the natural environment.
11 "Products" includes both tangible goods as well as services.
12 This section is excerpted in part from M. Rossi, J. Tickner, and S. Edwards, 2004, "Setting the context for the Lowell workshop on designing safer alternatives: chemicals, materials + products" (Lowell: Lowell Center for Sustainable Production).
13 Examples of chemicals as product include: intermediates, process aids (e.g., chlorinated solvents in degreasing), disinfectants, cleaning products, etc. In such instances, chemicals are considered either singly or often as a mixture of chemicals.
14 Industrial hygiene hierarchy of controls: substitute to reduce or eliminate exposure, engineering controls (e.g., ventilation), and personal protection controls (e.g., goggles or masks).
15 Waste management hierarchy: prevent, reuse, recycle, incinerate, and landfill.
16 Adapted from the definition of "toxics use reduction" as defined by the Massachusetts Toxics Use Reduction Act of 1987.
17 Adapted from Wingspread Statement on Precautionary Principle (January 25, 1998); see C. Raffensperger and J. Tickner (eds.), 1999, *Protecting public health and the environment: Implementing the precautionary principle* (Washington, DC: Island Press), Appendix A.
18 J. Lohse, et al., 2003, *Substitution of hazardous chemicals in products and processes*, compiled by Ökopol GmbH and Kooperationsstelle Hamburg for the European Union Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities (Hamburg: Ökopol GmbH).
19 See for example: J.A. Todd and M.A. Curran (eds.), 1999, *Streamlined life-cycle assessment: a final report from the SETAC North America streamlined LCA workgroup* (Pensacola: SETAC).
20 Swedish Environmental Objectives Council, 2004, *Sweden's environmental objectives—a shared respon-sibility* (Bromma, Sweden: Swedish Environmental Protection Agency), p. 6. See also, www.miljomas.nu/english/english.php
21 Ibid, p. 10.
22 Ibid, p. 9.
23 Developed by McDonough Braungart Design Chemistry (MBDC).
24 The Ecology Center, 2005, *Moving towards sustainable plastics: a report card on the six leading automakers* (Ann Arbor: The Ecology Center).
25 Quoted bullets are from Chapter 4 in: Swedish Environmental Objectives Council, 2004, *Sweden's environmental objectives are we getting there?* (Bromma, Sweden: Swedish Environmental Protection Agency).
26 See "Defining the Terrain of Chemicals, Materials, and Products" section of the Introduction for further details on the distinction between chemicals, materials, and products.
27 Source: *http://www.epa.gov/dfe/pubs/tools/ctsa/ch10/ch10.htm*.
28 P. Anastas and J. Warner, 1998, *Green chemistry: theory and practice* (New York: Oxford University Press).
29 P.T. Anastas and J.B. Zimmerman, 2003, 12 principles of green engineering, *Environmental Science and Technology*, 37 (3): 94A-101A.
30 Levy, S. B. 2001. Antibacterial Household Products: Cause for Concern. Emerging Infectious Diseases 7(3, Supplement): 512-515
31 Global Reporting Initiative (GRI), 2002, *Sustainability reporting guidelines*, *http://www.globalreporting.org/guidelines/2002/GRI_guidelines_print.pdf.*
32 For example, see Langdon Winner, 1986, *The whale and the reactor: a search for limits in an age of high technology* (Chicago: The University of Chicago Press).
33 See US EPA Cleaner Technologies Substitute Assessment performance assess module at *http://www.epa.gov/dfe/pubs/tools/ctsa/ch7/mod7-2.pdf*
34 US EPA, Office of Pollution Prevention and Toxics, 1993, *Pollution prevention technologies for the bleached kraft segment of the U.S. pulp and paper industry* (EPA/600/R-93/110).
35 For environmental accounting see *http://www.epa.gov/opptintr/acctg/resources.htm* and for the US EPA Cleaner Technologies Substitute Assessment cost analysis module see *http://www.epa.gov/dfe/pubs/tools/ctsa/ch7/mod7-3.pdf*.

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Alternatives Assessment Framework
of the Lowell Center for Sustainable Production

The Lowell Center for Sustainable Production uses rigorous science, collaborative research, and innovative strategies to promote communities, workplaces, and products that are healthy, humane, and respectful of natural systems. The Lowell Center is composed of faculty, staff, and graduate students at the University of Massachusetts Lowell who work collaboratively with citizen groups, workers, businesses, institutions, and government agencies to build healthy work environments, thriving communities, and viable businesses that support a more sustainable world.

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