# Guidelines for the Creation of a Program for Type III Environmental Declarations in the United States

by
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**Abstract**

There currently exists a demand in the United States for information about the environmental impacts of consumer products, but there is no consistent system for providing this information. This project proposes guidelines for the creation of a Type III environmental declaration program which will provide objective information about the environmental impacts of products based on life cycle assessment (LCA) methods.

To more easily convey complicated information to consumers, the use of an original data presentation format, the "radar area graph", was selected based on the results of a consumer survey. Because printed labels do not allow convenient product comparisons, a model internet website was created to demonstrate the potential of interactive product data. One original recommendation is an interactive personal database that allows consumers to track the impacts of their activities, thus making data more interesting and useful to consumers.

Because evaluating products using LCA can be time consuming, we created a method of efficiently and consistently calculating environmental impacts. It includes guidelines for defining system boundaries and functional units, and for characterizing environmental impacts. Ten environmental impact category indicators were selected, and original methods were developed for characterizing land use and water depletion using spatial data. A spreadsheet calculator was created for determining human and ecological toxicity indicators. Finally, original software was developed to demonstrate the proposal for a common database of process and material parameters.

To guide an administrator during the creation of a new Type III program, recommendations are provided for organizational structure, product registration procedures, and budget management for continued operation and growth.

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**Acronyms**

| | |
|---|---|
| BSP | Biodiversity Support Program |
| DfE | Design for Environment |
| EDIP | Environmental Design of Industrial Products |
| EPD | Environmental Product Declarations. |
| EU | European Union |
| EWG | Environmental Working Group |
| GIS | Geographic Information Systems |
| FAO | Food and Agriculture Organization |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| JEA | Japan Environment Association |
| JEMAI | Japan Environmental Management Association for Industry |
| KOECO | Korea Eco-Products Institute |
| LCA | Life Cycle Assessment |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Assessment |
| PCR | Product Category Rules |
| RFID | Radio Frequency Identification |
| RHU | Regional Habitat Unit |
| SETAC | Society of Environmental Toxicology and Chemistry |
| TRI | Toxics Release Inventory |
| UNEP | United Nations Environment Program |
| UPC | Universal Product Code |
| U.S. EPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |

## Executive Summary

### The need for Type III environmental declarations

Within the past two decades, consumers around the world have seen a dramatic increase in the number of claims that producers make about the environmental attributes of their products. While this information may be required by law in some cases, in the U.S. it is almost always offered voluntarily. This provides evidence that producers believe that there is a demand for products that are less harmful to the environment. The term "ecolabel" has been widely adopted to describe these claims that commonly appear on product packaging in the form of a symbol or text description. However, the use of this word is misleading when used to describe environmental information in general, since it implies that only printed package labels are included. This report will use the term "environmental declaration" as defined by the International Organization for Standardization (ISO) to refer to a claim which indicates the environmental aspects of a product or service. ISO has identified three general types of voluntary environmental declarations:

- *Type I* declarations are based upon multiple criteria and are awarded by a third party to indicate the overall environmental preferability of a product within a product category using life cycle considerations (ISO 14024).
- *Type II* declarations contain informative environmental self-declaration claims (ISO 14021).
- *Type III* declarations provide quantified environmental data based on life cycle assessment (LCA) using categories set by a qualified third party and verified by that or another qualified third party (ISO/TR 14025) . The goal of Type III environmental declaration is to provide the opportunities to give a quantitative and verified description of the environmental products and services based on a comprehensive life cycle perspective.

According to the Consumers Union, there are 72 third party organizations offering different environmental certifications in the U.S. Some of these are well-known and respected, such as the USDA Organic or Forest Stewardship Council (FSC) certifications. But the remaining certifying organizations are unfamiliar to consumers, and very little information is conveyed by their on-package logos. Furthermore, although organizations such as Green Seal are committed to ISO's principles of presenting verifiable, relevant information in a transparent way, the content of many of these claims is of questionable quality. The prevalence of self-declared producer claims only increases the confusion felt by customers. Some of these claims, such as ones that specify the percent and origin of recycled content, are somewhat meaningful and qualify as legitimate ISO Type II declarations. But most general claims either lack sufficient information to be meaningful, or are misleading. For example, the claims "non-toxic," "biodegradable," and "environmentally friendly" are too unclear to be useful for consumers when made without additional explanation. While the expanding number of environmental declarations in the U.S. reflects the desire of producers to attract consumers who wish to reduce the environmental impacts of their purchases, most of these declarations have done little but add to consumers' confusion and skepticism.

In the U.S., consumers lack access to the type of information that is becoming available in other countries, since no third party-certified declarations are currently available that consider the full range of a product's environmental impacts. Relying on existing organizations to provide this information, such as Green Seal, is not feasible since it is not their mission to provide comprehensive data to general consumers. Therefore, although it may seem counterproductive to the goal of reducing confusion caused in part by the excessive number of declaration programs, the establishment of a new program is required to fill the gap in information.

Any new program, even one that adheres to ISO standards, will face the same difficulty in gaining consumer recognition and confidence. Successful Type I programs in other countries have benefited from the support of their respective national governments in building the level of consumer trust that allows them to recommend one product over all others. In the U.S., however, such government support is unlikely. Without an established, reputable body making product recommendations with a Type I declaration, a Type III declaration that provides only quantitative information has the greatest potential for gaining acceptance from consumers in the U.S.

The goal of this report is to provide recommendations for the creation of a Type III environmental declaration program that provides information consistently and objectively. This report is intended to act as a guide for a potential program administrator. It includes recommendations for measuring environmental characteristics of products, publishing declaration results, and setting up an organizational structure, product registration procedures, and budget management for continued operation and growth.

**Program administration for Type III declarations**

The three existing Type III environmental declaration programs in Korea, Sweden, and Japan can serve as an example in forming guidelines for a new program in the U.S. However, these existing programs are all administered with some degree of involvement from their respective national governments. In the U.S., a high level of governmental support for a Type III declaration program is unlikely. The national governments of Korea, Sweden, and Japan are more actively involved in promoting environmental awareness among consumers, and the relationship between government and industry tends to be more cooperative. In the U.S., a federal program promoting Type III declarations would likely face resistance from industry, even if the program were not mandatory. While it may be possible for an industry association to establish a program, the range of products covered would be limited.

> Key Recommendation : A comprehensive Type III environmental declaration program for the U.S. is most realistically administered by a private company.

Managing a Type III environmental declaration program with potentially hundreds of applicant companies and thousands of registered products requires a great deal of planning and coordination. The program administrator plays an important role in every stage of the registration process, from establishment of program methods to the publication of declaration results. The main activities that are primarily the responsibility of the program administrator:

- Establish methods for product evaluation
- Organize committees
- Establish Product Category Rules (PCR) with committees
- Create and maintain a database of LCA parameters
- Manage the verification process
- Control product registration status
- Manage an internet website to publicize environmental declarations
- Promote the program and educate consumers and applicants
- Cooperate with other Type III declaration programs

The administrative organization for Type III declarations is generally quite small, especially for new programs. Since the workload and range of expertise required to effectively manage a program exceeds the capacity of the direct staff, existing programs either delegate responsibility to the applicants, or rely on external support in the form of committees and contracted experts.

Committees are used by existing programs to provide expert opinion on product evaluation methods and to oversee key program tasks, such as approval of applications. In addition to reducing the workload of the administrator, the participation of outside parties through committees is one way to help eliminate bias and build the trust of users and potential applicant companies.

> Key Recommendation: In order to maintain objectivity in decision making, committees shall be composed of an equal number of representatives from industry, academia, and consumer interest groups.

The program administrator should follow clearly defined procedures when registering new environmental declarations. Requiring that all product applications undergo the same process for approval is important for consistency and helps gain the confidence of program participants and users of the declarations. Product category rules (PCR) are used by the existing Type III programs to ensure objectivity in the product evaluation process and comparability between environmental declarations. Although Type III declarations may allow consumers to compare products across different product categories, rules for collecting data and performing life cycle assessments must be defined separately for each product category.

In the existing Type III programs, the tasks of data collection and LCA calculation are performed by the applicant. Some program administrators make their own propriety software available to applicants, which include databases for the material and energy flows for common processes as well as characterization factors for calculating environmental indicators. The applicant first collects detailed product data, which is then entered into the software for automatically calculating the environmental impacts. Although the administrator has the additional responsibility of creating and maintaining a database, the effort required by companies to perform life cycle assessments is reduced, and the declaration results will be consistent with other product declarations.

> Key Recommendation: To ensure consistency and comparability between product declarations, the program administrator shall create and maintain a database of common process data and characterization factors for use in life cycle assessment.

> Key Recommendation: For a new Type III program, the database and software should be made available free-of-charge in order to encourage the participation of more companies.

Managing a budget is one of the most important tasks for the program's administrator. Existing programs collect revenue from product registration fees at the time of initial registration and from an annual registration renewal fee. The fees are based either on the size of the company, the net product sales, or the product price. In all cases, the product registration fees must be set low enough so that companies are not discouraged from participating, but not so low as to prevent the administrator from paying for fixed expenses such as database creation and the salary of staff, independent verifiers, and committees. For a new program, it is recommended that fees be biased towards higher verification and initial registration fees, and lower registration renewal fees, in order to offset the higher initial costs of program administration. As the program becomes more well-established, the fees can be shifted away from the verification and initial registration fee in order to build a larger database of product results. A universal fee for product registration is not recommended because it discourages the participation of small companies.

**Measuring environmental impacts**

Life cycle assessment (LCA) is a relatively new tool for assessing environmental performance. Although ISO requires that Type III declarations are based on LCA results, the methods for conducting assessments are continually evolving. Therefore, a Type III declaration program must clearly define the methods of LCA for product evaluation, and stay informed of developments in methodology that will improve the quality of LCA study results. ISO standards specify that the goal of an LCA study *shall unambiguously state the intended application, the reasons for carrying out the study and the intended audience.* For a new Type III declaration program, LCA results should not only provide information about the relative difference between two products, but should also help consumers gauge whether the environmental impacts of a product are significant or not, so that they can concentrate their limited time and fiscal resources on decisions with a greater environmental impact.

> Key Recommendation: Product life cycle assessments should generate information so that consumers and producers can make relative comparisons between products, as well understand the level of significance of the product's absolute environmental impact.

Life cycle assessments evaluate environmental impacts in terms of a "functional unit," which is based on a product's ability to perform a specified function. For example a functional unit for a bottle of laundry detergent might be defined as the recommended amount to wash 32 loads of laundry. This feature makes LCA a tool that is uniquely suited to the task of developing environmental product declarations, since it allows comparisons to be made at the product level, instead of more general comparisons of company policies. However, there is no single functional unit that can be applied across the entire range of consumer products. A single package functional unit may be appropriate for some product types, while other product types may require a serving-size or performance-based functional unit.

> Key Recommendation: As a general guideline, for products which have a clearly defined primary function, whose alternatives are products in the same product category, and whose product performance/ number of uses/ serving size are determined objectively and clearly conveyed to the consumer, the functional unit shall be in terms of performance/ number of uses/ serving size. For products which do not meet these requirements, the functional unit shall be expressed in package units.

The product evaluations conducted for a Type III program should include consideration of all life cycle stages, including production, transportation, use, and disposal. Analysis of these life cycle stages should account for all processes and flows related to a product, except for those associated with the transportation of the product by the end user from the point of sale, and those associated with accessory products required for the function of the evaluated product. However, it is still necessary to define boundaries for product analysis, partly because of the potential interaction between two different products, especially during their use phases. To allow for an accurate estimation of absolute environmental impacts for a combination of products, the product boundaries between the various products in a product system should neither overlap nor have gaps between them.

> Key Recommendation: When defining boundaries for the products in a product system, overlaps and gaps between the boundaries of the various products should be avoided.

Ideally, product-specific data would be available for every material and process along a product's entire production chain and through every stage of the product's life cycle. But requiring producers to collect this information would be unreasonable. Therefore, a boundary should be to define when it is acceptable to use generic data and when product specific data should be used.

> Key Recommendation: The use of product-specific data is generally preferable to non-product specific data. Additional effort to use specific data should be made when the material or process contributes significantly to a product's overall impact, or when the producer or consumer exercises a high degree of control over the use of a particular material or process.

During the impact assessment phase of LCA, the detailed data for resource use and emissions are assigned to environmental impact categories, and for each category, an indicator result is calculated. The selection of impact categories requires that subjective, values-based decisions be made. Decisions about the inclusion, exclusion, and aggregation of impact categories reflect not only one's understanding about the issues that threaten the environment, but also how one prioritizes the balance between the present and the future, between humans and wildlife, and between oneself and the world. The impact categories used by a Type III program should be determined considering the latest scientific understanding of environmental issues. Moreover, they should allow consumers to make decisions based on their personal values, if possible.

> Key Recommendation: Life cycle analysis results should be presented in terms of ten impact categories: Climate change, Acid rain, Eutrophication, Photochemical smog creation, Ozone depletion, Human toxicity, Ecotoxicity, Land use, Water depletion, and Non-renewable resource depletion.

**Data publication**

Making the results publicly available in a useful manner is critical to the success of an environmental declaration. To facilitate the inclusion of a large number of products, the program should only require the disclosure of information that many companies are willing to provide. The results should be published in a range of media and arranged in a format that can effectively summarize the product profiles to a large number of people. Certainly, in some cases, the interests of applicant companies are different from those of consumers and the program administrator. It is therefore critical that any program policies for data publication consider the needs of all parties involved.

Producers will be reluctant to share detailed product data with the program administrator in some cases, even if given assurance that the information will be kept confidential. The level of secrecy will vary for different companies and product categories, but it is expected to be of particular concern to companies that depend upon proprietary formulations (e.g, processed foods, personal care products, cleaners).

> Key Recommendation: The Product Category Rules (PCR) shall state the number of LCI items that can be withheld from submission to the administrator for that particular product category, to be replaced with category indicator results calculated by the applicant.

Some information should be provided by an applicant company with the assurance that it will be kept confidential by the program administrator:

- General product information, such as product content and structure
- Life cycle inventory (LCI) , as an itemized list of resource use and emissions
- The contribution of each LCI item to the total environmental impact for each category.

Other information should be provided by the applicant with the understanding that it may be published as part of the environmental declaration information:

- The total indicator results in terms the common unit of characterization for each category
- The total category indicator results for each life cycle stage after normalizing relative to an average individual's daily impacts
- The total normalized category indicator results for all life cycle stages
- Optional information, as agreed by the applicant and administrator.

An important goal of this program is to convey the product information to consumers in an easy to understand way. A variety of both graphical and numerical data presentation formats were considered, based on the basic criteria of: being easy to read, being compact, and explicitly describing the environmental impact

An example of the recommended graphical format for presenting product environmental declarations is shown in the figure below. This radar area format was selected based on the results of a survey that measured the ease and accuracy with which consumers could read various formats. Ten white, wedge-shaped segments are each shaded red in an area that is proportional to that category's environmental impact. The total segment area represents the average American individual's Total Daily Consumption Impact (TDCI) for that category, as indicated by the 100% label at the outermost grid circle. The red shaded area extends radially to a distance that is the square root of that shaded area. It represents the category percentage of the TDCI for this product.

When comparing products in-store, printed media is likely to remain a main source of information for consumers considering the convenience and immediacy of information provided by the format. However, the usefulness of printed media for environmental declarations is impaired by several obstacles, including:

- The printed area is too small to contain the necessary information.
- The distance between printed declarations is too great to allow for convenient product comparison.
- User-specific conditions, such as location of purchase, can not be easily included.
- Some program participants may choose not to print quantitative results directly on product packaging.

Still, printed information is a good way to gain wider recognition for a new program. In combination with web-based media, it should be employed to the greatest extent possible. Printed information can not be shown directly on small products (pencils) or products without packaging (vegetables). Even some large products, such as refrigerators and computers, are often displayed in the store without packaging. In these cases, printed information can only be displayed on a sign that is posted near the product. The size of the sign may vary depending on the type of product and retailer preference, but a 13 x 18 cm (5 x 7 in) card size would be generally acceptable. The product name should be prominently shown on the sign so that it is clear to the consumer to what the information is referring. The advantage of the on-shelf sign is its relatively large size that can be easily read without omitting detail and explanation. However, if the consumer wants to compare products that are not immediately adjacent to each other, they will need to remember the information from one sign as they walk to the other product's sign.

Producers should not be required to print any information on the product packaging. However, participants will be encouraged to publicize the fact that their product has undergone a life cycle assessment by an independent party. Ideally, this will be in the form of the radar area chart displayed as an on-product label. However, some participants may wish to advertise the fact that their product has been subject to a life cycle assessment, but do not want to show the results on the product packaging. This might be case when the product's environmental impacts are high relative to alternative products. Participating companies therefore should be given the choice to display a logo with only the program administrator's URL web address and a product identification number on the product packaging so that consumers can access the environmental declaration data using the internet.

The internet is an essential communication tool for any Type III environmental declaration program because it provides a single access point to the entire range of the program's publicized data, and it enables users to interact more actively with the data than printed labels. Even when environmental impact data is displayed as on-product labels, consumers may still have some difficulty making product comparisons. An interactive website can make comparisons easier by allowing the user to make side-by-side comparisons of products using either the radar area graph format or a numerical tabular data format.

One of the greatest benefits of a web-based data publication system is the flexibility it provides for users to interact with the data. If the administrator's website has a read/write database that allows registered users to access information that they have saved during a previous session, they might be able to estimate the total environmental impacts of their activities, or set preferences for how data is presented to them.

Key Recommendation: A program's website should allow users to aggregate the data from their purchases, and provide an estimate the total environmental impacts of their consumption activities.

# 1. INTRODUCTION – THE NEED FOR TYPE III ENVIRONMENTAL DECLARATIONS

## 1.1. ENVIRONMENTAL INFORMATION FOR CONSUMER PRODUCTS

### 1.1.1 Definition of an Environmental Declaration

Within the past two decades, consumers around the world have seen a dramatic increase in the number of claims that producers make about the environmental attributes of their products. While this information may be required by law in some cases, in the U.S. it is almost always offered voluntarily. This provides evidence that producers believe that there is a demand for products that are less harmful to the environment. The term "ecolabel" has been widely adopted to describe these claims that commonly appear on product packaging in the form of a symbol or text description. However, the use of this word is misleading when used to describe environmental information in general, since it implies that only printed package labels are included. This report will use the term "environmental declaration" as defined by the International Organization for Standardization (ISO) to refer to a *claim which indicates the environmental aspects of a product or service* [1]. ISO has identified three general types of voluntary environmental declarations whose characteristics are summarized in Table 1.1.

- *Type I* declarations are awarded by a third party to indicate, based upon multiple criteria, the overall environmental preferability of a product within a product category using life cycle considerations (ISO 14024).
- *Type II* declarations are informative self-declared environmental claims (ISO 14021).
- *Type III* declarations provide quantified environmental data with pre-set categories of parameters based on a life cycle assessment (LCA) that has been reviewed by a third party. (ISO/TR 14025) [2].

| | Type I (ISO14024) | Type II (ISO14021) | Type III (ISO14025) |
|---|---|---|---|
| Basic Characteristics | - Indicates overall environmental preferability within a product category<br>- Program administrator decides product categories and judgment standard<br>- Program administrator certifies product applications | - Self-declared claim by companies<br>- Describes an environmental attribute of a product in a way that is not misleading<br>-Not verified by a third party | - Quantified environmental data with preset impact category indicators<br>- Provides no final product judgment based on pass or fail criteria<br>- Judgment is left to consumers |
| Administrator | Independent third party | Product manufacturer | Independent third party |
| Participation of interested parties (consumer,NGO...) | Possible | Low possibility | Possible |
| Prevalence worldwide | Relatively high | High | Low |
| Comparability | High because it is determined based on category average | Low because criteria may vary between companies | - High if data is presented relative to a category average<br>- Medium if data is not presented relative to an average; depends on registration of other products |
| Readability | Easy | Easy | Difficult because it requires some environmental knowledge |
| Certification of contents | Certified by a third party | Certified by manufacturers | Certified by a third party |
| International mutual certification | Under development | Under development | Under development |
| Judgment for pass or fail | Yes | Yes | No |
| Presents Quantitative environmental information | No | No (depends on manufacturer) | Yes |
| Environmental attributes considered | Only attributes identified as important by the administrator for that category | Any attribute selected by the manufacturer | Total impacts of product life cycle in pre-set indicator categories common for all product types |

**Table 1.1** Characteristics of ISO Type I,II, and III declarations
[3] [4]

### 1.1.2 Environmental Declaration Trends Worldwide

The growth in the use of environmental declarations can be linked to a growing global concern for environmental protection on the part of governments, businesses, and the public. As companies have come to recognize that these environmental concerns may provide an opportunity to gain a market advantage, various claims about environmental characteristics have been added to products and services in the marketplace. This attempt to present products as being environmentally-friendly has resulted in an increase in the number of misleading claims as well[1] [5] It was in response to this trend that ISO began in 1999 to publish a series of standards for environmental declarations. In order to promote the communication of accurate product information that is not misleading, these standards outlined as general principles that environmental declarations:

- Be accurate, verifiable, relevant and not misleading.
- Not create unnecessary obstacles to international trade.
- Be based on scientific methodology that is sufficiently thorough and comprehensive to support the claim and that produces results that are accurate and reproducible.
- Be transparent, with the supporting procedures, methodologies, and any criteria made available and provided upon request to all interested parties. [1]

The establishment of these ISO standards has been met by an increase in the number of organizations around the world whose mission is to create and certify Type I and III declarations.[2] Some of the more well-known organizations are introduced in this section.

***Type I declarations***

A Type I environmental declaration is like a seal-of-approval because it indicates that a third party has certified that a product meets certain minimum requirements. When the term "ecolabel" is used, it is most commonly in reference to these declarations.

The first ecolabel program in the world was Germany's Blue Angel. Created in 1977 by the German government, the program currently has over 3,400 products registered from nearly 600 different companies [6]. The second oldest program, Japan's Eco Mark, was established in 1989 by the Japan Environment Association (JEA), a non-governmental organization under the guidance of the Ministry of the Environment. In 2005, Eco Mark had over actively 4,800 registered products [6]. In the U.S., the only Type I declaration program is Green Seal, an independent non-profit organization that began certifying products in 1992. Because Green Seal has focused its efforts on providing information for Federal government purchasing, it is less well-recognized by general consumers than its counterparts in Germany and Japan. In 2006, 492 products were actively registered by Green Seal [7].

**Figure 1.1** Logos of existing Type I declaration programs

[1] In the early 1990's as environmental claims were coming into widespread use, one marketing study found that approximately 50 percent of environmental advertising was deceptive or misleading.

[2] Type II declarations are not covered by third-party certification organizations, since, by definition, Type II are "self-declared". For this reason, this report does not assess Type II declarations.

From left to right; Green Seal (U.S.), Eco Mark (Japan), and Blue Angel (Germany)

Although there is no single program that applies Type I certifications internationally, the Global Ecolabelling Network (GEN) was established as a non-profit organization to promote the use and credibility of Type I declarations, and the development of global standards. Among the 26 member programs from around the world are the European Union's "Flower" program, the Korea Eco-Products Institute (KOECO), the Environmental Choice program in Canada, and the programs mentioned above[8].

> What about other certifications, like Energy Star?
> There are some third party certification systems that consider only a single environmental attribute of a product, or account for only one stage in a product's life cycle. For example, the Energy Star program of the U.S. Environmental Protection Agency's (EPA) considers only the energy consumed during the use phase of a product. Other programs, such as Japan's Eco Mark, have modified their product assessment methods in order to comply with the ISO 14024 standard. While single-attribute declarations may still be classified as Type I if the departure from the ISO standard is justified, this report only evaluates declarations that consider the full range of a product's environmental impacts.

### *Type III declarations*

Unlike Type I declarations, Type III declarations do not contain comparative assertions, but instead present quantified environmental data for products. Because the ISO definition[3] for Type III declarations is relatively new, and the product evaluation process involved is more comprehensive, this type of declaration is less common than Type I with only a few programs worldwide. To more broadly apply Type III declarations according to common standards, the Global Type III Environmental Product Declarations Network (GEDnet) was created in 1999 to assist member organizations in the development of their programs. GEDnet does not use the term "ecolabel", instead referring to Type III declarations as Environmental Product Declarations (EPD) which are intended to *provide easily accessible, quality assured and comparable information regarding the environmental performance of products and services*.[9]

Of the seven full member organizations of GEDnet, only three currently have active Type III environmental declaration programs. These are the Korea Eco-Products Institute (KOECO), The Swedish Environment Management Council, and the Japan Environmental Management Association for Industry (JEMAI). Organizations from China, the U.S., Australia, Germany, Denmark and Norway that may one day establish Type III declaration programs are also participating in GEDnet as associate members.

[3] In 2000, ISO issued a technical report, ISO/TR14025, which while not an international standard, provides information for Type III environmental declarations about which experts are in agreement. [Reference 034]


**Figure 1.2** Logos of existing Type III declaration programs
Top: EPD (Sweden), Bottom Left: Ecoleaf (Japan), Bottom Right: EDP (Korea)

Existing Type III programs do not require that detailed environmental information be displayed on the printed product label, although as shown in Figure 1.2, the Korean EDP program has a label format that allows this. Instead, the logos are designed to show that environmental information for a product information has been collected, has been certified by a third party, and is accessible via the internet.

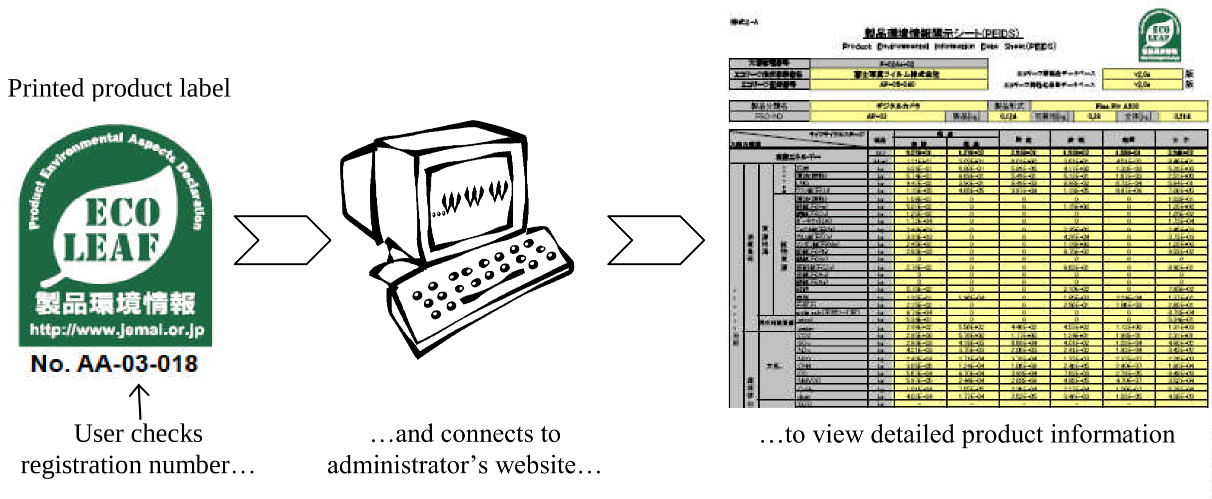


**Figure 1.3** Accessing product information for existing Type III declarations

## 1.2. A NEW TYPE III PROGRAM FOR THE U.S.

### 1.2.1 The Problem with Current Environmental Declarations

Apart from the members of GEN and GEDnet that strictly adhere to ISO guidelines for environmental declarations, there are many third party organizations currently certifying environmental claims.

According to the Consumers Union, there are 72 third party organizations offering 75 different environmental certifications in the U.S. [10] Some of these are well-known and respected, such as the USDA Organic or Forest Stewardship Council (FSC) certifications, and Green Seal is a member of GEN and therefore committed to following ISO standards. But the remaining certifying organizations are unfamiliar to consumers, and very little information is conveyed by their on-package logos. Furthermore, because most of these organizations do not attempt to follow ISO's principles of presenting verifiable, relevant information in a transparent way, the content of many of these claims is of questionable quality.

The prevalence of self-declared producer claims only increases the confusion felt by consumers. For non-certified, general claims, the Consumers Union lists 62 different claims used by manufacturers, [10] but the actual number is likely much higher than this. Some of these claims, such as ones that specify the percent and origin of recycled content, are somewhat meaningful and qualify as legitimate ISO Type II declarations. But most general claims either lack sufficient information to be meaningful, or are misleading. For example, the claims "non-toxic," "biodegradable," and "environmentally friendly" are too unclear to be useful for consumers when made without additional explanation.

While the expanding number of environmental declarations in the U.S. reflects the desire of producers to attract consumers who wish to reduce the environmental impacts of their purchases, most of these declarations have done little but add to consumers' confusion and skepticism.[4]

### 1.2.2 An Appropriate Environmental Declaration Program for the U.S.

In the U.S., consumers lack access to the information that is becoming available in other countries. There are currently no third party-certified declarations in the U.S. that consider the full range of a product's environmental impacts. Relying on existing organizations to provide this information, such as Green Seal, is not realistic, since it is not their mission to provide comprehensive data to general consumers. Therefore, although it may seem counterproductive to the goal of reducing confusion felt by consumers, the establishment of a new program is required to fill the gap in information.

Any new program, even one that adheres to ISO standards, will face the same difficulty in gaining consumer recognition and confidence. Successful Type I programs in other countries have benefited from the support of their respective national governments in building the level of consumer trust that allows them to recommend one product over all others. In the U.S., however, such government support is unlikely. Without an established, reputable body making product recommendations with a Type I declaration, a Type III declaration that provides only quantitative information has the greatest potential for gaining acceptance from consumers in the U.S.[4]

### 1.2.3 General Characteristics of Type III Declarations

In 2000, ISO issued a Type 2 technical report,[5] ISO/TR14025, which while not an international standard, provides information for Type III environmental declarations about which experts are in agreement [11]. The ISO technical report defines a Type III environmental declaration as:

[4] For more a detailed discussion about the reaction of consumers in the U.S. to existing environmental declarations, and their preferences for new declarations, refer to 5.2.2APPENDIX A. Presented there are the results of a survey in which we asked 100 customers if they recognized the logos, and understood the meaning of some major Type I declarations. Even among customers classified as the most "green", less than 4% knew the meaning of "Green Seal," "Marine Stewardship Council" and "Forest Stewardship Council" labels. Even for the most popular Type I labels, "Energy Star" and "USDA Organic", more than half of respondents misunderstood the meaning of the labels.

[5] A type 2 report (not be confused with a Type II declaration) is issued by ISO when *the subject is still under technical development or where for any reason there is the future but not immediate possibility of an agreement on an International Standard*.

*quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040[6] series of standards, but not excluding additional environmental information provided within a Type III environmental declaration program.*

In other words, Type III declarations present quantitative information for preset environmental impact categories based on standard life cycle assessment methods that consider all stages of a product's life cycle; including resource extraction, manufacturing, transportation, use, and disposal stages. Therefore, although they require that consumers have some knowledge of environmental issues, Type III declarations can describe environmental information in more detail than Type I declarations.

Table 1.1 summarizes the differences between the three types of environmental declarations. The basic principles of Type III declarations are:

- Objectivity
  Quantified environmental data with preset impact category indicators is based on scientifically accepted and valid methods of life cycle assessment (LCA). This quantitative analysis is more objective than the qualitative certification method used for Type I declarations.
- Non-selectiveness and neutrality
  There are no predetermined environmental performance levels that must be met. The evaluation of the product information is left to consumers.
- Comparability
  The information in the environmental declaration is collected and calculated using common rules. Due to the differences between product categories, data collection and life cycle assessment calculation methods that are unique for a category are defined as category rules.
- Credibility
  The environmental declarations are reviewed and verified by a third party, thus giving the LCA results more credibility than self-declared environmental claims characteristic of Type II declarations. [11]

***Benefits for the environment***

For all three types of environmental declarations defined by ISO, the stated overall goal is:

*through communication of verifiable and accurate information that is not misleading on environmental aspects of products and services, to encourage the demand for and supply of those products and services that cause less stress on the environment, thereby stimulating the potential for market-driven continuous environmental improvement.* [11]

Specifically for Type III declarations, this means promoting environmental improvement by providing quantitative information which allows users to evaluate the environmental characteristics of products. But in order to be judged truly successful, environmental declarations can not simply meet the ISO objective of encouraging products that *cause less stress on the environment*. It is difficult to argue that a declaration which encourages an overall increase in consumption is successful when it leads to greater total stress on the environment. However, it is nearly impossible to predict the potential of an environmental declaration to cause a reduction in environmental stress, in part because of the complexity

[6] The ISO 14040 series of standards outline methods for conducting life cycle assessments to evaluate the environmental impact of a product.

of the systems involved. In fact, even looking back on several decades of international experience with declarations, there are no known studies which quantify the actual environmental effects of these programs [12]. This is partly because even when environmental improvements are found, there are so many other factors involved that it is difficult to assign causality to the declaration itself. In fact, a U.S. Department of Agriculture (USDA) study concluded that the success of the Dolphin-Safe Tuna label in reducing inadvertent dolphin deaths was likely more a result of regulation and trade policies of the U.S. government than of the market demand generated by the label [13].

An effective environmental declaration should encourage a net reduction in stress on the environment. Type III declarations can achieve this net reduction in part by encouraging the market for environmentally preferable products, as Type I declarations do. But in addition, because the quantified information in Type III declarations can be compared across product categories, they have the potential to cause a shift in consumption patterns away from the product categories with more significant impacts.

*Reducing net stress on the environment by encouraging environmentally preferable products*

Any change in market demand brought about by environmental declarations has the potential to give producers an incentive to improve their products. Using the information provided by Type III environmental declarations, consumers can compare environmental characteristics and select the superior products. This provides companies with an incentive to use LCA methods to improve the environmental performance of their products, and announce the results to consumers. The left half of the feedback loop, shown conceptually in Figure 1.4, is critical to reducing the net environmental stress caused by consumption because if producers do not respond to demand by continually improving their products, the potential environmental improvements are very limited.

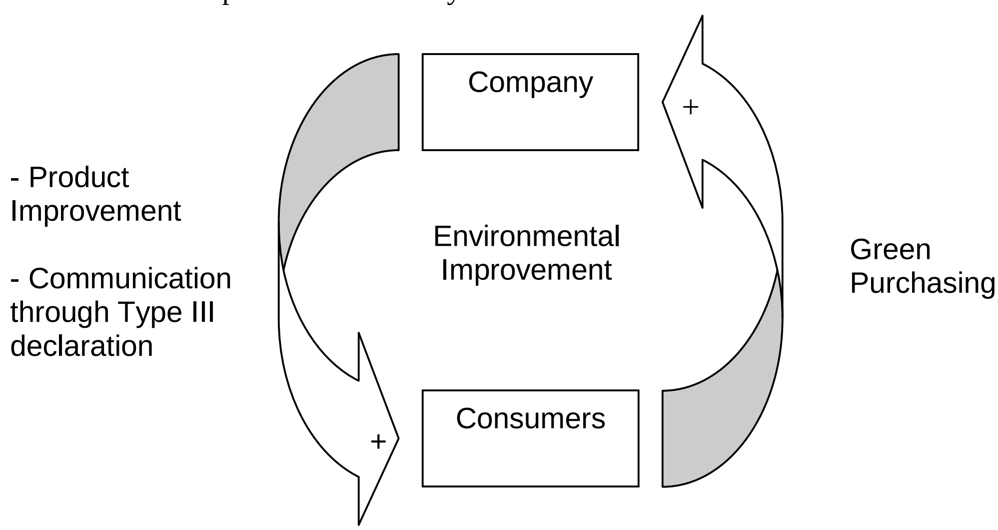


**Figure 1.4** Feedback loop for environmental improvement

*Reducing net stress on the environment by changing consumer behavior*

Even if Type III declarations are available only on a very limited number of products, the presence of any information can help to encourage a wider awareness of environmental issues. When presented with quantitative information, consumers may be introduced to previously unfamiliar concepts that compel them to consider the environment in their other activities.

Type III declarations might also help shift consumer behavior away from the consumption activities that cause the greatest environmental damage. Until now, life cycle assessments have been used primarily as a tool for optimizing production practices. More recently, some experts have identified the potential for LCA to promote efficient levels of consumption as well.[7] This is related to the unique potential of Type III declarations to facilitate comparisons between product categories. Although not stated by ISO as a goal, by presenting quantitative information about the total environmental impacts of a product, users can not only judge a product relative to other similar products, but also determine the significance of those impacts. This information can then be used by consumers who choose to shift their consumption patterns away from more harmful activities.

***Benefits for users of a Type III declaration***

The potential users of Type III include not only individual consumers, but also purchasers for companies and government agencies, non-governmental organizations, and investors. Each of these groups may have a different reason for researching a product's environmental impacts, but for all of these users, Type III declarations can provide information that is not available elsewhere.

*For supply chain management using DfE and EMS (company purchasers and product developers)*

Consideration of Type III environmental declarations can be integrated into the decisions made by a company's purchasing department and product developers, especially if the company uses an Environmental Management System (EMS) and Design for Environment (DfE) practices (see section 3.1.2 ALTERNATIVE TOOLS for more detail on EMS). Companies that use EMS/DfE may require their suppliers to meet performance levels in order to lessen the total environmental impact of the final product. EMS/DfE and Type III declarations are mutually reinforcing, since companies can use quantified environmental information in Type III declarations to reduce the environmental impacts of the supply chain. In turn, companies in the supply chain have an incentive to provide that information and demonstrate their superior performance [14]

*For considering environmental impacts in everyday decisions (individual consumers)*

Because of their personal concern about environmental issues, a number of consumers want to know the environmental impacts of a product when they are making a purchasing decision. A Type III environmental declaration can give consumers an idea about the significance of the environmental impacts, as well as the flexibility to judge products based on the impact indicators that are of greatest concern to them. Although not available through existing programs, when combined with internet technology, information from Type III declarations can be presented to consumers in a number of interesting ways. Among some of the possibilities discussed in more detail in section 4.3.2 WEB-BASED MEDIA are personal databases that track the cumulative environmental impacts of an individual's activities, and a customized presentation format that allows users to prioritize impact categories.

*For evaluating a company's policy regarding environmental issues (investors)*

The growth in the number of individuals interested in socially responsible investing has created a demand for environmental information as investment companies try to put together portfolios based on,

[7] Hertwich (2005) proposed that, in agreement with the goals of both sustainable production and consumption called for by the 2002 World Summit for Sustainable Development in Johannessberg, LCA methods be applied to promote efficient levels of consumption. [Reference 037]

among other things, the environmental performance of companies. Additionally, companies that closely track and publish environmental information about their operations and product designs are attractive to investors who are interested in a company's ability to apply energy efficiency and pollution prevention measures, engage in risk management, and improve the company image to increase shareholder value. In addition to corporate sustainability reports, a company's use of Type III environmental declarations may be used as a standard metric by investors who can learn the extent to which environmental issues are considered in a company's management.

***Incentives for producers to participate***

Companies also benefit from the use of Type III declarations in their marketing and production management, since it is one of the few tools to evaluate environmental impacts objectively. [15] Type III declarations can help participating companies:

*Through integration into an Environmental Management System*

One aspect of an Environmental Management System (EMS) is the consideration of environmental impacts in the entire range of a companies activities, including product design, supply chain management, institutional management and marketing. A growing number of companies are acquiring ISO 14001 certification for EMS, with over 90,000 certificates issued in 127 countries as of 2004 [16]. Because the the emphasize EMS places on supply chain management, companies may integrate the application of a Type III label into their management system criteria.

*To market environmental attributes to consumers*

The LCA method is a useful tool for companies that want to improve the environmental performance of product design and manufacturing process. Companies that apply for a Type III program can demonstrate to consumers that they have developed products with the consideration of environmental issues. This benefit can be realized even if there are too few participants in the same product category to allow product comparison. Companies can use the environmental declaration in their advertising, websites, or product labels in stores to attract consumers who want objective and reliable information.

*To simplify LCA practice*

If the program administrator provides a software database of LCA parameters, a company can more easily conduct evaluations of many products. Because administrators develop the database, manufacturers can conduct LCA at relatively low cost, and more easily find the appropriate data, even without detailed knowledge of LCA methods. Existing and developing Type III labels programs in the world are cooperating to develop a common database, as is described in section 2.2.1 ACTIVITIES PERFORMED BY THE PROGRAM ADMINISTRATOR.

*To comply with international regulations*

Especially for global companies, environmental assessment of products based on LCA is becoming increasing important. The European Union is developing environmental regulation about life cycle of products, such as the Waste Electrical and Electronic Equipment Directive (WEEE) [17] and the Restriction of Hazardous Substances Directive (RoHS) [18]. In April 2005, the EU adopted the Directive for eco design of energy using product (EuP). The EuP provides coherent EU-wide rules for eco-design and encourages manufacturers to design products with environmental impacts in mind throughout their entire life cycle for energy using products such as electrical and electronic devices or heating equipment [19]. Type I labels are regarded as compliant with the implementing measures now, but Type III environmental declarations may also be able to become standard in this program in the future.

In addition, to comply with the RoHS, companies must track the amount of toxic materials used in their supply chain. Manufacturers which export their products to EU may collect LCA data from sub-contractors or suppliers to demonstrate that the amount of material does not exceed limits set by the regulation. Other countries may implement similar regulations or voluntary standards. The companies which have experience with LCA and evaluating environmental impacts throughout their supply chain will gain an advantage by proactively complying with any new regulations. In this regulatory trend, Type III label can have advantage for procurement and manufacturing decision making.

*To improve and protect the overall company image*

Competitive environmental strategy of companies can enhance the marketability of products and services because more consumers prefer environmental friendly products are interested in environmentally responsible companies. Future business may consider three benefits [20] related to market growth of environmental performance expected of vendors and suppliers as well as customers.

1) *More Beneficial Supplier Relationship*
   *Corporate environmental professionals can work suppliers to reduce cost and risk and can apply contracts with other companies by implementing proactive environmental management systems. Environmental considerations become one more aspect of the value offered by a company.*
2) *Enhanced Environmental Attributes of Products*
   *Companies can appeal to environmentally conscious consumers by using recycled and recyclable materials, eliminating hazardous product constituents, and reducing adverse environmental effects of products and services.*
3) *Safeguarding of Corporate Image and Brand Names*
   *In many industries, environmental performance has become a lightning rod for public inquiry and consumer decision making. Word of environmental shortcomings travels fast through the press and other channels, influencing consumer performance, spurring boycotts, and in some cases affecting the bottom line. A solid environmental record enhances public perceptions of a company and can improve the marketability of its products and services.*

## 1.3. ABOUT THIS REPORT

### 1.3.1 Goals of this report

The goal of this report is to propose the consistent and objective Type III environmental declaration program in terms of an administration, methods to measure environmental characteristics of products, and data publication methods. The Type III environmental declaration of the proposed program will create a method which is both compact and comparable in a store. This program's environmental declaration describes a general summary of environmental indicators of a product on a printed label and shows more detailed LCA results on a website. This is similar to existing Type III declarations but different because even the printed label has more meaning than just describing evidence of certification. In addition, other presentation technologies are proposed.

Here, the ISO/TR14025 report will be referred to as an authoritative document on the subject of Type III environmental declarations. At the same time, it is recognized that the report is not a standard, and will undergo some revision before it is adopted as such.

Existing Type III environmental declaration programs (in Sweden, Japan, Korea) mostly target environmentally sound procurement (Business to Business; or BtoB). In some countries, governments require the public sector to purchase "green" products. Type III labels can be a standard for such green purchasing, and can be used for their procurement decision in the near future.

This program also targets individual consumers in their private purchases (Business to Consumer; or BtoC), although of existing Type III programs, only Japanese Ecoleaf tries to target BtoC. Type III labels require readers' knowledge to understand LCA results. Because existing Type III labels only describe the

LCA results as numeric information like inventory data, it is difficult for general consumers to understand the meaning. On the contrary, this program mainly presents the results of life cycle impact assessment (LCIA), which describes how each indicator has an impact on global and regional environments. In addition, this program presents the environmental impact in a graph which is designed for easy understanding. This is based on the original survey in Appendix A, and uses benchmarks for each environmental impact indicator, which is also described in Chapter 4. Therefore, even general consumers can intuitively comprehend environmental characteristics of products, and relatively easily compare environmental characteristics of products, although at the beginning of usage of the environmental declaration they can need to know the meanings of each indicator explained in the website. The design of the environmental declaration adopted this program is shown in Figure 1.5.

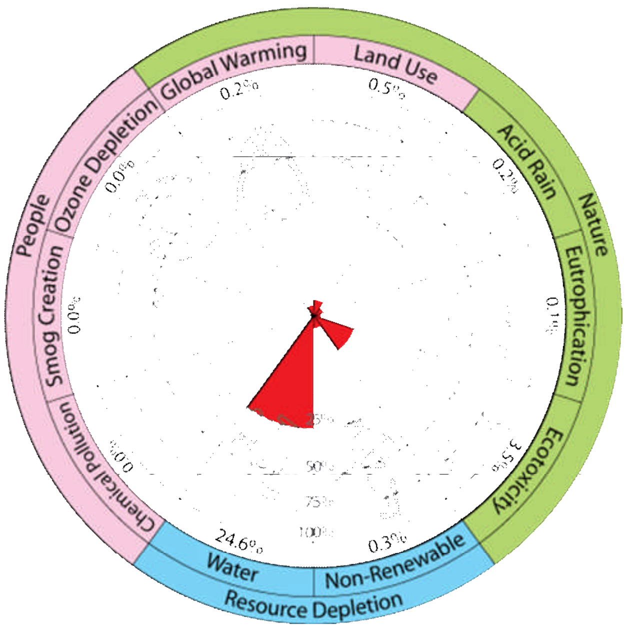


**Figure 1.5** Picture of the proposed program's environmental declaration

## 2. PROGRAM ADMINISTRATION FOR TYPE III DECLARATIONS

This chapter examines the administrative practices of three existing Type III environmental declaration programs in Korea, Sweden, and Japan. The organizational structures, procedures for registering declarations, and budget management for continued operation and growth are considered. Particular attention is given to the Japanese Ecoleaf program. Based on the analysis of these programs, recommendations for the establishment of a Type III declaration program in the U.S. are presented in the final section of this chapter.

### 2.1. RELATIONSHIP BETWEEN TYPE III PROGRAMS AND GOVERNMENT

The existing Type III declaration programs in Korea, Sweden, and Japan are all administered with some degree of involvement from their respective national governments. The Korea EDP program's administrative body, the Korea Eco-Products Institute (KOECO), was established by law to "support purchasing of eco-products". Although acting as a corporation, KOECO is overseen by the Ministry of Environment which manages the overall activities of the EDP program. (Figure 2.2) The Swedish EPD Type III environmental declaration program is managed by the Swedish Environmental Management Council (SEMCO), which is a company jointly owned by the national and local governments, and a confederation of private companies and administers. (Figure 2.3) And the Japanese Ecoleaf program is administered by the Japan Environmental Management Association for Industry (JEMAI), an association that was formed as part of a government initiative to reduce the environmental impacts from industry. (Figure 2.1)

In the U.S., this level of governmental support for a Type III declaration program is unlikely. The national governments of Korea, Sweden, and Japan are more actively involved in promoting environmental awareness among consumers, and the relationship between government and industry tends to be more cooperative. In the U.S., a federal program promoting Type III declarations would likely face resistance from industry, even if the program were not mandatory. While it may be possible for an industry association to establish a program, the range of products covered would be limited. Therefore, in the U.S., a comprehensive Type III environmental declaration program would most realistically be established by a private company.

> Key Recommendation : A comprehensive Type III environmental declaration program for the U.S. is most realistically administered by a private company.

| | Japanese Ecoleaf | Korea EDP | Swedish EPD |
|---|---|---|---|
| Legislation | None | The provision of the "Environmental technology supporting development act" regulates the program | None |
| Administration | Japan Environmental Management Association for Industry (JEMAI) (administration, certification, database creation, PCR management) | Ministry of Environment (overall management)<br>Korea Eco-Products Institute (KOECO) (daily administration)<br>Environmental Management Committee (certification)<br>Korea Environmental Protect Association (investigator education) | Swedish Environmental Management Council (SEMCO) ,(administration) Swedish Board for Accreditation and Conformity Assessment (certification of verifiers), private independent companies (data verification) |
| Government Involvement | Government-sponsored industry association | Financial support from national government<br>Conducts activities directed by the Ministry of Environment | National and local governments are council members |

**Table 2.1** Administration and legislation of existing Type III programs [22] [23] [21] [24]

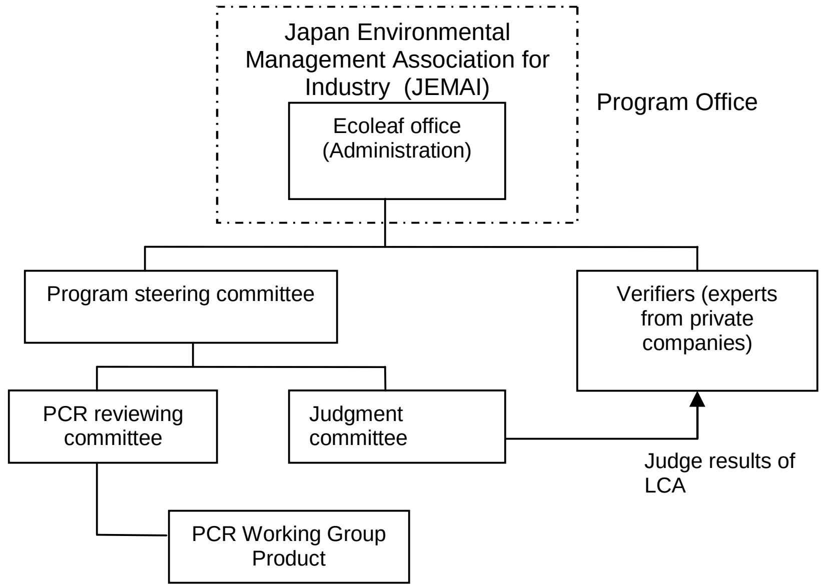


**Figure 2.1** Relationship of outside agencies to Ecoloeaf

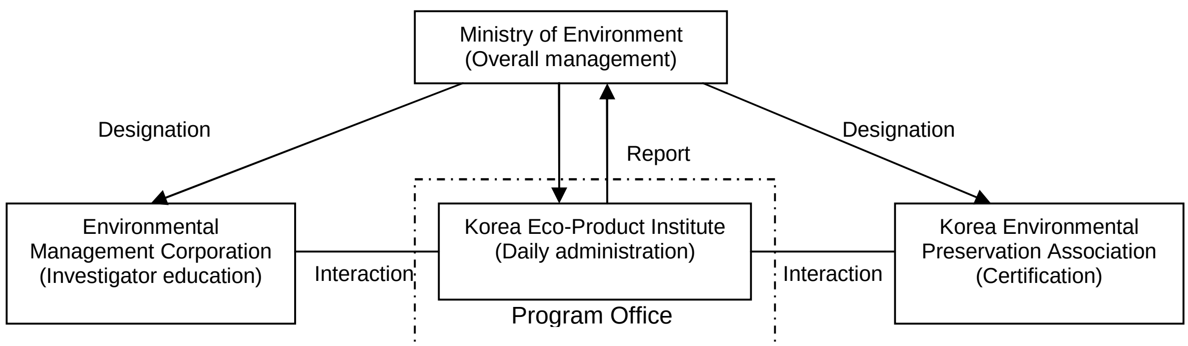


**Figure 2.2** Relationship of outside agencies to Korea EDP

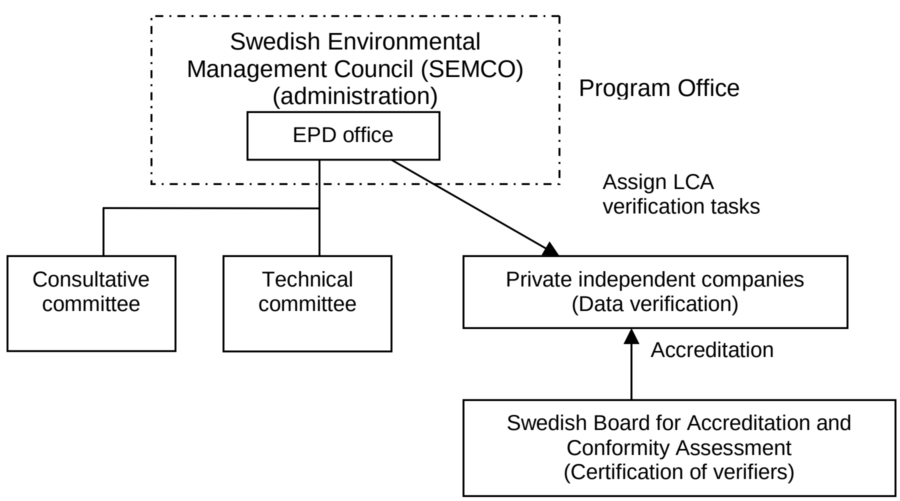


**Figure 2.3** Relationship of outside agencies to Swedish EPD

## 2.2. ROLES AND RESPONSIBILITIES OF THE PROGRAM ADMINISTRATOR

Managing a Type III environmental declaration program with potentially hundreds of applicant companies and thousands of registered products requires a great deal of planning and coordination. By clearly defining the responsibilities of each party involved, the work of registering product declarations can be accomplished efficiently, with better methodological consistency, and with less chance of duplication or omission of tasks. Although the delegation of some specific tasks might vary, the existing programs divide core work between the administrator and the applicant in generally the same way.

### 2.2.1 Activities Performed by the Program Administrator

The program administrator plays an important role in every stage of the registration process, from establishment of program methods to the publication of declaration results. The main activities that are primarily the responsibility of the program administrator are shown here.

1) Establish methods for product evaluation
   At the program inception, the administrator must define the methods for evaluating the environmental impacts of products (e.g. which scientific methods and environmental indicators will be used, etc.) and how the evaluation results will be presented. External experts can give advice during this process through participation in a "Program Establishment Committee".[8]

2) Organize committees
   Committees are an effective means of conducting an open, participatory consultation with interested parties as directed by the ISO technical report on Type III declarations, ISO/TR14025. The administrator has the responsibility of selecting committee members and contacting them as required to solicit their expertise and opinion. During the selection process, the administrator should act impartially in order to guarantee the objectivity of the program.

3) Establish Product Category Rules (PCR) with committees
   Having appropriate Product Category Rules is critical to guaranteeing comparability between products. The program administrator should establish and maintain the category rules using the input collected from interested parties through a dedicated PCR committee or means. In the case of the Ecoleaf program, the PCR committee is convened every two or three month after several proposals for new category rules are submitted.

4) Create and maintain a database of LCA parameters
   The life cycle assessment (LCA) calculations used for product evaluations employ characterization values and generic process parameters to convert emissions and resource flows into environmental impacts. Programs that require the use of specific parameters for methodological consistency must create and maintain a database of those values. This database should be frequently revised as product categories are added and more reliable data is published by others. The licenses for database use can be provided free-of-charge to applicants, or sold to offset the costs of creating the database.

5) Manage the verification process
   The results of the LCA conducted by applicant for product evaluation are reviewed by verifiers who are either contracted or directly employed by the administrator. The administrator must accredit

[8] This document is intended to act as a guide for a Program Establishment Committee to establish a Type III environmental declaration program for the U.S.

verifiers who have expertise in LCA methods and the program's database and software, and assign them to inspect the LCA results when a product is submitted for registration. The selection of verifiers should be impartial in order to maintain objectivity.

6) Control product registration status
The administrator has the authority to specify a trim period after which a product registration will expire. Only while a registration is active can companies refer to the environmental declaration information to promote a product. To control the registration status, the administrator must maintain the product data, keep companies informed of the status, and provide notice for periodic registration renewal.

7) Manage an internet website to publicize environmental declarations
The internet is an important tool for publicizing environmental declarations. Except for confidential information, relevant data for registered products should be accessible to interested parties. The administrator should update the website regularly to reflect the changing status and content of environmental declarations.

8) Promote the program and educate consumers and applicants
The potential to gain a market advantage is a primary incentive for participating companies. The administrator should try to strengthen this incentive by promoting consumer awareness of the program, and teaching consumers how to find and use the declaration data. Also, the administrator must instruct the staff of applicant companies how to conduct evaluations and register their products. For example, the administrator may participate in symposiums in order to advertise the program to both consumers and companies, and conduct seminars periodically for new program applicants. Particular attention should be paid at the beginning of the program to increase awareness among consumers and companies.

9) Cooperate with other Type III declaration programs
The interconnected nature of the global economy can make the process of collecting product data more complicated. Existing Type III programs are now discussing the mutual recognition of declarations, which would allow a product registered by a program in one country to be quickly registered by programs in other countries. The Global Environmental Declaration Network (GEDnet) is an organization that would likely lead this kind of cooperative effort. In the future, it is possible that Type III programs will cooperate to create a common database to be used globally[9]. Asian countries are already considering to do this in discussions initiated by the Japanese Ecoleaf program. If such a database is created, participating programs can expect to benefit from the decreased costs of maintaining separate databases. To benefit from these cooperative activities, maintain the program's relevance, and avoid incompatibility with other programs, the administrator should become actively involved in the international discussions about mutual recognition and common database creation.

### 2.2.2 Activities Performed by the Program Applicants

By performing key tasks internally, the administrator can better maintain the consistency and integrity of the program's environmental declarations. However, some items should be delegated to the applicants,

[9] The use of a global database does not mean that region-specific parameters are forbidden in LCA calculations. Rather, a global database is a collection of regional and global parameters that can be consistently applied by programs in various parts of the world.

who are more familiar with their own products and can perform certain tasks more efficiently. The main activities that are the responsibility of the applicant are listed here.

1) Learn life cycle assessment (LCA) methods
A company should designate at least one staff member who is knowledgeable about LCA methods act as a lead representative during the application process. Large companies can be expected to have LCA experts on staff, but for small companies, this requirement may create a burden. In order to ease such difficulties, the administrator should conduct lectures to teach LCA and data collection methods. (see item 8 above) This knowledge will not only be helpful to applicant companies as they attempt to register their products, but can also be used to conduct LCA studies of their supplier chain, production processes, and product design. If applicant companies choose not to appoint an internal expert, they may hire an LCA consulting firm to collect the LCI data and conduct the impact assessment. Alternately, the applicant may submit the LCI data, and request that the administrator conduct a life cycle impact assessment.

2) Collect life cycle inventory (LCI) data
At the beginning of the product evaluation process, the applicant must first collect data about the resource and energy use, and emissions related to all stages of a product's life cycle in the form of a life cycle inventory (LCI). This is the most important task that the applicant will perform, and it may also be the most time-consuming since the inventory can be very extensive and should include activities performed by outside parties such as suppliers, subcontractors, and end-users. The boundaries for the inventory are defined in the PCR. To generate an accurate inventory, the applicant should ideally require that suppliers and sub-contractors provide LCI data for supplied parts, materials, and services. However, it is often difficult to obtain information from suppliers or sub-contractors because of their concerns about confidentiality or a lack of ability. As a general rule, the applicant should collect as much specific data as possible, but if necessary, be permitted to use generic values from an approved database10 to estimate the inventories of common materials and processes.

3) Conduct life cycle impact assessment (LCIA)
To convert a product's life cycle inventory data to more meaningful indicators of environmental impacts, the applicant should conduct a life cycle impact assessment according to the methods specified by the administrator. The applicant will normally enter the product's LCI data into an approved software package that will automatically calculate environmental impacts using the characterization values from the administrator's database. (see item 4 above)

4) Pay fees
The applicant should pay various fees to the administrator to support the ongoing operation of the program. These may include a product analysis fee, an initial registration fee, and renewal registration fees. If a company chooses to not to pay the fee to continue a product's registered status, the administrator can suspend the company's right to refer to the environmental declaration in marketing activities. (See item 6 above)

[10] The approved databases of generic values for LCI should be specified in the PCR, and can be either a commercial database, or one created and maintained by the administrator. In the latter case, when new PCR are established, the administrator should identify the generic data necessary to conduct an LCI for that product category and add it to the database.

5) Track and report product changes
   The participating company should evaluate if any changes made to the materials or processes for a registered product will influence the results of the LCI and impact assessment. If it is determined that a change will affect the environmental declaration results, the participating company must inform the administrator who may request the submission of a revised application for registration.

6) Publicize environmental declaration information
   Although not a program requirement, the administrator will generally encourage participating companies to publicize the fact that their products are registered in the program. A company may refer to registered environmental declarations in their advertising, and if possible, display printed information on their product packaging. The descriptions may contain detailed information, or simply refer to the product's registrations status, and must conform to the program guidelines for format and content.

7) Reduce environmental impact
   Although not a program requirement, giving producers the incentive to reduce the environmental impacts of their activities is one of the main objectives of a Type III declaration. As a result of the registration process, the company will collect environmental impact information using objectively constructed methods. The company may then use this information to improve the environmental performance of their own activities, or the performance of their supply chain by asking suppliers and sub-contractors to reduce material inputs and emissions.

## 2.3. ORGANIZATIONAL STRUCTURE – EXISTING PROGRAMS

The administrative organization for Type III declarations is generally quite small, especially for new programs. The Ecoleaf program, after four years of operation, directly employs only five permanent staff members while the Swedish EDP program employs only two. Since the workload and range of expertise required to effectively manage a program exceeds the capacity of the direct staff, existing programs either delegate responsibility to the applicants, or rely on external support in the form of committees and contracted experts.

### 2.3.1 Program Office

Type III declaration programs may be internally directed from the program office, as is the case with the Ecoleaf program. In this case the directors of the program office must determine the overall program goals and the organizational structure, in addition to managing the routine program administration tasks.

Although the number of direct staff members of existing programs is very few, they perform key tasks of coordinating the product application process, maintaining registration status, and promoting the program to consumers and potential applicant companies. The tasks of the direct staff are described in more detail in section 2.2.1 ACTIVITIES PERFORMED BY THE PROGRAM ADMINISTRATOR.

### 2.3.2 Committees

Committees are used by existing programs to provide expert opinion on product evaluation methods, and to oversee key program tasks, such as approval of applications, with a degree of impartial objectivity. In addition to reducing the workload of the administrator, the participation of outside parties through committees is one way to help eliminate bias and build the trust of users and potential applicant companies.

*Participation of interested parties*

Life cycle assessments are inherently complicated, and even when presented with a high degree of transparency, bias in the selection of data and methods may not be visible in the results. This bias might be an attempt to improve a specific product's results by selectively excluding data, or it might be a bias in methods that unjustifiably favor one process over another. Even when bias is not present, for users of Type III declarations to consider the results in their decision making process, they need to have confidence in the methods used and the objectivity of the program administrator. By consulting interested parties such as universities, government agencies, consumer-interest groups, and companies, the administrator can help assure users that a program is objective and without bias.

The ISO technical report ISO/TR14025 [11], which seeks to promote consistency and quality in Type III declarations places a special emphasis on the importance of interested-party input.

*The process of developing and administering Type III environmental declarations and programs shall include an open consultation with interested parties. The scope of interested-party roles needs to be considered when developing Type III environmental declarations and programs. Reasonable efforts should be made to achieve a consensus throughout the process.*

*…in whatever level of input is determined adequate, the interested-party input process should be designed to:*

- *Ensure adequate access to the details and sources of data and information used*
- *Encourage an appropriate mandatory review time*
- *Consider comments in a timely manner*
- *Setting the third-party program administrative requirements, where applicable.*

The ISO report further states that this consultation should be ongoing, and interested parties continue their involvement after the program is established.

*Consultation is an ongoing process that occurs in the selection of product categories, selection of pre-set categories of parameters, establishing product-specific information requirements within each category of parameters and the procedures for periodic review of the required information.*

*…programs may consider obtaining interested-part input in, for example, the following stages:*

- *Selection and definition of product categories*
- *Critical review of technical analysis used to determine product categories*
- *Selection, development and modification of product environmental information relevant to the Type III environmental information and identification of product function characteristics*
- *Critical review of product environmental information*
- *Certification/Type III information (if applicable)*
- *Definition of content and format of external communication*
- *Selection of pre-set categories of parameters.*

Although one goal of collecting input from interested parties is to develop a program that is free of bias, the interested parties themselves are expected to exhibit some bias. It is the role of the administrator to consider the various interests, and find a balance while still satisfying the goals of the program.

*There are multiple purposes and opportunities for interested-party input. Interested parties should have the opportunity to provide input that reflects their special interests, addresses technical issues and ensures overall specific credibility.*

***Example of committees – Ecoleaf program***

The existing Type III programs in Korea, Sweden and Japan all conduct some form of consultation with interested-parties as described by the ISO technical report. Here, the Japanese Ecoleaf [22] [25] program's method of collecting input is presented as an example. Although the experience of a Japanese program is not entirely applicable for the U.S., the Ecoleaf program can provide some guidance since it is not directly managed by the government[11], and a single organization covers the key roles of program administration, product certification, database creation, and PCR management.

The various committees of the Japanese Ecoleaf program work towards the goal of ensuring that the environmental declarations are accurately and fairly prepared, verified, and approved.

The types of committees used by the Ecoleaf program are the:

- Program steering committee
  Composed of experts from academia, industry, consumer interest groups, and government, the committee makes decisions about the general operation of the program and supervises and evaluates the activities of the Product Category Rules (PCR)12 and Judgment committees.

- PCR review committee
  Evaluates the category rules proposed by the PCR Working groups and establishes the final PCR. Members of this committee are experts from academia and industry, and consumer interest groups with a high level of knowledge of environmental issues related to products.

- Judgment committee
  Judges whether to accept the data verification reports compiled by external verifiers. If the committee finds any errors or has questions about a report's contents, they can request further explanation, a resubmission of the report, or reject the report if necessary. This double-checking of results helps make the published environmental declarations more credible. The review committee members are experts in life cycle assessment who are knowledgeable about ISO's environmental declaration standards, as well as representatives of consumer interest groups and non-profit organizations.

- PCR working group (PCR-WG)
  When a new product category is created, the PCR Working Group is directed by the Ecoleaf program office to develop draft category rules. This draft is submitted to the PCR review committee for approval. The PCR Working Group is composed of product and LCA experts including representatives from companies related to the subject product category who have applied for the position in response to an announcement by the Ecoleaf program office.

[11] The administrator of Ecoleaf, the Japan Environmental Management Association for Industry (JEMAI), is an independent organization although it is supported by the Japanese Ministry of Economy, Trade and Industry.

[12] Ecoleaf refers to Product Category Rules (PCR) as Product Specification Criteria (PSR) while Swedish EDP refers to them as Product Specific Requirements (PSR). All terms have the same meaning.

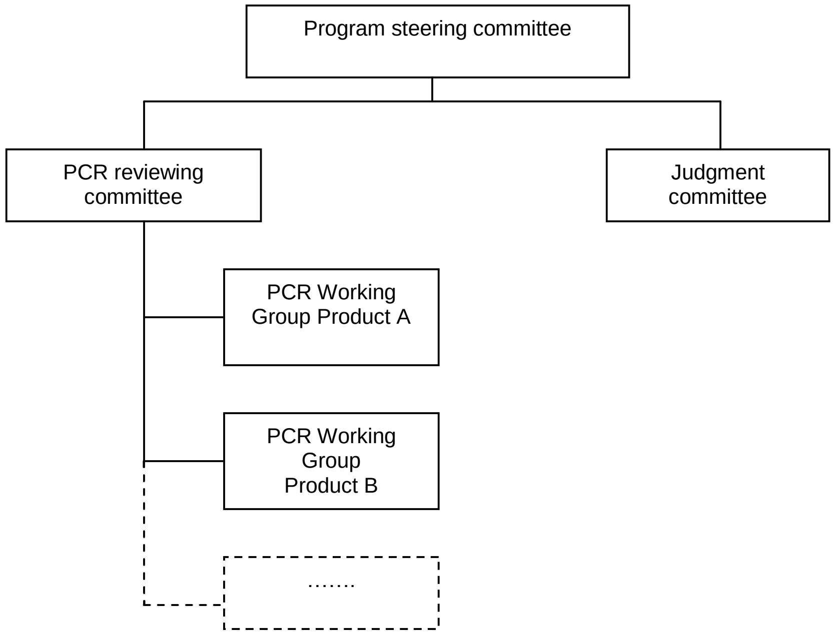


**Figure 2.4** Relationship between the committees of the Ecoleaf program [25]

An important characteristic of Ecoleaf's committees is that, with the exception of the judgment committee and PCR working groups, all have representation from different interest groups. Their membership takes into account the balance between groups which sometimes have opposing views. For example, the PCR reviewing committee is made up of 2 members each from industry, academia and consumer-interest groups for a total of 6 members. By forming committees that are not dominated by a singe interest group, it is easier to avoid potential bias and promote objectivity.

For membership in the judgment committee, which is responsible for checking the accuracy and objectiveness of the LCA reports submitted by applicant companies, expertise in LCA methods is considered a more important qualification than the balancing of interests.

The PCR working groups are composed largely of industry representatives because they have expertise about their own product categories. However, if a single company in the PCR working group dominates the category rules development process, other companies may not be willing to participate in the program and apply those rules. Therefore, the program administrator should encourage a variety of companies to participate in the PCR working group. Alternately, as in the case of the Ecoleaf program, the PCR reviewing committee can collect recommendations from other companies after the PCR working group proposes the draft category rules. This allows an opportunity for the opinions of other companies and interested parties to be reflected in the final PCR version adopted by the reviewing committee.

### 2.3.3 Contracted Experts

The program administrator can delegate tasks that require special expertise to contractors, thus reducing the workload on the direct staff. The Ecoleaf program contracts experts in life cycle assessment to verify applications submitted for product registration. This use of contracted experts is described in more detail in section 2.4.4 VERIFICATION OF DATA AND PRODUCT REGISTRATION.

## 2.4. PROCEDURES – EXISTING PROGRAMS

The program administrator should follow clearly defined procedures when registering new environmental declarations. Requiring that all product applications undergo the same process for approval is important for consistency and helps gain the confidence of program participants and users of the declarations. These procedures should be summarized and published so that potential applicant companies can understand what their responsibilities are in the registration process, and estimate the time and resources required for product registration. The basic steps used by the existing Type III programs in Korea, Sweden, and Japan to register a product environmental declaration are to:

- Develop product category rules
- Evaluate product performance using life cycle assessment (LCA)
- Verify product data and register product
- Publish environmental declaration

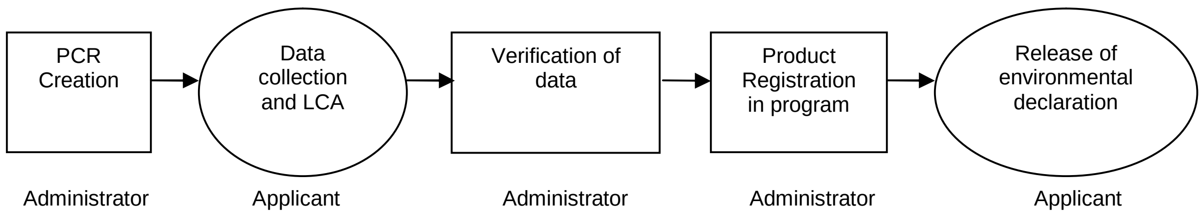


**Figure 2.5** Procedure for registering environmental declarations - Ecoleaf

### 2.4.2 Creation of Product Category Rules

Product category rules (PCR) are used by the existing Type III programs in Korea, Sweden, and Japan to ensure objectivity in the product evaluation process and comparability between environmental declarations. Although Type III declarations may allow consumers to compare products across different product categories, rules for collecting data and performing life cycle assessments must be defined separately for each product category. For example, the data collection boundaries for a refrigerator, which has many component parts produced by various companies, will be much different than for the production of grapes, which has a much simpler flow of inputs and outputs. When creating product category rules, the administrator should define:

- the product boundaries, and definition of included components
- a single product unit for evaluation
- Scope and factor in data collection
- the conditions for LCA calculations, such as allocation and cutoff rules
- the requirements for use of site-specific and generic data in LCA calculations
- the requirements for information disclosure and publication

***Example of PCR creation procedures – Ecoleaf program***

When product category rules already exist for a product, this step is not necessary. However, if an applicant wishes to register a product that does not fit into existing categories, new PCR must to be established. In the case of the Ecoleaf program, as with the other existing Type III programs, the process begins when a stakeholder requests that the administrator establish new category rules.[13] These stakeholders may include any party with an interest in the program, including producers, consumers, LCA specialists, and the administrator itself. The PCR reviewing committee then decides whether or not the

[13] It is also possible for the administrator to define category rules in advance of any proposals. However, this is only feasible for the product types which are most likely to be submitted, because the total number of potential product categories is so numerous.

request will be met, taking into account if the proposed category can conform to the program goals and can feasibly be implemented.

If accepted by the committee, the Ecoleaf administrator then publicly calls (via its website) for representatives from interested parties to serve in a PCR working group that will draft the category rules. The group members should have knowledge about LCA methods and the production processes related to the candidate product category. If the proposal was submitted by a company, their representative usually participates in the working group. Within several weeks, the working group members create a PCR draft for submittal to the PCR review committee, which may request the working group to make revisions or reinvestigate the subject. Before giving final approval, the PCR review committee has the authority to make revisions to based upon public comments collected and their own opinions.

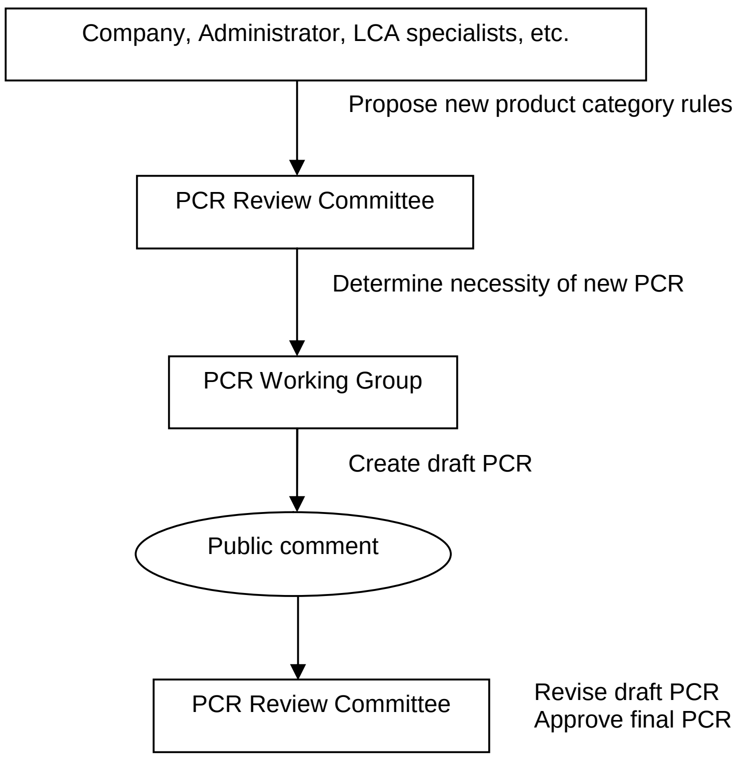


**Figure 2.6** PCR creation process for the Ecoleaf program

### *Examples of criteria for creating PCR – Ecoleaf and Swedish EDP*

Among existing Type III programs, there is no single standard format for category rules. Because the Ecoleaf program has placed a high priority on guaranteeing the quality of product comparisons, the PCR define the requirements for conducting life cycle assessments very specifically. Conversely, the Swedish EPD program is characterized by its greater flexibility to register declarations based on the various methods of applicant companies. Therefore, that program's category rules provide only qualitative information.

| | Ecoleaf | Swedish EPD |
|---|---|---|
| Degree of detail in PCR for LCA requirements | LCA conditions quantitatively specified | LCA requirements only described qualitatively |

**Table 2.2** Degree of detail in PCR of existing Type III programs

A description of the category rules for both programs is presented in this section. For the Swedish EDP program, the guidelines for creating category rules are very general, as shown in the Table 2.3.

| Swedish EDP program – Criteria for product specific requirements (PSR) | |
|---|---|
| 1. General information<br>2. Product description<br>3. List of materials and chemical substances<br>4. Functional unit<br>5. System boundaries<br>6. Cut-off rules | 7. Allocation rules<br>8. Units<br>9. Calculation rules and data quality requirements<br>10. Parameters to be declared in the EPD<br>11. Recycling declaration<br>12. Other environmental information |
| *1. General information* informs about the applicability of the PSR rules and the companies/organizations in charge of the preparation of the document. It includes:<br>- The nature of business intended for use of the document<br>- Which type of products/services for which the document is valid<br>- Geographical coverage<br>- Name of companies and organizations responsible for preparing the PSR | |
| *2. Product description* describes product characteristics in terms of specific aspects to highlight on a manufacturing and use phase perspective as well as the intended normal use of the product in a technical specification. The technical specification shall include information sufficient for a customer to assess and evaluate the technical performance and usefulness of the product. It includes:<br>- Definition of the product/service with reference to standards or equivalent (if available)<br>- Specific aspects with regard manufacturing phase, e.g. the use recycled materials or water-based paints<br>- Main function(s) such as the cooling capacity per volume in a refrigerator or the intended route and cargo capacity for a transportation service | |
| *3. List of materials and chemical substances* informs about the composition of materials and chemical substances in the product of special concern with regard to health and environment based on existing and upcoming legislation and market needs. If a list of materials and chemical substances is found not relevant to include, it should be justified. | |
| *4. Functional unit* defines a reference unit in an LCA study expressed as quantified performance of the product system. The functional unit is important as a basis for the collection, handling and calculation of LCA data to ensure the possibility to "add up" information from EPD´s in the supply chain and to be able to compare EPD´s in the same product category. | |
| *5. System boundaries* specify the unit processes to be included in the study and what type of "upstream data" that could be omitted. System boundary settings reduce the number of LCA data, thereby facilitating the calculations provided that no significant information is lost. This information includes:<br>- A graphical illustration over the mass and energy flows to include in the study.<br>- A short description should be given as comments to clarify the information in the flow chart. Definitions for the meaning of main parts and components shall be given. A short description of the used scenario for the use phase may be given.<br>Boundary settings may be specified as:<br>- Boundaries of time - Boundaries towards other technical systems<br>- Boundaries towards nature - Boundaries regarding geographical coverage<br>- Boundaries in the life cycle | |
| *6. Cut-off rules* clarify and describe rules for omitting inventory data in the manufacturing phase (from cradle-to-gate) which are negligible from the point of view of being relevant in the study. | |
| *7. Allocation rules* are used to distinguish the emissions for the product under study, in case of the parallel manufacturing of different kinds of products and where there is only information available about the total level of emissions from the manufacturing plant. | |
| *8. Units* In order to make EPD-information easily-understandable and to facilitate its use for e.g. adding-up information in the supply chain and for comparisons to be made, common units ought to be used. (SI units, kW (MW) for power, kWh (MWh) for energy) | |
| *9. Calculation rules and data quality requirements* describe common use of data and recommended data quality to ensure the possibility to "add up" information from EPD´s in the supply chain and to be able to compare EPD´s in the same product category. This information includes:<br>- Data quality requirements - Operation time<br>- Life time of the product - Specific calculation rules (if relevant)<br>Recommendations:<br>- Specific data should always be used, e.g. plant-specific data from manufacturing processes or transportation. If other types of information are used, this should be described and motivated.<br>- Generic data should be used in cases where they are representative for the purpose of the study, e.g. purchase of bulk and raw materials on a spot market and in the use- or waste- handling phases. Generic data may also be used if there is a lack of specific data possibly having a negligible influence on the final result. Generic data can also be used when specific data is lacking, e.g. if a product consists of many components. As a general rule, the sum of the contribution to all parts of the life cycle to the separate impact categories from the use of generic data, instead of product-specific data, must not exceed 10% of the total contribution to the impact categories. If another rule for the acceptance of generic data is recommended, this has to be justified.<br>- Data should represent annual average values for a specific year. | |
| *10. Parameters to be declared in the EPD* describe the overall environmental performance of the product/service based on the LCA study including data concerning the resource use, pollutant emissions in terms of potential environmental impact and waste generation. | |
| *11. Recycling declaration* describes important and environmentally beneficial aspects of the product with regard to recycling and reuse which not have been able to cover in other parts of the EPD. This information is optional. | |
| *12. Other environmental information* describes other environmental information of special value for the full understanding of the environmental performance of the product. This information is optional. | |

**Table 2.3** Criteria for creating PCR[14] - Swedish EPD program (condensed) [26]

[14] The Swedish EDP program refers to product category rules as product specific requirements (PSR).

As shown in Table 2.4, the Ecoleaf program's PCR should provide the details for life cycle assessment and data collection methods including the definition of each life cycle stage and the allocation and cut-off rules for that product category.

| Ecoleaf program – Requirements for the creation of product category rules (PCR) | | | |
|---|---|---|---|
| Main Item | Item | Sub Item | Requirements |
| Background for PCR creation | Product | Definition | Define a product type, considering structure, function, performance, process, etc. |
| | | Boundary | Set the boundaries of a product, and list the items to cover considering:<br>The boundary of the main body of a product, which performs the main function<br>The boundary of supplemental parts such as packaging or manuals |
| | LCA | Target life cycle stages (Boundary) | Define the targeted life cycle stages |
| LCI input data<br>. | Manufacturing stage | Component parts and Materials | I. Product raw materials/parts (except recycle/disposal phase)<br>1. Set the raw materials/parts that are type A<br>- Type A: Raw materials/Parts which environmental impact information for processing and assembly at final production site of, must be obtained<br>2. Clarify the difference between Type B and C raw materials/parts.<br>- Type B: Raw materials/Parts whose assembly environmental impact before receiving by the site is required to be estimated but whose processing environmental impact is not required.<br>- Type C: Raw materials/Parts whose processing/assembly environmental impact before receiving by the site is required to be estimated using the Common Unit List supplied by this program.<br>3. List the materials that compose the part using standard materials classifications.<br>II. Recycle/ disposal phase<br>1. Set the target of the recycle/disposal phase<br>2. List the materials involved in the recycle/disposal phase using standard materials classifications. |
| | | Material and energy input and emissions | 1. Set input, consumption, and emission items<br>2. Set treatment methods of materials which is recycled outside a company.<br>(a) Valuable materials (b) Disposed/recycled material<br>3. Determine conditions about (a) input materials and energy, (b) disposed/recycled material, (c) transportation. |
| | Transportation stage | Transportation condition | Set any typical transportation conditions if applicable (method, distance, load), or specify which information must be provided by the company. |
| | Use stage | Use condition of a product | Set any typical use conditions of a product or specify information to be provided by the company.. It is favorable that companies data publicized by public organizations. The following should be considered:<br>1. Use conditions (including consumption and emission items)<br>2. Quantity and disposal/recycle condition of consumables and reparable parts required in the use stage.. |
| | Disposal/recycle stage | Disposal/recycle condition of a product | I. Product (except disposal phase)<br>Specify the information to be provided by the company considering the items below<br>1. Scenarios for disposal, recycle and reuse.<br>2. Scenarios about deducting recycled materials from impacts<br>3. Validation standard for recycle/reuse potential of component parts.<br>4. Assumed rate of product collection. The rate is based on previous data or specified in PCR with appropriate evidences.<br>5. The number of reuses.<br>6. The calculation method of disposal impact of used products which are sold as valuable materials.<br>II. Treatment service<br>Specify the standard calculation for environmental impacts deduced from recycle/reuse |

| | | | |
|---|---|---|---|
| Product environmental data | Inventory analysis | LCI calculation formula | Determine premise of LCI calculation<br>1. Determine methods to apply generic data on materials and clarify the evidence.<br>2. Consider whether determination of calculation formulas is needed in each stage.<br>(a) Propose specific formulas when needed and clarify the evidence<br>(b) When new generic data is needed for the calculation, clarify the evidence. |
| | Impact assessment | Adding categories | Consider whether impact category and category names should be added to the "common specific coefficient list". If added, list the category names and relevant materials, and clarify the evidence. |
| Detail datasheet (Detail data for the input and output for each life cycle stage) | Data processing | Allocation | Determine allocation methods of site data, although it is basic to determine methods which do not need allocation.<br>1. Basis of allocation (occupied area of production site, volume of shipment, production price…)<br>2. Detail of allocation (scope, representativeness, completeness…) |
| | Data collection | Scope of data collection | Determine scope of data collection of items below. In this case, consider representativenes of collected data.<br>1. Site of collection (domestic, abroad, representative factory…)<br>2. Period of data collection (year, season, month…) |
| | | Cut-off rule | Determine standards for cut-off rule application as defined in ISO14041.<br>1. Determine objectives that can not be cut off.<br>2. Determine standard value (the marginal value that can be cut off)<br>3. Determine indicator (mass, energy, environmental impact…) |
| | Database | Selection of common generic data | Determine applied common generic data along "LCI common generic data list". |
| | | Adding generic data | When common generic data is not available or does not exist, add generic unit considering items below.<br>1. Determine form of new generic data.<br>2. Select either adopting PCR specific generic data or adopting individual common generic data |
| | | Adding specific coefficient | Consider new necessary specific coefficients, when specific coefficients which should be applied to each environmental impact item is impossible to be specified with inventory items defined by "common specific coefficient list". |
| Product environmental information | Production form | | Determine items of production form |
| | Contents of data presentation | | 1. Determine publicized items of environmental impact besides required information.<br>2. Determine publicized stages individually.<br>3. Determine data presentation methods (text, table, graph…) |
| Other environmental information | Optional description items | | Determine environmental information which can be confirmed, that is, which relates to items below.<br>1. Type I/Type III ecolabel<br>2. ISO14001<br>3. Certification by public organizations<br><br>In addition, companies can present toxic chemical use etc. In that case, they determine objective stage name, component parts name, and material name. |

**Table 2.4** Criteria for creating PCR - Ecoleaf program (translated and condensed) [27]

An important characteristic of a product declaration is the extent to which generic data was used in the life cycle assessment instead of specific data for that product. In the guidelines for creating category rules, both examples presented above mention the use of generic data. However, because the Ecoleaf program administrator provides the generic data for the applicants' use, the PCR used by that program must define the source of the generic data. [28] (see PRODUCT-SPECIFIC AND GENERIC DATA section for more detail)

The Ecoleaf program's PCR criteria describe the options that can be used when selecting new generic data for new product categories.

1) When generic data is already existing for the materials and processes typically used in that product category, the PCR criteria specifies the applicable generic data from the "LCI common generic data list".
2) When generic data is not existing for the materials and processes typically used in that product category, the PCR criteria specifies:
   - The form of the new generic data.
   - Whether generic data will be specific for that product category, adopting as common generic data by other product categories.

***Product category definition***

When a new product category is created, it is important that the scope of the category is defined appropriately. A category definition that is too broad can reduce the accuracy of product evaluations since the category rules and generic data can not be equally applicable to a very wide range of product types. On the other hand, of the categorization is too fragmented, the administrator would be overwhelmed by the task of managing many small product groups, each with its own committees and documents. Additionally, if the category rules define different methods and impact indicators, it would not be possible to compare products between categories.

### 2.4.3 Product Evaluation: Data Collection and Life Cycle Assessment

In the existing Type III programs, the tasks of data collection and LCA calculation are performed by the applicant. The Ecoleaf administrator makes its propriety software available to applicants, which includes a database for the material and energy flows for common processes as well as characterization factors for calculating environmental indicators. The applicant first collects detailed product data, which is processed using the values from the database. Ecoleaf generally assumes that applicants collect site-specific data for the main, in-house production processes. For other processes, applicants are allowed to use the generic values from the database. Once the applicant enters the collected data, the Ecoleaf software automatically calculates the environmental impacts. Although the administrator has the additional responsibility of creating and maintaining a database, the effort required by companies to perform life cycle assessments is reduced, and the declaration results will be consistent with other product declarations. KOECO provides a similar database to Korea EDP program applicants, while still allowing them to refer to other data sources. Similar to the Ecoleaf program, the Korea EDP program specifies, for each product category, which items require site-specific data. For all other items, generic data is allowed. In contrast to this, the Swedish EPD program limits the use of general data, requiring that over 90% of the total data for each environmental indictor is site-specific. This reduces the burden on the Swedish EDP administrator, who does not need to create proprietary software and databases. Instead, applicants are required to use a reference data source, or commercial software such as SimaPro or Gabi. The increased flexibility of the Swedish EDP program may be attractive to companies that have already established their own LCA methodology, while the larger role in data collection may be seen as a burden, especially for smaller companies. However, the reduction in comparability that results from inconsistent product evaluation methods is a major drawback of the Swedish EDP program's approach.

| | Ecoleaf | Korea EDP | Swedish EPD |
|---|---|---|---|
| Site-Specific Data | Main manufacturing phase (Main parts/ Processing of materials/ Assembly process). | Required specific data is specified for each product category. | Specific data is required for over 90% of total data in all life cycle stages. |
| Generic Data (Processes and Characterization Factors) | The administrator creates database . | The administrator creates database. | The administrator indicates references or applicants use general references. |
| LCA Calculation | The administrator provides software. | The administrator provides software and allows the use of commercial software (e.g. SimaPro). | Applicants use commercial software (e.g. SimaPro). |
| Advantage | Applicants have a reduced burden because database is provided. Conformity between product declarations is high. | Similar to Ecoleaf | Applicants can flexibly prepare and expand database depending on products. |
| Disadvantage | The administrator has an increased burden to create and maintain database. | Similar to Ecoleaf | Applicants have an increased burden for LCA calculations. Conformity between product declarations is low. |

**Table 2.5** Data collection and LCA for existing Type III programs

### 2.4.4 Verification of Data and Product Registration

Because the quality of the final environmental declarations is so highly dependent on the data provided by the applicant, all existing programs have procedures to verify the submitted data. In the Ecoleaf program, the applicant completes standard forms for summarizing product information based on the LCA results, and submits these documents to the administrator for verification. This verification is conducted by LCA experts who, although not staff members of the program administrator, are compensated by the administrator for their work. These external verifiers review the evidence supporting the life cycle assessment calculations, and conduct on-site inspections as necessary to confirm the data.

The verifiers must consider these points in their investigation [29]:

1) Whether the LCA methods employed conform to program requirements.
2) Whether specific calculation conditions conform to PCR requirements.
3) Product characteristics (mass of component, materials, etc.) from inspection of an actual product.
4) Completeness, accuracy, and applicability of the collected data.
5) Validity of the applied allocation and cutoff rules.
6) Whether the provided documents create a sufficient basis of evidence for the evaluation results.

The Ecoleaf administrator estimates that the external verification process usually takes three to four hours for each product. Afterwards, a verification result report is submitted to the administrator for approval by the judgment committee. The committee also evaluates the validity of LCA method, the reliability of the data, conformity to the PCR, and if it is misleading to readers. The environmental declaration can be registered and released for publication once approval is given.

The Swedish EPD and Korea EDP programs conduct on-site inspections during the verification process, whereas the Ecoleaf verifiers will not conduct inspections unless it is deemed necessary to confirm the data. A more stringent verification process that includes on-site inspections is preferable because it is then possible to evaluate how representative the data is of actual conditions. However, this takes more time and human resources, and the increased costs are finally reflected in the program's application fee. Therefore, administrators who want to reduce the inspection fee may choose to forego on-site inspections, requiring the verifiers to check only the submitted documents. This off-site inspection may lead to incorrect declarations if companies submit false data to improve the results. In order to guarantee credibility of verification, the Ecoleaf program applies sanctions to applicants that intentionally cheat, and the applications for product declarations which appear to be based on false data are dismissed. However, the three to four hours spent by the Ecoleaf administration does not seem sufficient to conduct a thorough off-site inspection.

The Swedish EPD administrator seeks external assistance, and assigns the verification task to private companies. Registration of the Swedish EPD is administered by the Swedish Environmental Management Council, which is a company owned jointly by the Swedish Government, the Confederation of Swedish Enterprises and the Swedish Association of Local Authorities and Regions. On the other hand, the verification process is conducted by any of nine independent certification bodies approved by Swedish Board for Accreditation and Conformity Assessment, the national accreditation body under the Ministry of Foreign Affairs. This is different from system used by the Ecoleaf program, in which program administration and product certification tasks are conducted by the same organization. The Swedish system can reduce the burden on the administrator, allowing it to focus on administrative tasks. However, the involvement of multiple verification bodies may lead to inconsistencies if the standard verification method is not clearly defined.

The Japanese Ecoleaf program offers applicants who are licensed by the administrator the option of conducting the verification by themselves. In this "internal verification" system, applicants select a verifier, and assign them the task of evaluating the validity of data. The verifier may be either directly employed, or contracted by the applicant who can assign and change them at their discretion. When the verification process is complete, the applicant then submits a set of documents to the administrator. This system is especially beneficial to a new program like Ecoleaf's, where the administrator's resources are very limited and a reduced lead time for registration might encourage more new companies to apply. However, there the internal verification system might result in a reduction in the credibility of the program's declarations. The Ecoleaf administrator assumes that accredited companies do not cheat, but it would be very easy for them to manipulate the data because it can not be inspected by a third party.

### 2.4.5 Publication of Environmental Declaration

Once an environmental declaration of a product is approved and registered, a company can refer to the declaration in advertising, and display the information in their website and on products in stores. The printed product labels for the existing Type III programs do not contain any quantitative information from the life cycle assessment results. Instead, they show only the program's certification logo with a product registration number and the administrators' website address where the detailed declaration information can be found. This is inconvenient for consumers who might prefer to compare environmental declaration information in the in store at the same time they are considering other product attributes.

## 2.5. BUDGET – EXISTING PROGRAMS

Managing a budget is one of the most important tasks for an environmental declaration program's administrator. Product registration fees must be set low enough so that companies are not reluctant to participate, but not so low as to prevent the administrator from paying for fixed expenses such as database creation and the salary of staff, independent verifiers, and committees. In this section, the Ecoleaf program's budget is presented as an example.

### 2.5.1 Registration Fee

The Ecoleaf program charges two fees for product registration; a certification fee that is determined based on the sales price of the product, and an annual registration renewal fee. These are shown in Table 2.6.

| Item | Sales Price of Product | Fee |
|---|---|---|
| Verification/Initial registration | <90 USD (10000 JPY) | 2,550 USD (280000 JPY)/product |
| | <455 USD (50000 JPY) | 3,000 USD (330000 JPY)/product |
| | <910 USD (100000 JPY) | 3,360 USD (370000 JPY)/product |
| | <1,820 USD (200000 JPY) | 3,820 USD (420000 JPY)/product |
| | >1,820 USD (200000) | 4,270 USD (470000 JPY)/product |
| Registration renewal (Annual fee) | - | 90 USD (10000 JPY)/year/product |

**Table 2.6** Product registration fee structure – Ecoleaf program

Note: Currency rate $1(US)=¥110. verification/judgment fee for subsequent versions of same product series are discounted by 25% for the 2nd and 3rd versions, 50% for 4 and 5th versions, and 75% for after 6th version.

This product price-based fee system is based on the idea that the production of more expensive products usually involves more complicated manufacturing processes, and therefore the LCA is more difficult to conduct. Furthermore, it can be assumed that more expensive products have a higher profit margin, and are better able to absorb the higher fees without increasing the price. In any case, the highest registration fee charged by the Ecoleaf program is only 4270 USD, which would be considered an incidental expense by most companies. After the first year of a product's registration, if the company wishes to continue referencing the declaration in its advertising, they must pay a registration renewal fee of 90 USD per year.

A "product price-based fee" is only one of several possible ways to structure a registration payment system that considers the applicant's potential willingness and ability to pay. Other possible methods include "sales volume-based" and "size of company-based" fees. Deciding fees based on the volume of products sold would be difficult for newly registered products, since it is impossible to predict the sales in advance. However, it is possible to use this method to set the annual registration renewal fee using the previous year's sales data. A "size of company-based" fee system considers the number of people employed by a company, and is based on the assumption that large companies can afford to pay higher fees than smaller companies. The disadvantage of this method is that large companies have to pay a higher fee for all products, even if they are very inexpensive and have a small profit margin. The Ecoleaf program uses the "size of company-based fee" to charge applicants that opt to use the "internal verification" system,[15] as is shown in Table 2.7. The fees for Ecoleaf program's internal verification system are relatively high because the participating companies can submit an unlimited number of products while avoiding the usual verification fees.

| Item | Size of a company (Number of workers) | Fee |
|---|---|---|
| Certification | <500 | 14,500 USD (1600000 JPY) |
| | <1,000 | 17,300 USD (1900000 JPY) |
| | <1,500 | 20,000 USD (2200000 JPY) |
| | <2,000 | 22,700 USD (2500000 JPY) |
| | >2,000 | 24,500 USD (2700000 JPY) |

**Table 2.7** Fee structure for Ecoleaf's internal verification system

The fee structure of the Swedish EPD program, shown in Table 2.8, is slightly different from the fee structure used by the Ecoleaf program. At first, a one time registration fee of 1300 USD (10000SEK) is charged for all products. Then, an annual fee of 0.01 percent of the product's net sales is charged, with a

[15] Ecoleaf's internal verification system, described in more detail in the section , the Ecoleaf program's internal verification system allows manufactures that are certified by the administrator to verify the LCA results by themselves.

1300 USD (10000SEK) minimum fee and a maximum fee of 3200 USD (25000 SEK) [30]. Therefore, most of the revenue collected by the administrator comes from the registration renewal fees. After several years, the costs for an applicant in the Swedish EPD program are likely to be higher than in the Ecoleaf program, especially since they must pay additional inspection fees to independent verifiers.

| Item | Net Sales of Product | Fee |
|---|---|---|
| Initial registration | | 1,300 USD (10,000 SEK)/product |
| Registration renewal (Annual fee) | <13 million USD (100 million SEK) | 1,300 USD (10,000 SEK)/product |
| | 13 million USD (100 million SEK) to 32 million USD (2.5 billion SEK) to | 0.01 percent of net sales |
| | >32 million USD (2.5 billion SEK) | 3,200 USD (25,000 SEK)/product |

**Table 2.8** Product registration fee structure – Swedish EPD program
Note: Currency rate $1(US)=7.7 SEK

### 2.5.2 Expenditure

The fees charged by the program administrator must be set high enough to cover program expenses. The two main expenditures are (1) the fixed cost of salary for program staff that coordinate the program and manage the database, and (2) the variable cost if compensation for external verifiers and committee members.

In case of the Ecoleaf program, each product application is inspected by two verifiers. A main verifier is given compensation of 1090 USD, and a sub-verifier is given 730 USD for a total expense of 1820 USD (200000 JPY) per product. The Ecoleaf administrator assigns the task of verification to external LCA experts, usually employed by engineering consulting companies, who are certified by the program.

The judgment committee's four members are each paid 180 USD (20000 JPY) every time the committee convenes. Because the Judgment committee meets every two months after reviewing the verification results which were submitted in advance, the administrator's total cost is 4360 USD per year. The nine members of the PCR review committee and the 15 members of the steering committee are also compensated 180 USD per meeting. The travel costs for these committee members in the Ecoleaf program are not very high because most members can come from around Tokyo, where the meetings occur. Consequently, the total committee costs are very low compared to the costs of compensating verifiers.

The administrator's workload, and therefore the number of people employed directly as program staff, depends on the extent to which work is delegated by the administrator to outside parties. Because the Ecoleaf administrator develops its own LCA database, five staff members are employed directly by the program office [16]. On the other hand, the Swedish EPD program, which allows applicants to use commercial LCA software, has a staff of only two. Both programs outsource various tasks, such as verification, allowing them to employ relatively few staff members.

### 2.5.3 Break-even Point

After a new program is established, even if the administrator sets fees appropriately and recruits a significant number of participating companies, it is nearly inevitable that the financial balance will be in deficit for the first several years. However, the program can eventually become profitable as annual renewal fees are collected for an increasing number of previously registered products.

Main expenditures can be calculated by:

[16] The Ecoleaf program office located in the office of the Japan Environmental Management Association for Industry

*(Expenditure) = (number of staff) x (salary per staff) + (number of new certified products) x (compensation for verifiers and committee members) + (other activities (seminar, advertisement etc)) + (miscellaneous costs)*

Main revenue can be calculated by:

*(Revenue) = (number of new certified products) x (certification fee) + (number of currently registered products) x (registration renewal fee)*

A graphical representation of the conceptual relationship between income and expense is shown in Figure 2.7. In order for the revenue to exceed expenses, the registration fee and the number of products registered must be high enough to cover fixed and variable costs. At the beginning of the program, the fixed costs are higher than revenue. But as long as the incremental revenue from new product registrations is greater than the marginal cost, the program has the potential to become profitable.

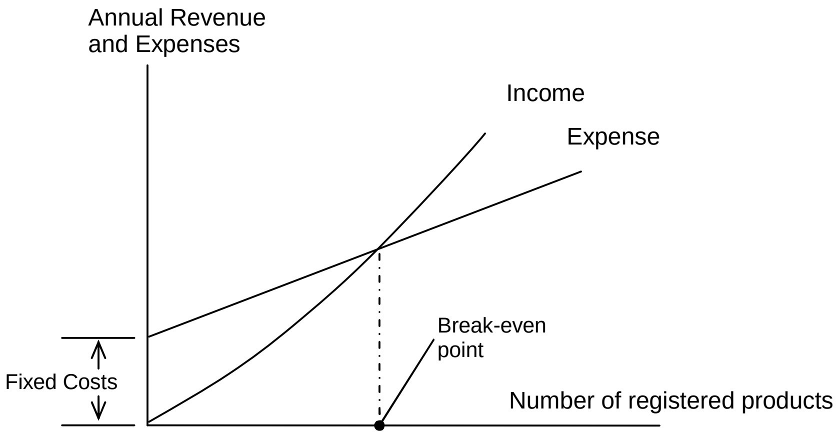


**Figure 2.7** Break-even point for program income and expenses

The Ecoleaf program has been in deficit since its inception in 2002, during which time its activities have been supported by the activities of its parent organization, JEMAI, such as environmental consulting and certification and auditing of ISO14001 compliance. In their 2005 annual budget, the expected income and expenses were 405,081 USD (44,559,000 JPY) and 720,219 USD (75,623,000 JPY), respectively. Half of these expenses were for staff salary, and the remainder was for other administration costs such as compensation to verifiers and committee members, and educational activities [31].

The Ecoleaf administrator expects to achieve a positive account balance within three years as the number of registrations reaches from 800 to 900 products. The annual registration of new products in the Ecoleaf program has been increasing steadily, as shown in Figure 2.8. As of January 2006, a total of 350 products had been registered.

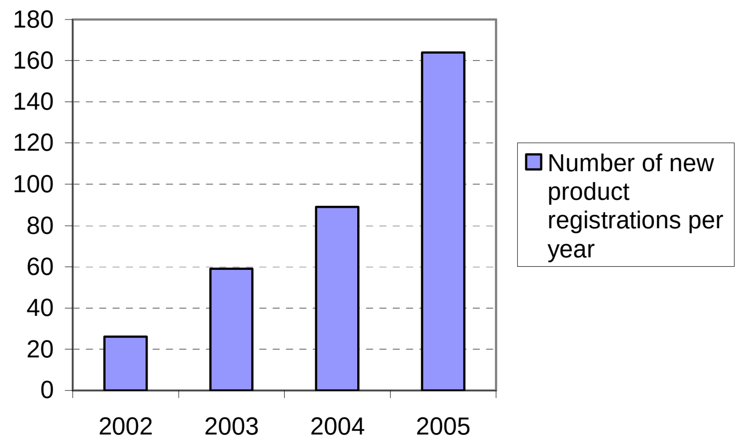


**Figure 2.8** Number of new product registered in the Ecoleaf program

## 2.6. RECOMMENDATIONS FOR THIS PROGRAM

### 2.6.1 Organization - Recommendations

Key Recommendation : A comprehensive Type III environmental declaration program for the U.S. is most realistically administered by a private company.

Key Recommendation: In order to maintain objectivity in decision making, committees shall be composed of an equal number of representatives from industry, academia, and consumer interest groups.

Key Recommendation: To maintain the objectivity of the judgment and PCR review committees, single-company representatives shall not serve on the committees, although recognized industry representatives can. Instead, single-company input will be included through solicitation of opinion, and through their participation on working group committees.

### 2.6.2 Procedures - Recommendations

Key Recommendation: To ensure consistency and comparability between product declarations, the program administrator shall create and maintain a database of common process data and characterization factors for use in life cycle assessment.

Key Recommendation: Applicant data submission using a combination of general process data from the administrator and specific data from the applicant is best.

Key Recommendation: For a new Type III program, the database and software should be made available free-of-charge in order to encourage the participation of more companies.

***Product category rules***

The U.S. Census Bureau has defined a comprehensive system for classifying economic activity based on industrial sectors called the North American Industry Classification System (NAICS) [32] [33]. Because the system was created jointly by the governments of the U.S., Canada, and Mexico, and is widely used by North American industry, it could easily be used for an environmental declaration program in the U.S. The categories are defined by codes of two to six-digits, with each of the first five digits progressively dividing the industry sectors, and the final digit specifying the country. An example of the structure is shown in the table below.

| NAICS hierarchical structure | Example |
|---|---|
| XX Industry Sector (anticipating up to 20 industries) | 33 Manufacturing |
| XXX Industry Sub-sector | 335 Electrical Equipment, Appliance, and Component Manufacturing |
| XXXX Industry Group | 3352 Household Appliance Manufacturing |
| XXXXX Industry | 33522 Major Appliance Manufacturing |
| XXXXXX U.S.(Canadian, or Mexican) National Industry | 335222 Household Refrigerator and Home Freezer Manufacturing |

**Table 2.9** The NAICS hierarchical structure

For a Type III environmental declaration program, the most detailed "U.S. National Industry" classification seems the most appropriate level for defining product categories. In the example above, product category rules would be created for the "Household Refrigerator and Home Freezer Manufacturing" U.S. national industry. It should be noted that since the NAICS categories were created to track economic activities, and not the flow of products and goods, it may be necessary in some cases to slightly modify or combine the NAICS categories to suit the needs of a Type III program.

### 2.6.3 Data Verification - Recommendations

For any environmental declaration program, verification of the applicant's data would ideally include an on-site inspection, thereby reducing the potential occurrence of cheating as well as legitimate data errors. However, the increased workload would be reflected in the program fees and the time period from application to registration. Therefore, when deciding how to allocate the responsibilities of data verification, the administrator must balance considerations of the program fees, time to register, and credibility of the declaration.

### 2.6.4 Budget - Recommendations

The number of verifiers may be fewer (that is to say, only one) and instead verification fee may be reduced, although Ecoleaf method is very conservative (double checked by two verifiers and also checked by the Judgment committee).

In the case of the US, travel costs should also be regarded because it can be very high depending on the location of administrator and members.

The number of staff may not depend upon the number of registered products, because their main tasks are to develop the database and coordinate the program. Therefore, as the number of product and income increase, the fixed cost per product will decrease.

> Key Recommendation: A universal fee for product registration is not recommended because it discourages the participation of small companies.

> Key Recommendation: For a new Type III program, it is better to bias the fees towards higher analysis and initial registration fees, and lower registration renewal fees in order to offset the higher initial costs of program administration. As the program becomes more well-established, the fees can be shifted away from the verification fee in order to build a larger database of product results.

# 3. MEASURING ENVIRONMENTAL IMPACTS

> Key Recommendation: A primary function of this program is to facilitate the collection of accurate environmental information, and to disseminate that information to consumers with the goal of reducing the total environmental impacts of producing and consuming products.

## 3.1. LIFE CYCLE ASSESSMENT FOR PRODUCT EVALUATION

### 3.1.1 Background and Definition of LCA

Over the past several decades, concerns about the depletion of natural resources and damage to the environment have led to the development of new methods of managing potentially harmful activities. Life cycle assessment (LCA) is one tool in particular that gained popularity in the 1960's and 1970's as a result of the energy crisis and concerns about an increase in packaging waste. The common element of these studies was the consideration of all the life cycle stages associated with the product, from "cradle to grave", including production, transportation, use, and disposal. Since these early applications, LCA studies have been conducted with the aim of quantifying the environmental impacts of various alternatives in order to identify the environmentally preferable one [34]. Because of the inherent complexity involved and inconsistencies in study methods, an effort was made in the 1990's to create international standards for conducting life cycle assessments. The Society of Environmental Toxicology and Chemistry (SETAC) issued a series of reports in the early 1990's, [notably SETAC, A Conceptual Framework for Life-Cycle Impact Assessment, Workshop Sesimbra, 31.3.-3.4.1993 Brüssel 1993] Here, SETAC defined LCA as:

> *…an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and material uses and releases to the environment, and to evaluate and implement opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials, manufacturing, transportation and distribution; use, re-use, maintenance; recycling and final disposal.*

Building upon the international collaborative effort begun by SETAC earlier in the decade, ISO in 1997 issued several standards for conducting life cycle assessments, defining LCA succinctly as[35]:

> *Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle*

More recently, the development of LCA has focused on refining the methods and increasing the use of LCA. In 2002, the United Nations Environment Program (UNEP) and SETAC launched the "Life Cycle Initiative", with the goal of bringing LCA and life-cycle thinking into more widespread practice, and to provide specific recommendations to LCA practitioners on the best practices regarding data and methods worldwide [36]. Because LCA is a relatively new and continually evolving tool, LCA practitioners should always be aware of its limitations, and stay informed of developments in methodology that will improve the quality of LCA study results.

### 3.1.2 Alternative Tools

Life cycle assessment is not the only technique for managing environmental impacts. Depending on the application, other tools may be more appropriate (e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) [1]. However, unlike these other systems, life cycle assessment evaluates environmental impacts in terms of a "functional unit", which based on a product's ability to perform specified function. This makes feature makes life cycle assessment a tool that is uniquely suited to the task of developing environmental product declarations, since it allows comparisons to be made at the product level, instead of more general comparisons of company policies. Still, there are other tools that can be used in conjunction with life cycle assessment to improve the environmental performance of product systems, some of which are described below:

***Environmental Management Systems***

An Environmental Management System (EMS) is defined by the International Organization for Standardization (ISO) as "that part of the overall practices, procedures, processes, and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy [37]." Therefore, an organization that employs an EMS has the structures in place to manage activities related to the environment, but is not necessarily bound by any specific requirements for reducing their environmental impacts, or for measuring and reporting progress. Several organizations have developed standards for evaluating and certifying the successful implementation of EMS. Among these standards are ISO 14001, ANSI E4, ISO 9001, the International Chamber of Commerce Global Environmental Management Initiative (GEMI), and the Chemical Manufacturers Association Responsible Care. The U.S. EPA, in comparing existing systems, outlined six key elements that should form the basis of any successful EMS [37]:

- Organizational Structure: gives authority, input, and voice to environmental performance;
- Management Commitment: possess and demonstrate commitment to environmental excellence and insist on integration of environmental awareness and concerns in the business;
- Implementation: carry out daily business operations through integration of environmental protection into business conduct;
- Information Collection/Communication/Management/Follow-up: continually monitor environmental performance through formal tracking and reporting, evaluate and disseminate information, and use information to continually improve;
- Internal and External Communication: foster and use formal and informal channels to communicate environmental commitment and performance;
- Personnel: hire, train, and deploy personnel such that they are capable of developing and implementing environmental initiatives.

***Environmental Risk Assessment***

Environmental Risk Assessment (ERA) is defined as: *the process that evaluates the probability of adverse effects in the environment as a result of exposure.* [38] In 1984, the U.S. EPA began creating guidelines for conducting Risk Assessments in order promote consistency and technical quality [39]. These guidelines outline four steps in the process of risk assessment, and the issues are addressed in each step [40]:

- Hazard Identification
  Regardless of the probability of exposure, what, if any, adverse health effects are caused by exposure to a substance?
- Dose-Response Assessment
  What is the relationship between exposure and the severity of adverse health effects, and how can data from the laboratory be extrapolated to humans and lower doses?
- Exposure Assessment
  In the area under study, how much of the substance is emitted into the environment, what is the fate once emitted, and how are individual's exposed to the substance?
- Risk Characterization
  How likely is it that the health of individuals in the study area will be affected?

Risk assessment differs from LCA in two important respects [34]:

- Risk Assessment includes all the emissions for the region (including the existing build up of persistent substances) in order to determine the likelihood that an individual's exposure to the substance will exceed a certain threshold, while LCA only considers increases in the concentration of a substance that are associated with a certain set of activities.
- Risk assessment uses conservative values when there is uncertainty in the data or lack of knowledge about the concentration of a substance. This means that the actual concentrations of the substance might be lower than the estimated concentration, because the goal is to ensure with some confidence that the exposure will not exceed a certain level. In LCA, the goal of comparing various scenarios as accurately as possible can not be achieved after systematically adjusting values for certain substances and not others.

***Environmental Auditing***

Auditing generally applies to the process of confirming that a regulated organization is in compliance with certain laws. As applied by the US EPA, the goals of Environmental Auditing as outlined in the "Audit Policy" are "to enhance protection of human health and the environment by encouraging regulated entities to voluntarily discover, promptly disclose and expeditiously correct violations of Federal environmental requirements." In this case, the incentives for regulated entities to self-report violations include a reduction or elimination of civil penalties, and reduced likelihood of criminal prosecution [41].

***Pollution Prevention (P2) Programs***

In 1990, the US Congress passed the Pollution Prevention Act, which set the objective that "pollution should be prevented or reduced at the source whenever possible [42]." This regulation has resulted in programs to share technical knowledge about reducing pollution, an expansion of the Toxics Release Inventory (TRI) to inform the public of pollution sources, and new regulation that has shifted in focus from "end-of-pipe" treatment to source reduction.

## 3.2. LCA METHODS FOR THIS PROGRAM

The methodology outlined by the International Organization for Standardization (ISO) in the 14040 series of standards for conducting life cycle assessments is nearly universally used by LCA practitioners, and will be adopted for this program. The ISO standard does not specify an exact step-by-step procedure for conducting an LCA, but rather allows for flexibility to adjust the methods as appropriate for a particular application.

*There is no single method for conducting LCA studies. Organizations should have flexibility to implement LCA practically as established in this International Standard, based upon the specific application and the requirements of the user* [35].

The ISO standard describes four phases in life cycle assessment, which are described in detail in this section. They are:

1) Definition of goal and scope,
2) Inventory analysis,
3) Impact assessment, and
4) Interpretation of results.

### 3.2.1 Definition of Goal and Scope

***Goal***

ISO 14040 specifies that the goal of an LCA study *shall unambiguously state the intended application, the reasons for carrying out the study and the intended audience.* The goal of any LCA initiated by this program will be to generate information that facilitates more informed decisions by both consumers and producers.

> Key Recommendation: Product life cycle assessments should generate information so that consumers and producers can make relative comparisons between products, as well understand the level of significance of the product's absolute environmental impact.

Providing information for comparing two products that provide a similar function is a common goal for LCA studies, and requires no further explanation. However, the more difficult task of gauging whether the environmental impacts of a product are significant or not is less common in LCA. But this additional information can assist the decision making process by allowing the user to concentrate their limited time and fiscal resources on decisions which have a greater environmental impact.

***Scope***

Although life cycle assessment should include consideration of all activities related to a product, from resource extraction to product disposal, every LCA study is limited by the availability of data, and the boundaries to which the analysis can extend. The scope of a study that satisfies the ISO 14040 standard *should be sufficiently well defined to ensure that the breadth, the depth and the detail of the study are compatible and sufficient to address the stated goal.* In addition to the boundaries of the study, the scope includes descriptions of the product and the analysis of the product, including the methodology, data requirements, assumptions, limitations, and type of review process.

*Function and Functional Unit*

In life cycle assessment, a functional unit is the quantification of the specified product functions. It acts primarily as a reference to which inputs and outputs are related. It is extremely important to select a functional unit that meets the program goals, since all product comparisons will be made in terms of those functional units.

> Example: For a light bulb, the functional unit might be defined as: "light output of 800 lumens for 5000 hours" thus allowing a comparison of bulbs of differing brightness or lifetime in terms of the service that they provide.

However, the function of many products can not be so easily quantified. In the case of food products, one might attempt to define the product function as the ability to satisfy hunger, or provide a specific level of nutrition or caloric energy. Although these measures might be appropriate in some cases, food is frequently purchased simply for the enjoyment of consuming it, regardless of other functions that food may provide.

> Example: If the environmental impacts associated with two soft drinks are presented in terms of calories provided, producers of diet soft drinks would be penalized for their low-calorie drinks, and consumers would be encouraged to purchase products with the highest calorie density. Clearly, calories are not a useful functional unit, because soft drinks are not purchased primarily for the food energy they provide.

In cases where a product might serve multiple functions, the ISO life cycle assessment standard 14041 recommends that when product A performs an additional function not performed by product B, that either the additional function be excluded from the analysis, or be added to the boundary of product B's results to allow for an even comparison [43]. But this advice is not always feasible.

> Example: A bottle of shampoo formulation that also serves as a replacement for conditioner for hair serves two distinct functions. If the functional unit were defined as a single shampoo and conditioning, a comparison to a product that only provides the shampoo function would be difficult. Adding the delivery of the conditioning function to the second product would require an estimation of the average environmental impacts of conditioner. And excluding the conditioning function from the first product's assessment would make it impossible to compare with the results of products that only provide the conditioning function. In this case, the only logical choice of functional unit is probably the single package.

For personal care products, and many other products types which often lack information about serving sizes, consumers are already accustomed to making decisions considering the factors of price, product mass/volume, multiple functions, and their previous experience with how many uses a single package can be expected to provide. So a single package unit might also seem to be a logical choice for a functional unit, since this often forms the basis for another important comparison; price[17]. However, differences in product formulations and package sizes can make the package unit a less than ideal selection.

> Example: An assessment of laundry detergent, on a per package basis, would seem to favor those products with smaller package sizes (or at the very least, force one to recalculate the results.) This would have the unintended consequence of promoting packages containing less detergent, which even at a reduced price would benefit neither the environment, nor consumers.

As demonstrated above, there is no single functional unit that can be applied across the entire range of consumer products. A single package functional unit may be appropriate for some product types, while other product types may require a serving-size, or performance-based functional unit. For products whose primary function is unclear, or that perform multiple functions, the program goal of providing information about the absolute measure of environmental impacts makes the choice of functional unit more difficult than for a relative assessment of two products because the results for a product that does not perform a certain function can not be adjusted to include it. Therefore, the functional units used in the assessment conducted by this program must be defined separately for each product category, and according to ISO 14041, the functional unit "shall be consistent with the goal and scope of the study [43]."

> Key Recommendation: The choice of functional unit should be made separately for each product category.

> Key Recommendation: As a general guideline, for products which have a clearly defined primary function, whose alternatives are products in the same product category, and whose product performance/ number of uses/ serving size are determined objectively and clearly conveyed to the consumer, the functional unit shall be in terms of performance/ number of uses/ serving size. For products which do not meet these requirements, the functional unit shall be expressed in package units.

[17] Price is also often presented on a per product mass/volume basis. Without this "unit price" information, it is difficult to compare the value of products with different package sizes.

Determining the appropriate functional units for foods and beverages requires particular attention because of the wide range of product alternatives and package sizes and types. Fortunately, the subject of labeling food for nutritional information has already received much attention. This project will base the functional units for food and beverages on the most recent US Food and Drug Administration's (USFDA) definitions of serving size. These serving sizes are based on surveys of food portions in 129 food product categories that define "reference amounts customarily consumed per eating occasion (RACCs)[18] [44].

> Key Recommendation: The Functional Unit for each food and beverage category shall be expressed as the edible portion of the food (excluding bones, pits, etc…) in mass or volume units as a multiple of the RACC for that food category as defined by the U.S. Code of Federal Regulations, Title 21 Part 101 (Food Labeling)

The proposed method for determining an appropriate functional unit is shown graphically in Figure 3.1 and demonstrated with examples in the Table 3.1.

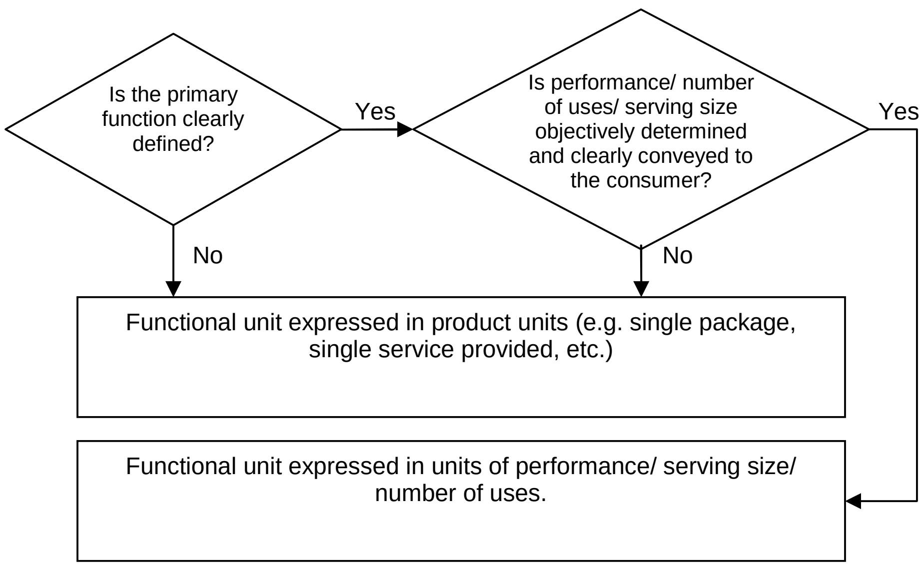


**Figure 3.1** Decision flow diagram for selecting functional units

[18] RACC is not the same as "serving size". RACC's are expressed in metric units, while serving sizes are required to be presented in terms of "a household measure most appropriate to their specific product."

| Example Product | Primary Function | Alternative Products | Performance/ Number of Uses/ Serving Size Marked on Packaging | Acceptable Functional Unit | Functional Unit Type |
|---|---|---|---|---|---|
| Three roll package of 500 sheet 1ply Paper Towel | Unclear (Absorb Water, Food napkin) | Cloth napkin, Paper napkin, Facial Tissue, etc… (different product categories) | Unmarked | - 1 three roll package | Package |
| Package of four 60 watt incandescent light bulbs | Provide Light | Florescent bulb (same product category) | Marked "800 lumens for 6000 hours" | - 1 lumen-hour of light | Performance |
| Package of Rigatoni Pasta 16oz. (454g) | Provide meal (Pasta included in one of the four FDA defined meal groups) | All other meal products[19] | Marked "Serving Size: 2 oz. (57g)" | - 8 servings (16 oz. or 454g)[20] | Serving Size (mass) |
| Bottle of Liquid Laundry Detergent 32 FL OZ (946 mL) | Clean fabric | Other Liquid Detergents, Powdered Detergents[21] | Marked "16 loads" | - 32 loads (a common size for liquid laundry detergent bottles) | Number of Uses[22] |
| Bottle of combined liquid laundry detergent and fabric softener (40 FL OZ (1.2 L) | Clean fabric, Soften fabric | Liquid Detergents, Powdered Detergents, Liquid Fabric Softener,- Fabric Softener Sheets, etc. | Marked "40 loads" | - 1 bottle 40 FL OZ (1.2 L) | Package[23] |
| 24 exposure Disposable Camera | Capture image on semi-permanent media | Film Cameras, Digital Cameras | Marked "24 exposure" | - 24 exposures (a common value for disposable cameras) | Number of Uses[24] |
| Digital Camera (with video capability) | Capture image on semi-permanent media | Film Cameras, Digital Cameras, Various Video Cameras | Unmarked | - 1 Package [25] | Package |

**Table 3.1** Examples of appropriate functional units for various products

In the cases of the pasta and the laundry detergent, the functional units based on serving size/ number of uses are the same as the package size. This allows the environmental declaration to convey the absolute environmental impacts of the product more directly to the user as outlined in the program goals.

> Key Recommendation: When the functional units are based on product performance/ serving size/ number of uses, the value should be scaled to match the most commonly available package size.

[19] Although alternate products in different food product groups may have different serving sizes, consumers will be expected, as when considering nutritional information, to account for the difference in serving size.

[20] In this case, the functional unit is most conveniently expressed as 8.25 times the RACC value of 55g, so that the most common package size (16oz.) is one functional unit.

[21] Combined detergent and fabric softeners would be assigned to a different product group

[22] A volume or mass based functional unit is not appropriate because differences between powder and liquid detergents, and concentrated/non-concentrated formulations.

[23] Although the number of uses is marked on the packaging, this product's primary function is not clearly defined, so a combination of alternative products with different definitions of 'use' might serve as a replacement. Therefore, for comparability with these alternatives, 'number of uses' should not be used as a functional unit.

[24] A package based functional unit could also be used, for consistency with non-disposable cameras. However, 'number of use' measure is generally preferable- See Key Recommendation.

[25] The only choice because of the uncertainty about the product performance/ number of uses.

In the case of the digital camera, the functional unit could have also been based on a single package containing the camera with pre-loaded film. The environmental declaration for a 36 exposure camera would then presumably be similar to that for a 24 exposure camera. This selection of functional unit is not ideal , since it does not highlight the environmental benefits of buying consumable items in bulk in order to reduce the environmental impacts associated with transportation and packaging.

Key Recommendation: When presented with a choice, a functional unit based on performance/ serving size /number of uses is preferable to one based on package units.

However, a number of use-based functional unit is not possible in the case of the digital camera because of the uncertainty in the number of uses.

Even using the method guidelines presented here, the choice of the most appropriate functional unit may still be uncertain. Discussion of these points, and which functional unit best satisfies the program goals should occur when the product category rules (PCR) are established. (see section 2.4.2 CREATION OF PRODUCT CATEGORY RULES for more detail)

*Product Systems and Product Boundaries*

For a life cycle assessment to fully account for all the environmental impacts of a product, the study boundaries would need to extend far enough to cover not only the entire ecosphere, but the technosphere as well due to the interconnected nature of transportation, energy, and production systems and underlying infrastructure. In the case of this program, there is insufficient time and resources to conduct such comprehensive studies. However, if system boundaries are set appropriately and consistently for each product, life cycle assessments can still be used as a basis for product evaluation. This program will consider the life cycle stages of production, transportation, use, and disposal when assessing products. These stages are defined as:

- Production Phase: All processes and flows related to the creation of a final product, including the extraction, processing, and transportation of raw materials and subcomponents.
- Transportation Phase: All processes and flows related to transporting a final product to the end user from the point of creation to the point of sale. This includes any transportation packaging materials that are not provided to the end user with the final product.
- Use Phase: All processes and flows of energy, resources, and emissions related to the use of a final product. This does not include accessory products. (e.g. batteries for a camera, or cooking oil for a cast-iron pan. The characteristics of these accessory products would be more appropriately presented in their own product declarations.)
- Disposal Phase: All processes and flows related to the disposal of a product, including transportation from the end user to the point of disposal.

The life cycle stages defined here account for all processes and flows related to a product, except for those associated with the transportation of the product by the end user from the point of sale, and those associated with accessory products required for the function of the evaluated product.

Defining the boundaries of the use phase in a product's life cycle can be challenging, because the interaction of several products in a product system is sometimes required to deliver a required product function. Here, the term *product system* is defined as: two or more products that operate together to provide a specified function or service. For example, a camera, film, batteries, and film processing service operate together as a product system to perform the function of capturing an image on a print. Because one of the goals of this program is to provide information about the significance of a product's absolute environmental impact, it is important that the boundaries of the various products in a product system do not overlap, because this would overestimate those products' actual environmental impacts. For the same reason, gaps between the boundaries of those products should also be avoided. A particular product boundary does not define the limits of the physical product, but rather defines which processes of the various life cycle stages belong to that product, and which do not.

> Example: The product boundary for a box of facial tissue might encompass the process of extracting fossil fuels for operating a chain saw to cut trees for paper production, and not include any of the processes related to transporting a purchased product from the point of sale to a consumer's home.

> Key Recommendation: When defining boundaries for the products in a product system, overlaps and gaps between the boundaries of the various products should be avoided.

Setting appropriate product boundaries for the production and disposal stages can also be challenging when recycled materials are involved, because it is difficult to say when a process involving recycled materials belongs to the disposed product, and when it belongs to the new product. This choice of boundaries can affect not only the life cycle assessment results for the products involved, but can also affect the relative environmental performance of different recycling scenarios. For example, producing paper from recycled pulp can result in more solid waste than when virgin wood is used. However, when paper is recycled, enough waste is diverted from landfills to more than offset the increased waste created from the use of recycled pulp [45]. This creates a dilemma that can be summarized as: 1) paper produced from virgin pulp has lower environmental impacts in some categories, 2) recycling paper reduces environmental impacts, and 3) paper can not be recycled if only virgin pulp is used to make new products. In this example, the net environmental impact is reduced if used products are recycled, and the recycled material incorporated in new products. Since a primary goal of this program is to reduce the total environmental impacts of producing and consuming products, the environmental declarations should in this case encourage consumers and producers to recycle and use recycled materials. This means:

- Paper products that are easily recycled should be rewarded.
- Paper products made from recycled material should also be rewarded.

The selection of boundaries for products that use recycled materials is illustrated in Figure 3.2. In Case A, the pulp recycling process is included within the new product's boundaries, but the paper recovery process is included with the old product. This is not an ideal choice, since the new product is penalized for the environmental impacts of the recycling process, but does not gain any benefit as a result of the waste diverted from recycling. In Case B, both the paper recovery and the recycling processes are associated with the old product. This is more desirable than Case A, since both the benefits of diverted waste, and the increased waste penalty from the recycling process are assigned to the old product. However, Case B not perfect, because the analysis does not reward the new product for incorporating recycled material. Case C, is the best choice for this program. Here, since both the benefit of diverted waste, and the penalty of the recycling process are assigned to the new product, producers will have an incentive to use recycled materials when there is a net environmental benefit, and avoid their use otherwise. Assigning the benefits of recycling to producers is logical at this time, since the market for recycled materials is often limited by the lack of demand.

> Key Recommendation: The system boundary for products that use recycled materials should include both the recovery and processing of the materials.

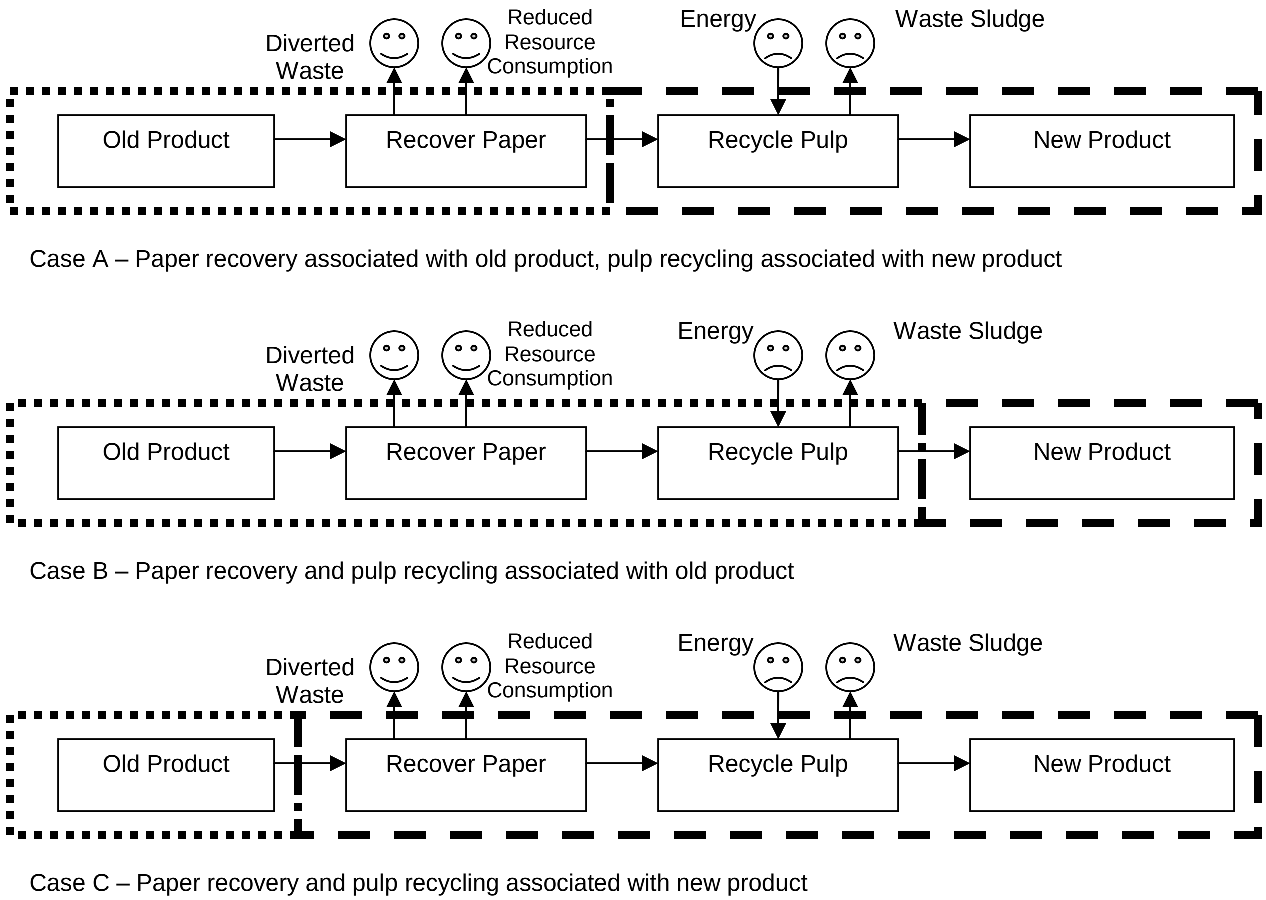


**Figure 3.2** Defining product boundaries considering recycled material

The method of setting boundaries for products that function as a system is shown graphically in Figure 3.3 and Figure 3.4. In the case of a 35 mm film camera, the function is clearly to capture an image on semi-permanent media. However, since it is not clear to the consumer the number of uses they might expect the camera to provide, the only choice of functional unit is a product unit. This can be illustrated by considering an average camera that can expose hundreds of rolls of film to a flimsy camera that becomes unusable after only a few dozen rolls. Without knowing the expected lifetime of either camera, an assumption based on the number of uses of an average camera would strongly favor the more flimsy camera, whose actual environmental impacts per exposure would be much higher than estimated. Although neither the number of use, nor the product-unit based functional unit will provide information about the flimsy camera's durability, the product-unit functional unit presents the information in a manner that is not misleading for the customer. In the same way that a shopper will consider durability when comparing the prices of two cameras, they might also consider product life-span when comparing environmental declarations.

For a camera, the product functional unit might include the camera itself, the packaging, instructional material, and any accessories included, such as a strap, a case, and a battery. It does not include replacement batteries, film, or film processing service. Therefore, although the film and replacement battery are physically installed in the camera body during the use phase, the camera product boundary is drawn to exclude them. (See Figure 3.3) Excluding these accessory products from the camera product boundary is not only necessary, as described above, but also logical since most consumers will likely consider film and batteries purchased years after the camera to be separate products. Some products in a product system can potentially be involved in the life cycles of more than one other product. Film, for example, is involved in the life cycles of both the camera, and the film processing service. Therefore, in order to avoid inconsistencies in product boundaries, it is important to clearly define all of the products in a product system, and set their individual boundaries during the initial establishment of the PCR.

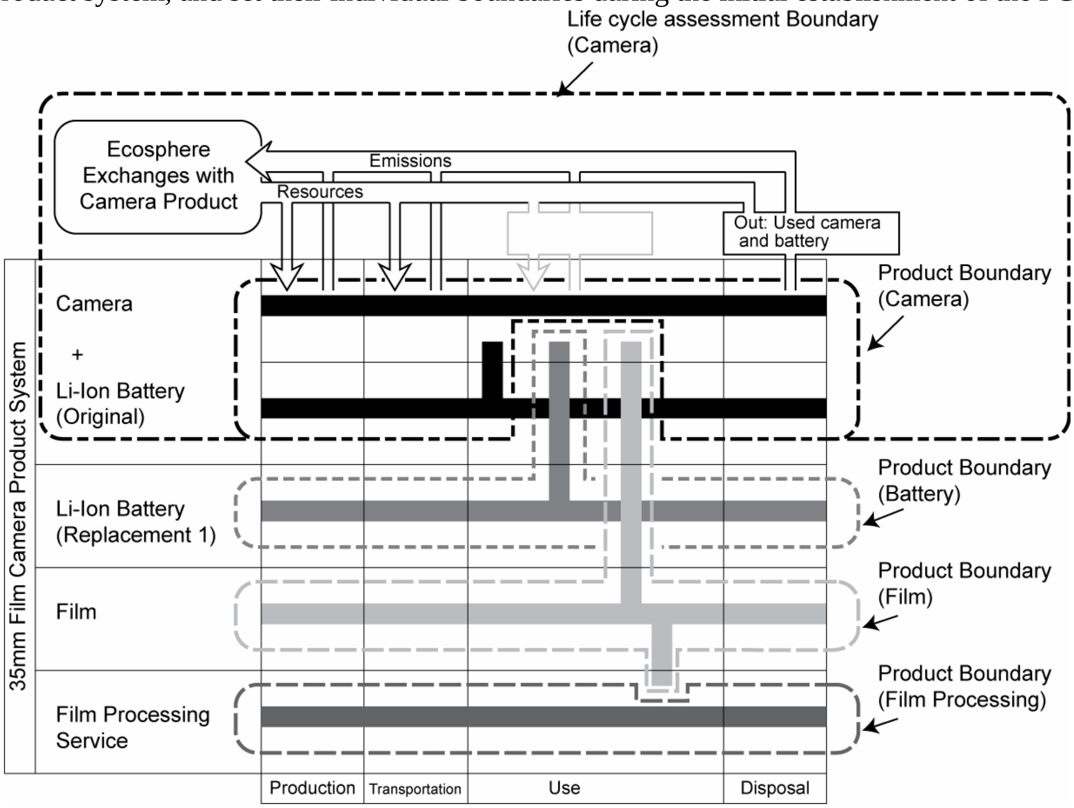


**Figure 3.3** Setting the LCA boundary for a camera within its product system

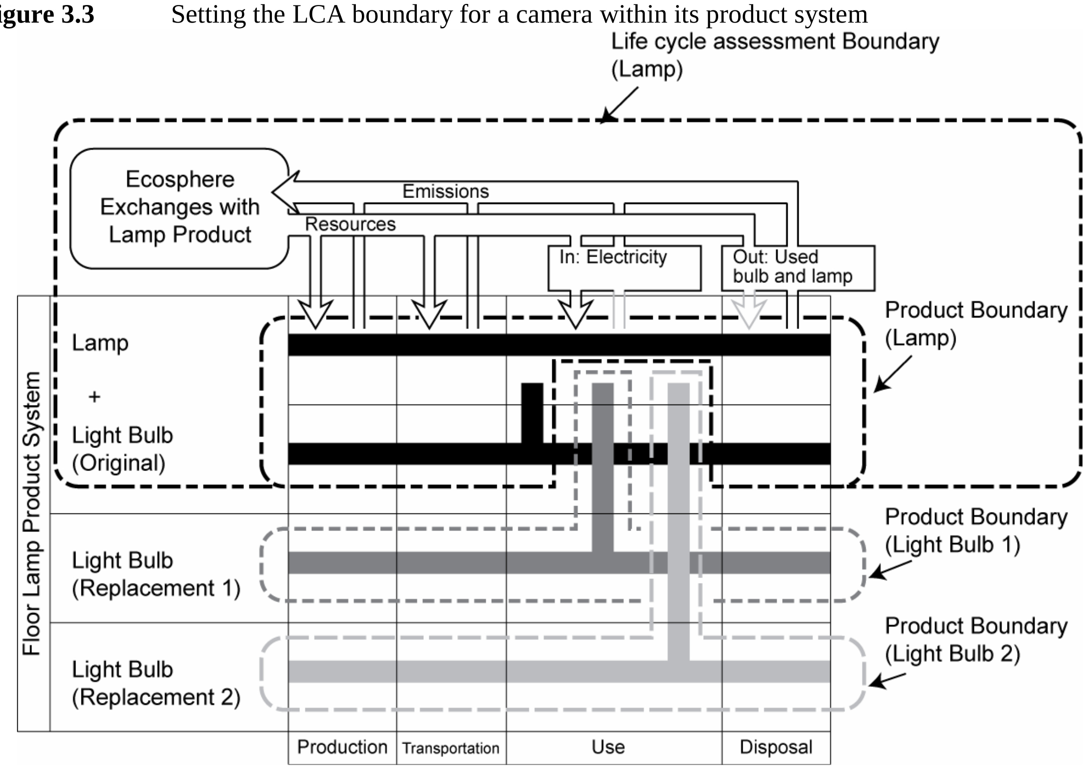


**Figure 3.4** Setting the LCA for a floor lamp within its product system

*Distinguishing between products produced at the same facility*

When several products are produced in the same facility, impacts such as land use, overhead energy use, etc. must be assigned to all the products produced there using a set of predetermined rules. These allocation rules define exactly which processes and materials are associated with each product made in that facility. The details of the allocation rules are subject to some debate[26] but the process of allocation is generally justifiable since it is clear that altering the process for a single product would alter the total impacts of that facility.

*Distinguishing between the product and the company*

However, the issue of allocating impacts becomes more complicated when a company's activities can not be associated with any particular product. For example, although a company that donates a certain percentage of its profits to rainforest conservation is making a real contribution to environmental protection, the environmental declaration can not include that activity unless the company can specifically identify the area of land that will be protected by the purchase of one product. This program will define corporate and marketing activity as those activities that can not be assigned to a single product and therefore lie outside of all product boundaries.

> Key Recommendation: Environmental impacts from company activities that can not be assigned to a single product are defined as "corporate and marketing activities", and are excluded from all product analyses.

However, if it can be shown that a quantifiable environmental impact is directly attributable to a single product, then the impact should be included in the analysis.

> For example, some airline companies have begun to offer emission credits to offset the greenhouse gas emissions of flying. If it can be shown that this policy results in a reduction in greenhouse gas emissions that would not have occurred if the passenger had not purchased the ticket, then the reduction in greenhouse gas emissions should be included in the analysis.

### 3.2.2 Life Cycle Inventory Analysis (LCI)

For a life cycle assessment, the phase involving the compilation and quantification of inputs and outputs for a given product system throughout its life cycle is known as a life cycle inventory analysis (LCI) [35]. For this program, the goal of the life cycle inventory analysis is to quantify the flows to and from the ecosphere across the product boundaries in order to estimate environmental impacts. Flows to the ecosphere are classified as emissions, and can be separated into emissions to air, water, and soil. Flows from the ecosphere are classified as resource flows, and include land use, water use, and non-renewable mineral and energy resource use. Flows of man-made materials and subcomponents are included within the product boundary, so that for these subcomponents, only process flows that are exchanged with the ecosphere as emissions or resource flows will cross the product boundary.

***Selection of Data for LCI***

Since it is not practical to model every single flow that crosses the product boundary, it is necessary to check that no significant flows have been excluded. The ISO standards for LCA recommend that the significance be defined in terms of the flow's mass, energy, environmental relevance, or a combination of

[26] For example, should impacts be allocated on a product mass basis, a product value basis, a floor space basis, etc.

these. Defining the significance of an emission simply in terms of its mass has obvious drawbacks, because of the potential to exclude highly toxic materials. Similarly, a judgment based only on the energy used by a particular process would exclude flows that have significant effects besides energy use. The environmental relevance of a flow would seem to be the ideal selection criteria for this program, but the same data limitations that prevent a full modeling of every flow also prevent an accurate assessment of every flow's environmental relevance. Because each of these criteria has a limited ability to estimate the significance of flows, this program will use a combination of mass, energy, and environmental relevance criteria.

> Key Recommendation: A combination of mass, energy, and environmental relevance criteria should be used to select which, if any flows can be excluded from further analysis.

When Product Category Rules (PCR) are first developed, the program administrator should collect information from committee members and previous LCA studies about materials and processes that may be of particular concern for that category, such as chemicals that are known to be highly toxic. This information should be regularly updated, and presented in the PCR as a list of items that can not be excluded from the life cycle inventory and life cycle assessment.

> Key Recommendation: The Product Category Rules (PCR) shall contain a list of materials and processes that can not be excluded from the analysis of products in that category.

***Product-specific and generic data***

Ideally, product-specific LCI data would available for every material and process along a product's entire production chain, and through every stage of the product's life cycle. But requiring producers to collect this information would be an unreasonable, even impossible burden. Conducting an analysis using only product-specific data would not be greatly beneficial either, since material and process differences become increasingly less significant to a product's total impacts as one moves further up the supply chain. Therefore, a boundary should be set to define when it is acceptable to use generic data and when product specific data should be used. This program applies the general rule to use specific-data when a material or process contributes significantly to a product's overall impact, or when the producer or consumer exercises a high degree of control over the use of a particular material or process.

> Key Recommendation: The use of product-specific data is generally preferable to generic data. Additional effort to use specific data should be made when the material or process contributes significantly to a product's overall impact, or when the producer or consumer exercises a high degree of control over the use of a particular material or process.

Because it is easier for applicants to submit non-specific data than specific data, it would be reasonable to create incentives to encourage the use of specific data. One possible incentive would be to adjust non-specific data so that it represents a conservative (higher) estimate of environmental impacts rather than the average value. The environmental impacts of an average product would therefore appear to be lower with the use of specific data. This method could be justified considering the uncertainty in the application of non-specific data. An extension of the "precautionary principle", which promotes action (or inaction) to avoid risk when given inconclusive evidence might support this penalization of uncertainty. However, because of the subjective nature of such a penalty, and the program goal to provide information about a product's absolute environmental impacts, such an adjustment to non-specific data will not be made at this time. Applicants will therefore have less incentive to submit specific data, especially when their product's performance is worse than the average. To avoid the situation where most applicants use generic data, thus making the results of one product indistinguishable from those of another product, the PCR will outline the processes for which specific data must be used.

> Key Recommendation: The Product Category Rules (PCR) shall contain guidelines for which life cycle stages and processes should be based on product-specific data.

The consideration of whether to use specific or non-specific data for the process of transporting a finished product from the producer to the customer at the point of sale presents some difficulty. Often these transportation impacts are significant, and they are at least partly controlled by the producer who can influence the mode of transportation. However, the applicant has no way of knowing the retail destination of every product. Even if every product could be evaluated separately, there would need to be a method of providing different product results to consumers at different locations. This program will allow printed labels to present the product results based on the transportation from the producer (or average producer location in the case of multiple facilities) to the average consumer location in the continental U.S. for that product. Alternative methods of presenting information to consumers, such as the internet, allow environmental declarations to be adjusted specifically for specific consumer conditions, such as the location of the purchase, and are discussed in more detail in the section on data presentation.

### 3.2.3 Life Cycle Impact Assessment (LCIA)

During the life cycle impact assessment (LCIA) phase of a life cycle assessment, the data compiled in the LCI phase are assigned to environmental impact categories, and for each category, an indicator is selected and an indicator result is calculated. The calculation of the indicator result consists of several steps:

- Classification – Assign the LCI results to the appropriate impact category
- Characterization – Aggregate the LCI data after converting the classified data to common units for that impact category. This conversion to common units requires the use characterization factors, which are dependent on the characterization model used.
- Normalization – Adjust the indicator results for each category using reference information in order to better understand the relative magnitude of each indicator result.[27]

***Normalization of Category Indicators***

Often, to make LCA results easier for consumers to intuitively understand, the impact category indicator results are presented after being normalized relative to a common reference Some examples of common reference values are:

- The total emissions or resource use for a given area
- The total emissions or resource use for a given area on a per capita basis
- A baseline scenario, such as a given alternative product system (This method might be useful for an internal company study to optimize their production processes)
- An average product within the same product category

[27] Although the normalization step is presented as "optional" in the ISO life cycle assessment standard [45], it is an important step in LCA for this program because of the program goal to provide information about the level of significance of the product's absolute environmental impacts.

- Target emissions or resource use for a given area based on scientific and/or political consensus.

By selecting an appropriate reference, this program can use the normalization process to present the results in a way that describes the product's absolute environmental impacts, according to the program goals.

| |
|---|
| Key Recommendation: Indicator results should be presented as values normalized relative to the total impact caused by the consumption activities of Americans in the year 2000 on a daily per capita basis. |

*Normalization methods used elsewhere*

Of the environmental impact indicators evaluated by this program, some are global in nature, such as climate change, and others effect regional and local areas. Therefore, it is not acceptable to select the emissions and resource use for a single area as a reference for normalization when the environmental impacts for the categories apply to different areas within and beyond the reference area. The CML guide to life cycle assessment addresses this concern and recommends that when different spatial scales are combined (local, global, and regional) [47]:

- Use only per capita normalization data.
- Base the normalization values for regional impact categories on the regions where the subject activities have taken place.
- If grouping or weighting is performed, group or weight the regionally normalized data using region-specific grouping methods and weighting factors.

The presentation of LCA results on a per capita basis is practiced by many of the programs discussed in section 3.3.2 CURRENT PROPOSALS FOR INDICATOR CATEGORIES , including the EDIP, Eco-Indicator '99, IMPACT 2002+ and CML methodologies. The Eco-indicator '99 method uses the concept of an *ecopoint*, defined as one thousandth the annual environmental load of an average European inhabitant to normalize damages [48]. The IMPACT 2002+ method, when presenting results as endpoint indicators, normalizes damages associated with a certain emission using the average individual average portion of the total emissions in Western Europe [49]. In the Danish Environmental Design of Industrial Products (EDIP) method, a different population is used to calculate normalization factors depending on the extent of the impact category. For example, impact categories with a global extent, such as the global warming, ozone depletion, and resource consumption use the world's population, while regional impact categories such as photochemical smog creation, acidification, eutrophication, and human and ecological toxicities, use Denmark's population to calculate normalization factors. The EDIP method also offers the option of using a per capita target impact for a future year as a normalization factor. These use factors are referred to as person-equivalent based on target emissions in the year 2000 ($PET_{2000}$), and are based on politically set targets [50].

The general formula for all per capita-based normalization factors for the *i*th impact category is:

$$\text{Normalization Factor}_i = \frac{\text{Total impact}_i \text{ for the area in question in the reference year}}{\text{Population in the inventorized area in the reference year}}$$

The normalized impact for that category is then expressed in units of (person* time)-1 as:

$$\text{Normalized Impact}_i = \frac{\text{Impact}_i \text{ of product}}{\text{Time period} \cdot \text{Normalization Factor}_i}$$

*Normalization method used for this program*

The technique of using different populations for the various indicators presents some problems when applied to a Type III environmental declaration program for use in the U.S. Because the U.S. per capita contribution to resource consumption and greenhouse gas emissions far exceeds the global average, using the total global impacts (e.g. GHG emissions) and world population only for these categories would underestimate the typical America consumer's impact, and thus exaggerate the severity of a product's impact in these categories relative to the regional categories. To avoid this concern, this program will use the American population for the calculation of the normalization factors in all impact categories.

The selection of an appropriate time period should consider the time period of the activity under study by the LCA. For Type III environmental declarations, this time period might be defined as the frequency with which a consumer purchases a product. While purchases of large appliances and vehicles may be purchased only every few years, consumer products are usually purchased on a nearly daily basis. Since it also offers consumers a convenient frame of reference for a single shopping trip, a time span of one day will be adopted by this program for normalization.

Therefore, for this program the normalization factor in the *i*th category is given by:

$$\text{Normalization Factor}_i = \frac{\text{Total impact}_i \text{ caused by the all consumption activity in the U.S. in the year 2000}}{365\,\text{days} \cdot \text{Population of the U.S. in the year 2000}}$$

Here the term Total Daily Individual Consumption Impact in the year 2000 ($TDCI_{2000}$) is defined as the environmental impacts that result from an average American's consumption activities. For the *i*th impact category, it is determined by the formula:

$$\text{TDCI}_{2000,i} = \frac{\text{Impact}_i \text{ of product}}{\text{Normalization Factor}_i}$$

Should personal transportation energy considered as consumption activity?

The largest contributor to the environmental impacts of most Americans is their personal transportation activity. The decision about whether or not to include this activity in the calculation of normalization factors might have a dramatic influence on the category indicator results. For example, excluding the impacts of personal transportation would make the results of all products seem more significant. This question is perhaps best answered by considering this program's method rule of avoiding gaps and overlaps between products within product systems. The purchase of gasoline to operate a vehicle would certainly be considered a product, and the environmental impacts of gasoline combustion would be included in the use phase of that product. Therefore, to avoid any overlap, the combustion of gasoline would not be included in the use phase of the vehicle. (However, for the purpose of comparing different vehicles, consumers should be able to evaluate the entire product system of gasoline and the vehicle over a time period of their choosing) It would be inconsistent to include some products of this system, such as the vehicle, in the normalization factor, while excluding others, such as gasoline. Therefore, personal transportation energy should be considered a consumption activity when calculating normalization factors.

### *Value-based Choices in Life Cycle Assessment*

It is sometimes necessary to make value-based choices when conducting a life cycle assessment. For example, when a life cycle assessment includes depletion of non-renewable energy resources, but does not include depletion of ground water, there is the implication that fossil fuels are valued higher by the LCA practitioner than drinking water. This is a concern since the personal values of those using the LCA results will not be the same as those inherent in the LCA. The inclusion of value-based choices is especially problematic during the impact assessment phase where data are aggregated and summarized. However, avoiding these choices entirely is not possible, since consumers would have little use for the raw numbers generated by the LCI phase. The ISO standard for life cycle assessment recognizes this situation, stating that "value-choices and assumptions made during the selection of impact categories, category indicators and characterization model should be minimized."

Key Recommendation: Value-based choices in life cycle assessment should be minimized. When possible, information should be presented in a way that allows the user to evaluate the results based on their own values. If unavoidable, value-based choices should be clearly described.

### 3.2.4 Interpretation of results

Because the goal of interpretation is to draw a conclusion and make final recommendations, this final phase of LCA is not appropriate for a program which aims only to provide consumers with information to assist their decision making process. However, companies that subject their products to a life cycle assessment will likely be interested in the interpretation phase, and they may use those recommendations to improve the product's environmental performance.

Key Recommendation: Because of differences in individual values and priorities, consumers should be presented with information to assist their decision making process, but not recommendations about which decision to make.

## 3.3. IMPACT CATEGORY INDICATORS FOR THIS PROGRAM

As stated earlier, the selection of impact categories requires that subjective, values-based decisions be made. Decisions about the inclusion, exclusion, and aggregation of impact categories reflect not only one's understanding about the issues that threaten the environment, but also how one prioritizes the balance between the present and the future, between humans and wildlife, and between oneself and the world.

An impact category is a class representing environmental issues of concern into which LCI results may be assigned. ISO defined the term "environmental mechanism" as all physical processes and variables which are connected with a given impact category. These processes and variables might include resource extraction, emissions, or other types of interaction between the product and the environment. [51].

Based on the latest scientific understanding of environmental issues, this section presents ten impact category indicators for use by this program. These are summarized in Table 3.5.

Key Recommendation: Life cycle analysis results should be presented in terms of ten impact categories: Climate change, Acid rain, Eutrophication, Photochemical smog creation, Ozone depletion, Human toxicity, Ecotoxicity, Land use, Water depletion, and Non-renewable resource depletion.

### 3.3.1 Category Endpoints and Number of Categories

Beginning in the 1990's, SETAC convened a series of working groups to identify best available practices for conducting LCA studies. In 1998, the second working group on LCIA (SETAC-Europe WIA-2) established a set of guidelines for the selection of impact categories [51]:

General starting point:

- Framework shall be developed which is open to further scientific progress and further detailing of information.

Starting points for the total of categories:

- The categories shall together enable an encompassing assessment of relevant impacts, which are know today (completeness).
- The categories should have the least overlap as possible (independence).

- The total of the impact categories should amount to a not too high number (practicality).

Starting points for separate impact categories:

- The category indicator can be chosen anywhere in the environmental mechanism of an impact category, from environmental interventions to category endpoints.
- The category indicator should (shall for comparative assertions) be modeled in a scientifically and technically valid way in relation to the environmental interventions, i.e., using a distinct identifiable environmental mechanism and/or reproducible empirical observation.
- The category indicator shall be environmentally relevant, i.e., it shall have sufficiently clear links to the category endpoints.
- It must be possible that characterization factors are multiplied with mass or other units indicating the magnitude of the environmental interventions.

For possible indicator types, the SETAC working group defined three levels in the environmental mechanism:

- environmental interventions - Particular extractions from, or emissions into the environment, or other variables at the boundary of the product system and the environment.

- category midpoints – variables in the environmental mechanism of an impact category between the environmental mechanisms and the category endpoints. (e.g. the concentration of toxic substances, the deposition of acidifying substances, etc.)

- category endpoints – variables which are of direct societal concern (e.g. human life span, incidence of species, fossil fuels and mineral ores, etc.)

The SETAC working group recognized that in the long run, it might be desirable to define all indicators at the endpoint level, resulting in a reduction in the total number of indicators to three or four. However, given the current level of scientific understanding of environmental impacts, this level of aggregation is not yet justifiable. Therefore, current life cycle assessment best practices allow the selected indicators to be presented at different levels in the environmental mechanism. For example, an indicator for acidification might be presented at the midpoint level (e.g. proton release), while an indicator for human health might be presented at the endpoint level (e.g. years of lost life, or YLL). When results are presented simultaneously for indicators at different levels, it is important to avoid overlaps or gaps between the various indicators' coverage of environmental impacts.

### 3.3.2 Current Proposals for Indicator Categories

***SETAC-UNEP Life Cycle Initiative***

As mentioned earlier, the SETAC and UNEP created the Life Cycle Initiative in an attempt to improve international comparability and methodological consistency of life cycle assessments. In 2003, the Initiative conducted a "user needs" survey to gather advice from LCA practitioners regarding which indicators should be included in life cycle assessment, and what the relative priority of those indicators should be. The international scope of the survey brought together the previously recognized practitioners from "traditional LCA countries" representing the values of Europe, North America, and Japan as well as practitioners from "non-traditional LCA countries" of Africa, Latin America and the Caribbean, and Asia and the Pacific. The results showed that several categories were widely accepted; Climate change, Acidification & Nutrification, Ozone Depletion, Human Toxicity, Ecotoxicity, and Photo-oxidant formation (Smog) were all classified as "Required" by more than 70 percent of respondents. However, indicators for salinization and erosion were cited as a unique concern by respondents from non-traditional LCA [52]. Results of this survey are summarized below:

Respondents were asked to classify impact categories as :"Required", "Nice to know", "Low Priority", or "No Opinion"
Results are classified as "Required" if more than 50% responded "Required". Results are classified as "Nice to know" if 70% responded "Required" or "Nice to know"

| Required | Nice to know | Low Priority |
|---|---|---|
| Climate Change | *Salinization | Health of workers |
| Ozone Depletion | *Erosion | Safety |
| Habitat loss as result of deliberate actions | *Soil Depletion | Landscape |
| Human toxicity | Habitat loss as a result of indirect actions | Extraction of biotic resources |
| Eco-toxicity | Noise | |
| Acidification and Eutrophication | Use of GMOs | |
| Photo-oxidants | | |
| Extraction of Minerals | | |
| Energy from Fossil Fuels | | |
| Nuclear Radiation | | |
| *** Water usage | | |
| * classified as "required" if only answers from non-traditional LCA countries are considered | | |
| ** classified as "nice to know" if only answers from non-traditional LCA countries are considered | | |
| *** Not in the initial list, but explicitly asked for by a number of respondents | | |

**Table 3.2** SETAC-UNEP user needs survey for LCA impact categories [53]

More recent activity by the SETAC-UNEP Life Cycle Initiative has focused on refining the recommendations into more concrete LCA guidelines [52] [53]. As of 2005, the Initiative's recommendations for indicator categories are similar to the "Required" list collected from the user needs survey, with the addition of categories for "Distribution of Invasive Species and GMO" and "Accidents" [54]. (See Table 3.2) Except for a few categories, the Initiative has still not reached a consensus on the best method for quantifying these indicators. The categories of Human toxicity, Eco-toxicity, and formation of Photo-oxidants in particular are the subject of ongoing discussions that reflect the difference of opinion between LCA experts from different regions, and the inherent uncertainties with any method.

### *Eco-Indicator '99*

Eco-Indicator '99 is an endpoint indicator methodology developed by PRé Consultants, an environmental consulting firm based in the Netherlands. The indicator was developed for use with their LCA software package, SimaPro, which is widely used around the world for environmental impact assessment. The goal of the Eco-Indicator '99 is the calculation of single scores by the aggregation of the three endpoint categories of Human Health, Ecosystem Quality, and Resources. Consistent with ISO requirements, PRé Consultants stipulates that the single score should only be used internally, and not for public comparisons, marketing,and ecolabelling. While PRé's Eco-Indicator '99 is clearly not appropriate for this program, it is still useful to refer to the midpoint indicators that are used in the calculation of the single score.

One interesting feature of the Eco-Indicator '99 is the application of Cultural Theory to adjust the results for different users depending on their individual values.[34] Hofstetter presented idea that the weighting factors in life cycle assessment could be adjusted depending on which of the five archetypal "ways of life" applied to the user. These archetypes include the fatalist, egalitarian, individualist, hierarchist, and autonomist. Autonomists, or those who isolate themselves from society, were excluded from further analysis. Some basic characteristics of the four remaining archetypes are in Table 3.3.

| | Hierarchist | Egalitarian | Individualist | Fatalist |
|---|---|---|---|---|
| **Perception of time** | Balanced distinction between short and long term | Long term dominates short term | Short term dominates long term | Involuntary myopia (short--sightedness) |
| **Future generations** | Resilient | Fragile | Self-sufficient | - |
| **Attitude towards risk** | Risk-accepting | Risk-aversive | Risk-seeking | - |

**Table 3.3** The four archetypes from Cultural Theory applied to LCA [34]

### *IMPACT 2002+*

The IMPACT 2002+ method was developed at the Swiss Federal Institute of Technology Lausanne (EPFL) under the direction of Dr. Olivier Jolliet, who also serves as the vice-chairman of the SETAC-Europe working group on impact assessment in LCA. The method converts the LCI data into four endpoint categories via 14 midpoint categories. While some of the midpoint characterization techniques were adapted from the Eco-indicator '99 and CML 2001 methodologies, IMPACT 2002+ utilizes agricultural and livestock production data rather than consumption surveys to estimate transfer of contaminants into human food, and average response data is used for human and eco-toxicities rather than conservative values. IMPACT 2002+ was developed so that either midpoints or endpoints can be normalized, and presented as final results [49].

### *CMLCA*

CMLCA refers to Chain Management by Life Cycle Assessment. CMLCA is not actually a life cycle assessment method, but a software tool developed by Reinout Heijungs at the Institute of Environmental Sciences (CML),University of Leiden, in the Netherlands. First released publicly in 2000, the software has continued to receive updates and revisions through 2004 and beyond. The software is notable because it is available free of charge to noncommercial users, and because the calculations are on matrix algebra, large databases, uncertainty parameters, statistical distributions, and Monte Carlo analysis can be quickly accommodated by an average desktop computer [55]. Although the software allows the practitioner to use various impact categories and characterization factors, including those of Eco-Indicator '99, Heijungs also included a set of impact categories based on the recommendations of the SETAC-Europe Working Group on Impact Assessment (SETAC WIA2) that will be considered here [47]. Notable among these are multiple subcategories for the Ecotoxicity indicator, and the inclusion of categories for nuisance odor and human casualties [47]. Otherwise, the impact categories are similar to those proposed by the SETAC-Europe working group.

### *EPA Framework for Responsible Environmental Decision-Making (FRED)*

The US EPA published a report outlining the Framework for Responsible Environmental Decision-Making (FRED) in 2000 to support Executive order 13101 which required the EPA to develop guidelines on environmentally preferable purchasing (EPP) for the federal government. The method was therefore specifically designed to produce results that can be used to compare the environmental performance of two products. The results are not, however, always appropriate for identifying absolute environmental impacts, as required for this program. For example, the ecotoxicity results are presented in terms of a TPB factor (Toxicity, Persistence, and Biomagnification), which is a unitless value for relative ecotoxicity that can not be easily normalized in order to understand its significance. The eight environmental indicators used in the EPA FRED method are similar to those used by the mainly European-developed programs described above, except that the FRED method includes water use and wood use subcategories in the Resource depletion category [56].

### 3.3.3 Indicator Categories Selected for this Program

Table 3.4 shows the category indicators that have been adopted by some well-established institutions in the field of life cycle assessment. This program will adopt the indicators identified as “required” in the SETAC-UNEP Life Cycle Initiative user needs survey (see Table 3.2), with a few of exceptions:

- The Acidification and Eutrophication category will be divided into two separate categories, “Acid Rain” and “Eutrophication”. This decision is consistent with the CMLCA method, and is necessary because there is not yet consensus within the LCA community about how to combine these two items into a single midpoint or endpoint indicator.
- Nuclear Radiation will not be considered. Although the effects of nuclear radiation on human health are of significant concern, it is not expected that this indicator would generate useful information for product comparison. The primary source of nuclear radiation is likely to be power generation during the production phase, and therefore the indicator result would depend more upon public policy and the country’s energy mix than on producer and consumer behavior. The number of products that directly cause exposure to radiation is expected to insignificant. However, if it is found that certain products create a high level of exposure, the Product Category Rules (PCR) can be modified to include the effects of radiation.
- “Loss of life support function” will be considered for the Land Use category, in addition to SETAC-UNEP’s “Habitat Loss” category. These two indicators will then provide information about the product’s impact on the ability of land to support human life through agricultural production in addition to the support of natural ecosystems.

| | This Program | SETAC-UNEP Life Cycle Initiative | Eco-indicator '99 | IMPACT 2002+ (midpoint indicators) | CMLCA SETAC-Europe (WIA2) | EPA FRED |
|---|---|---|---|---|---|---|
| **Natural Resource Depletion** | * | O | * | * | * | * |
| Water depletion | O | * | x | x | x | O |
| Non-renewable energy | O | * | O(e) | O | O | O |
| Mineral Extraction | O | * | O(e) | O | O | O |
| Wood depletion | x | x | x | x | x | O |
| **Human toxicity** | O | O | * | O | O | * |
| Human Toxicity- Cancer | * | ? | O(e) | | O | O |
| Human Toxicity-Noncancer | * | ? | x | | O | O |
| **Respiratory** | * | ? | o | | | |
| Respiratory (inorganics) | x | ? | | O | | |
| **Photo-oxidant formation** | O | O | | O | O | O |
| **Ionizing radiations** | x | ? | | O | O | |
| **Accidents/Casualties** | x | O(e) | | x | O(e) | x |
| **Noise** | x | O | | x | x | x |
| **Odor** | x | x | | x | O | x |
| **Climate change** | O | O | | O | O | O |
| **Stratospheric ozone depletion** | O | O | | O | O | O |
| **Land Use** | * | O | | * | * | * |
| Land competition | x | ? | | O | O | O |
| Loss of life support function | O | ? | | x | O | x |
| Loss of biodiversity | O | ? | | x | O | x |
| **Eco-toxicity** | O | O | | * | * | O |
| Aquatic ecotoxicity | * | * | | O | * | |
| *Freshwater aquatic ecotoxicity* | * | ? | | | O | |
| *Marine aquatic ecotoxicity* | x | ? | | | O | |
| *Freshwater sediment ecotoxicity* | x | ? | | | O | |
| *Marine sediment ecotoxicity* | x | ? | | | O | |
| Terrestrial ecotoxicity | * | * | | O | O | |
| **Acidification** | * | O | | * | O | O |
| Terrestrial acidification | x | * | | O | | |
| Aquatic acidification | O | * | | O | | |
| **Eutrophication** | * | O | | * | O | O |
| Terrestrial nutrification | x | * | | O | | |
| Aquatic eutrophication | O | * | | O | | |
| **Dispersal of invasive species & GMO** | x | O | | x | x | x |

**Table 3.4** Category indicators used in existing LCA methodologies

O - Results can be presented directly for this indicator; * - Consideration given for this indicator, but results can not be presented directly by aggregating or disaggregating other indicators; x - No consideration given for this indicator; ? - Undecided, or method under development; e – endpoint indicator.

The resulting ten main indicators selected for this program are summarized in Table 3.5.

| Impact Category | units | Normalization Factor (per person*day in the U.S. in 2000) | Description |
|---|---|---|---|
| **Climate Change** | gram CO2 equiv | 6.8876 10^4 | Emission of global warming gases converted to CO2 equivalents |
| **Acid Rain** | gram SO2 equiv | 284.08 | Emission of acid rain precursors converted to SO2 equivalents |
| **Eutrophication** | gram NO3- equiv | 164.30 | Emission of substances that contribute to nutrient enrichment of surface waters |
| **Photochemical Smog Creation** | gram C2H4 equiv | 61.866 | Emissions of smog precursors converted to C2H4 equivalents |
| **Ozone Depletion** | gram CFC11 equiv | 0.67178 | Emissions of ozone depleting gases converted to CFC-11 equivalents |
| **Human Toxicity** | | | Toxicity data combined with substance properties and multimedia fate model to estimate the length of time a compartment volume is contaminated |
| Contaminated Air | cubic meter Air*day | 2.9231 10^7 | |
| Contaminated Water | cubic meter Water*day | 5.3198 10^2 | |
| Contaminated Soil | cubic meter Soil*day | 1.8350 10^4 | |
| **Ecotoxicity** | | | Toxicity data combined with substance properties and multimedia fate model to estimate the length of time a compartment volume is contaminated |
| Contaminated Water | cubic meter Water*day | 4.0153 10^2 | |
| Contaminated Soil | cubic meter Soil*day | 1.0621 10^3 | |
| **Land Use** | | | Occupied land area weighted depending on ability to support biodiversity, or agricultural productivity |
| Agricultural Productivity | global Agricultural hectare | 6.0777 10^-3 | |
| Biological Diversity | global Biodiversity hectare | 6.0777 10^-3 | |
| **Water Depletion** | cubic meter Water depleted | 1.5873 | The volume of water used that is not returned to its original source in the same watershed |
| **Non-Renewable Resource Depletion** | | | The embodied energy of a resource, weighted depending on the energy required for extraction |
| Mineral Resource Depletion | megajoule equivalent | TBD | |
| Energy Resource Depletion | megajoule equivalent | 8.7265 102 | |

**Table 3.5** The ten main impact category indicators selected

### *Climate change*

*Description of indicator*

A combination of the direct emissions of greenhouse gases resulting from the production of the product, and the carbon sequestration change resulting from land use changes that are directly attributable to production. Because it is not realistic to identify the original land cover of an area before human intervention, land cover after land use changes will be compared to the land cover of the site immediately preceding the activity related to production. (E.g., land used for pasture would be compared to the previous agricultural use, rather than the original, forested condition) Changes in the amount of carbon sequestered will be divided by the lifetime of carbon dioxide gas in the atmosphere, and distributed over the life of the product.

*Characterization*

The Intergovernmental Panel on Climate Change (IPCC) was established by WMO and the United Nations Environment Program to scientifically assess the potential impacts of climate change, and recommend options for adaptation and mitigation. Among the accomplishments of the IPCC has been the determination of numerical values for the main green house gases for their potential to cause global warming, relative to the potential of carbon dioxide. These values for global warming potential (GWP) are periodically reviewed and revised by the IPCC, with the most recent values having been published in the IPCC's Third Assessment Report (TAR). Some sample GWP values from that report are shown in Table 3.6 [57].

| Gas | | Lifetime (years) | Characterization Factor = Global Warming Potential (GWP) (Time Horizon in Years) | | |
|---|---|---|---|---|---|
| | | | 20 yrs | 100 yrs | 500 yrs |
| Carbon dioxide | $CO_2$ | | 1 | 1 | 1 |
| Methane | $CH_4$ | 12.0 | 62 | 23 | 7 |
| Nitrous Oxide | $N_2O$ | 114 | 275 | 296 | 156 |
| HFC-23 | $CHF_3$ | 260 | 9400 | 12000 | 10000 |
| HFC-32 | $CH_2F_2$ | 5.0 | 1800 | 550 | 170 |
| $SF_6$ | | 3200 | 15100 | 22200 | 32400 |
| $CF_4$ | | 50000 | 3900 | 5700 | 8900 |
| HFE-125 | $CF_3OCHF_2$ | 150 | 12900 | 14900 | 9200 |

**Table 3.6** Climate change characterization factors

For many gasses, the time frame considered can have a dramatic impact on the calculated impact value. This program will consider a 100 year time horizon, which is consistent with the U.S. EPA's national greenhouse gas inventory reporting practices.

Accounting for land use
When land use changes occur as a result of activities related to a product's life cycle, it would be desirable to include the change in the GHG sequestration potential of a site in the product's environmental declaration. The IPPC Guidelines for National Greenhouse Gas Inventories identifies three sources and sinks that are affected by land use practices: aboveground biomass, belowground biomass, and soil carbon. At this time, this program does not have access to spatial data for specific land cover changes and how those changes would affect sequestration potential. Therefore, this program will not include consideration of the IPCC sectors of Agriculture and Land-Use Change and Forestry (LUCF) in product environmental declarations. However, in the future, if reliable data becomes available, changes in sequestration would ideally be included.

*Normalization*

The U.S. EPA publishes an annual report of the total U.S. greenhouse gas emissions and sinks. For emissions, the various compounds are aggregated into a total CO2 equivalent mass using the 100 year values for global warming potential (GWP) from the IPCC Second Assessment Report (SAR). However, since the release of the IPCC Third Assessment Report (TAR) in 2001, the EPA also lists TAR GWP values for comparative purposes. This program will use these TAR GWP values for normalization since they are consistent with this program's characterization method for climate change, and represent the latest scientific understanding of the subject. The EPA report summarizes GHG emissions according to sector, as shown in Table 3.7 [58].

| Sector | Year 2000 from TAR GWP (Tg CO2 equiv) |
|---|---|
| Energy | 6,009.3 |
| Industrial Processes | 325.6 |
| Solvent and Other Product Use | 4.6 |
| Agriculture | 471.4 |
| Waste | 264.0 |
| Total | 7,074.9 |
| Land-Use Change and Forestry | (690.2) |
| Net Emissions (Sources and Sinks) | 6,384.7 |

**Table 3.7** Total U.S. emissions GHG's in 2000 [58]

Because this program will not consider Land-Use Change and Forestry when calculating product impacts, this item will also be excluded from the normalization factor. Therefore, the normalization factor will be calculated as:

$$\text{Normalization Factor}_{\textit{Climate Change,US2000}} = \frac{7.0749 \cdot 10^{15}\,\text{g CO2 equiv.}}{365\text{days} \cdot 281{,}421{,}906\text{ persons}} = 6.8876 \cdot 10^{4}\,\text{g CO2 equiv.}(\text{person} \cdot \text{day})^{-1}$$

It should be noted that the methods used by the EPA for calculating the U.S. total emissions will not be exactly the same as those used by this program. For example, although the economic sectors in the table above can be generally related to consumer activities, some items considered by the EPA should not be, such activities related to the military. Additionally, the EPA method excludes the combustion of bunker fuels used in international shipping from consideration, whereas this program will include the contribution of international shipping to climate change.

***Photochemical smog creation***

*Description of indicator*

Ozone, when present at ground level, can degrade organic materials that are exposed to air, leading to respiratory problems in humans as well as causing damage to man-made structures and reducing crop yields. In the troposphere, ozone degrades rapidly, in a matter of weeks, and therefore can not rise though the atmosphere to counteract the effects of stratospheric ozone depletion. Ozone can be formed when volatile organic compounds, in the presence of oxides of Nitrogen (NOx) are exposed to sunlight. This ground level ozone is also commonly referred to as smog.

*Characterization*

Episodes of high concentrations of ground level ozone are of a local and regional nature, rather than global. In addition, the tendency for smog to form depends not only on the local concentrations of NOx and VOC gases, but also on the degree of sunlight exposure. Some LCIA methodologies have developed characterization factors for specific regions. However, at this time program does not consider local conditions for smog formation, although they may be incorporated in the future. This program will apply the EDIP method which uses characterization factors to convert emissions of VOC's to ethylene ($C_2H_4$) equivalents. Two factors are provided for each gas, one each for low and high background concentration of NOx. The high NOx value is intended for use at locations where the mean annual concentration of NOx is greater than 10 ppbv or 0.02 mg/m3 over rural areas. The low background NOx concentration will be used here, since this condition is representative of most of the area of the United States. An abbreviated list of these characterization factors is shown in Table 3.8.

| Substance emitted to Air | Chemical Formula | Characterization Factor Low NOx (g C2H4/g gas) | Characterization Factor High NOx (g C2H4/g gas) |
|---|---|---|---|
| Alkanes | | 0.40 | 0.40 |
| Methane | CH4 | 0.007 | 0.007 |
| Ethane | C2H6 | 0.1 | 0.1 |
| Propane | C3H8 | 0.5 | 0.4 |
| Alkenes | | 0.5 | 0.9 |
| Ethylene | C2H4 | 1.0 | 1.0 |
| Propylene | C3H6 | 0.6 | 1.0 |
| Aromatics | | 0.4 | 0.8 |
| Benzene | C6H6 | 0.4 | 0.2 |
| Toluene | (C6H6)CH3 | 0.5 | 0.6 |
| Alcohols | | 0.2 | 0.3 |
| Methanol | CH3OH | 0.2 | 0.1 |
| Ethanol | C2H5OH | 0.2 | 0.3 |
| Isopropanol | CH3CHOHCH3 | 0.2 | 0.2 |

**Table 3.8** Photochemical smog creation characterization factors [50]

*Normalization*

The U.S. EPA includes volatile organic compounds (VOC's) among six criteria pollutants for which it publishes emissions data. The estimated VOC emissions for the year 2000 are shown in the Table 3.9 [59].

| EPA Tier 1 Source Category | VOC Emission- Area Source (metric tons in the year 2000) | VOC Emission – Point Source (metric tons in the year 2000) |
|---|---|---|
| 01-Fuel Comb. Elec. Util. | 733 | 55,377 |
| 02-Fuel Comb. Industrial | 15,329 | 141,647 |
| 03-Fuel Comb. Other | 846,240 | 14,681 |
| 04-Chemical & Allied Product Mfg | 78,028 | 151,977 |
| 05-Metals Processing | 256 | 60,878 |
| 06-Petroleum & Related Industries | 287,885 | 100,816 |
| 07-Other Industrial Processes | 58,088 | 353,783 |
| 08-Solvent Utilization | 3,940,756 | 442,227 |
| 09-Storage & Transport | 970,771 | 96,096 |
| 10-Waste Disposal & Recycling | 353,044 | 23,873 |
| 11-Highway Vehicles | 4,831,119 | 0 |
| 12-Off-Highway | 2,398,316 | 14 |
| 14-Miscellaneous | 664,023 | 1,019 |
| Sub Total | 14,444,587 | 1,442,388 |
| Total | 15,886,975 | |

**Table 3.9** Total U.S. emissions of VOC's in 2000 [59]

Because the category indicator is measured in terms of ethylene ($C_2H_4$) equivalents, a characterization factor needs to be applied to the EPA data for VOC emissions before it can be used to calculate the normalization factor. This program will assume that the properties typical of alkanes are a sufficient estimate for the mixture of VOC emissions. The EDIP method assigns alkanes an equivalency factor of 0.4± 0.1 g $C_2H_4$/g alkane at both low and high background concentrations of NOx gas. An equivalent $C_2H_4$ value can then be calculated as [50]:

$$\text{Total U.S. VOC Emissions in 2000} = 0.4 \text{ g } C_2H_4/\text{g VOC} \cdot 1.5887 \cdot 10^{13} \text{ g VOC}$$
$$= 6.3548 \cdot 10^{12} \text{ g } C_2H_4 \text{ equiv}$$

And the normalization factor as:

$$\text{Normalization Factor}_{\textit{Smog Creation,US2000}} = \frac{6.3548 \cdot 10^{12} \text{ g } C_2H_4 \text{ equiv.}}{365 \text{days} \cdot 281{,}421{,}906 \text{ persons}}$$
$$= 61.866 \text{ g } C_2H_4 \text{ equiv.(person} \cdot \text{day)}^{-1}$$

***Ozone depletion***

*Description of indicator*

Depletion of the stratospheric ozone layer (not to be confused with ground level ozone creation) is a global-scale environmental impact that is a result of the breakdown of ozone gas in the stratosphere by emissions of halocarbons such as HCFC's, halons, and other gases containing chlorine and bromine that have long life-spans. The thinning of the ozone layer allows an increased amount of ultraviolet radiation from the sun to reach the earth's surface. The resulting increased exposure to UV light can increase the frequency of skin cancer in humans, and cause genetic damage to all life forms. In 1987, United Nations members signed the Montreal Protocol on Substances that Deplete the Ozone layer and agreed to eliminate the production and use of the most harmful ozone depleting substances in phases over the span of four decades [60]. The use of the most harmful substances, such as CFC-11, has already been largely phased out in the U.S. However, the use of replacement substances and methyl bromide in agriculture is still a cause for concern. However, as with the other indicators, the severity of this environmental concern will be periodically reviewed by the program administrator and if it is judged that ozone depletion no longer represents a significant concern, it may be removed consideration in the environmental declaration.

*Characterization*

The original Montreal Protocol grouped substances according to the potential damage they could cause to the ozone layer compared to the damage caused by CFC-11, considering their lifetime in the stratosphere and their reactivity. These Ozone Depletion Potential (ODP) values were listed in Montreal Protocol, and updated periodically to reflect the latest scientific understanding. The most recent publication by the World Meterological Organization (WMO) , the Scientific Assessment of Ozone Depeltion: 2002, made revisions to the ODP for some substances. This program will use the "Updated Semiempirical" ODP values from this report as characterization factors, since they offer the most recent and complete list. The Montreal Protocol will be used to obtain values that were not updated by this report. A selection of these characterization factors is shown in Table 3.10 [61].

| Substance | | | Characterization Factor = Ozone Depletion Potential (g CFC-11/g substance) |
|---|---|---|---|
| CFC-11 | CCl3F | Trichlorofluoromethane | 1.0 |
| CFC-12 | CCl2F2 | Dichlorodifluoromethane | 1.0 |
| CFC-113 | C2F3Cl3 | 1,1,2-Trichlorotrifluoroethane | 1.0 |
| CFC-114 | C2F4Cl2 | Dichlorotetrafluoroethane | 0.94 |
| CFC-115 | C2F5Cl | Monochloropentafluoroethane | 0.44 |
| Halon 1211 | CF2ClBr | Bromochlorodifluoromethane | 6.0 |
| Halon 1301 | CF3Br | Bromotrifluoromethane | 12 |
| CFC-13 | CF3Cl | Chlorotrifluoromethane | 1.0 |

**Table 3.10** Ozone depletion characterization factors [50]

*Normalization*

Because halocarbons also contribute to climate change, the EPA was required by the Clean Air Act Amendments of 1990 to list the global warming potentials of ozone depleting substances (class I and class II controlled substances) [62]. Emissions for these substances continue to be reported in the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks. For Class I and II substance for which U.S. emissions in the year 2000 exceed 0.05 Gg [63]:

| Substance | Emissions (Gg) (Year 2000 U.S.) | Ozone Depletion Potential (g CFC-11/g substance) | Emissions (Year 2000 U.S.) (Gg CFC-11 equiv.) |
|---|---|---|---|
| CFC-11 | 22.8 | 1.0 | 22.80 |
| CFC-12 | 17.2 | 1.0 | 17.20 |
| CFC-115 | 2.3 | 0.44 | 1.01 |
| Halon-1211 | 1.1 | 6.0 | 6.60 |
| Halon-1301 | 1.3 | 12.0 | 15.60 |
| HCFC-22 | 79.1 | 0.05 | 3.96 |
| HCFC-123 | 1.1 | 0.02 | 0.02 |
| HCFC-124 | 6.5 | 0.02 | 0.13 |
| HCFC-141b | 10.9 | 0.12 | 1.31 |
| HCFC-142b | 5.4 | 0.07 | 0.38 |
| | | Total | 69.01 |

**Table 3.11** Total U.S. emissions of selected ozone depleting substances in 2000 [63]

It should be noted that the EPA inventory does not include all non-Class I and II ozone depleting substances such as methyl bromide is not included. If reliable data for U.S. emissions for methyl bromide can be found, the program administrator should consider its inclusion for calculation of the normalization factor.

Based on the total emissions of ozone depleting substances in the U.S. in the year 2000,

$$\text{Normalization Factor}_{Ozone\ Depletion, US2000} = \frac{6.901 \cdot 10^{10}\ \text{g CFC-11 equiv.}}{365\text{days} \cdot 281{,}421{,}906\ \text{persons}}$$
$$= 0.67178\ \text{g CFC-11equiv.}(\text{person} \cdot \text{day})^{-1}$$

***Eutrophication***

*Description of indicator*

While the cycling of nutrients is essential to the functioning of all ecosystems, an excess of nutrients can cause a disruption of the natural process. Ecosystems are limited in their growth by either nitrogen (N) or phosphorous (P) as a nutrient, and increase in the limiting nutrient can have severely negative consequences. In aquatic ecosystems, the excess growth of algae or plants can result in a zone of oxygen depletion in the bottom strata where the plant matter is decomposed . On land, excess nutrients can disrupt some unique ecosystems that are normally nutrient-poor, such as bogs. The main source of nutrient enrichment in the U.S. is application of agricultural fertilizers in excess of a crop's ability to take up those nutrients, and their subsequent run-off to surface waters. Oxides of Nitrogen from the combustion process also contribute to nutrient enrichment.

*Characterization*

The phenomenon of nutrient enrichment is a local and regional phenomenon rather than a global one. Whether or not adverse affects will be seen depends on which is the limiting nutrient for the specific land area or body of water under study. The EDIP method provides two different sets of characterization factors for nutrient enrichment; one with N as a limiting nutrient, and with P as a limiting nutrient. Since this program does not currently have spatial data that provides this information, a combined characterization factor will be used that presents all nutrients in terms of nitrate (NO3-) equivalents. These characterization factors from the EDIP method are shown in Table 3.12. [50]

| Substance | | Characterization Factor = Eutrophication Potential (EP) (g NO3-/g substance) |
|---|---|---|
| N-Compounds | | |
| Nitrate | NO3- | 1.00 |
| Nitrogen dioxide | NO2 | 1.35 |
| Nitrite | NO2- | 1.35 |
| Nitrogen oxides | Nox | 1.35 |
| Nitrous oxide | N20 | 2.82 |
| Nitric oxide | NO | 2.07 |
| Ammonia | NH3 | 3.64 |
| Cyanide | CN- | 2.38 |
| Nitrogen, total | N | 4.43 |
| P-Compounds | | |
| Phosphate | PO4-3 | 10.45 |
| Pyrophosphate | P2O7-2 | 11.41 |
| Phosphorous, total | P | 32.03 |

**Table 3.12** Eutrophication characterization factors [50]

To assume that all nutrients emitted to the air and soil will eventually end up in the water would exaggerate the potential dangers of nutrient enrichment. Therefore, it is necessary to make some assumptions regarding how the various emissions of nutrients are partitioned to the air, water, and soil compartments. Ideally, local conditions, such as soil type, slope, precipitation, and proximity to surface water would be evaluated when estimating nutrient enrichment. A nutrient mass balance can be conducted over a limited area, as was done in a U.S. Geological Survey (USGS) study to evaluate the Nitrogen Mass balance over a 212km2 area in west-central Minnesota [64]. However, at this time, it is not practical for this program to conduct such a detailed analysis for nutrient enrichment. Instead, the emissions will be partitioned into the three compartments using the fugacity method with an assumption for an average ratio of surface water area to total area. (see the Human toxicity indicator method description for more detail)

*Normalization*

Although the U.S. EPA publishes comprehensive data for water quality, and nutrient content, it is not possible to use this data to estimate an annual loading of nutrients from all activities in the U.S. To estimate the total annual nutrient enrichment for the U.S., this program will use an original method to estimate nutrient enrichment from agricultural fertilizer usage. Some assumptions made in this estimation are:

- All nutrient enrichment comes from excess agricultural fertilizer application
- Nutrients that are not taken up by plant growth will eventually run-off to surface waters
- The nutrient requirements of corn are typical of all crops grown in the U.S.
- Nutrient enrichment that occurs outside of the U.S. as a result of American's consumption activities are ignored.
- Cropland soil nutrients are in equilibrium, neither being depleted, not supplemented.
- Nitrogen fixation from legumes is ignored

Assuming corn as a typical crop, by using data supplied by the U.S. Department of Agriculture (USDA) for the average crop yield, fertilizer application, and crop nutrient requirements, the rate of excess nutrient application can be estimated [65]. Then, from the USDA data for the total mass of N and P applied to all American crops, and the excess nutrient application rate, it is possible to estimate the total nutrients emitted to U.S. surface waters. The calculation is conducted as follows:

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$$\text{Fraction Excess Phosphate Applied}_{Corn,US} = \frac{490\text{lb } P_2O_5 \text{ applied per acre - } 410 \text{ lb } P_2O_5 \text{ removed per acre}}{490\text{lb } P_2O_5 \text{ applied per acre}}$$

$$= 0.163$$

$$\text{Total Excess Nitrogen Applied}_{US,2000} = 0.343 \cdot 1.1153 \cdot 10^{13} \text{ g N} \cdot 1.0 \text{ g } NO_3^- \text{equiv/g N}$$

$$= 1.8210 \cdot 10^{12} \text{ g } NO_3^- \text{ equiv}$$

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$$\text{Total Excess Nutrients Applied}_{US,2000} = 1.8210 \cdot 10^{12} \text{ g } NO_3^- \text{ equiv} + 1.5056 \cdot 10^{13} \text{ g } NO_3^- \text{ equiv}$$

$$= 1.6877 \cdot 10^{13} \text{ g } NO_3^- \text{ equiv}$$

$$\text{Normalization Factor}_{Eutrophication,US2000} = \frac{1.6877 \cdot 10^{13} \text{ g } NO_3^- \text{ equiv.}}{365\text{days} \cdot 281{,}421{,}906 \text{ persons}}$$

$$= 164.30 \text{ g } NO_3^- \text{equiv.} (\text{person} \cdot \text{day})^{-1}$$

In the future, this method could for calculating the normalization factor could potentially be made more accurate by:

- Calculating excess nutrient ratios for several major crops, and weighting them according the amount of fertilizer applied to the respective crops
- Including the nitrogen fixation of legumes
- Including nutrient enrichment from air emissions of oxides of Nitrogen

### *Human toxicity*

*Description of indicator*

Human exposure to chemicals that are released into the environment as a result of human activity can cause toxic effects that are damaging to health. The properties of a chemical and the conditions under which it was released will largely determine how it disperses into the environment, and how long it will remain a threat. Exposure to toxins can occur via inhalation, ingestion, and dermal routes. For environmental toxins[28], inhalation of contaminated air and oral ingestion of food are considered the most important exposure routes[50].

[28] Environmental toxins are defined by this program as distinct from workplace toxins which might be encountered by workers during the production process. These workers are considered to be outside of the LCA system boundary because in contrast to the public's ability to deliberately avoid harmful exposure to environmental toxins, safety practices to avoid potential exposure to workplace toxins are generally effective and more well-defined by law. (e.g. OSHA in the U.S.)

*Characterization*

Environmental toxins are dispersed into the environmental compartments of air, water, and soil on both local and regional scales. Therefore, an estimation of the potential health impacts to any specific population would have to include not only a model of the fate and transport of toxins over a region, but also involve consideration of that population's demographics and distribution over the study area. This type of analysis is considered an Environmental Risk Assessment (ERA), and although suitable for specific case studies is not appropriate for a Type III declaration program because of the intensity of the analysis, and lack of information about the background distribution of contaminants in the environment. Hazard identification is a simpler tool than risk assessment (actually is a first step in ERA), with which the damaging effects of exposure to a chemical are identified without considering the probability of exposure. This approach ignores such important factors as potential intermedia transfer of toxins (e.g. evaporation from water to air) and the length of time required for a chemical to break down. Therefore, hazard identification is considered to be too simple for meaningful product evaluations when used by itself.

This program will use a hybrid method between hazard identification and risk assessment that combines a multimedia fate model for a substance with the toxicity data for that substance. As a result, the human toxicity indicator gives some consideration to the potential exposure and harm to human health, but without the intensive modeling requirements of a full risk assessment. The method used by this program has been adapted from the EDIP method and is summarized here.

*Characterization - Screening*

The characterization process for toxicity can be time consuming, and with many different chemicals potentially emitted during a product's life cycle, it is helpful to screen for chemicals that are believed to present minimal risk to human health. The European Commission, an institution of the European Union, maintains a list of about five thousand dangerous substances in Directive 67/548/EEC (Directive on the classification, packaging, and labeling of dangerous substances). For each of these chemicals, the Directive provides Risk Phrases that summarize the damaging health effects that may occur as a result of exposure to the chemical [66]. The EDIP method assigns a toxicity score to a chemical based on the most severe health risk from 67/548/EEC using weighting factors. An exposure score is separately determined, and given a value of 8 if the risk phrases R53 (May cause long-term adverse effects in the aquatic environment) or R58 (May cause long-term adverse effects in the environment) are applied to the chemical, and a value of 4 otherwise. A toxicological impact score is then calculated for use as the screening value as the product of the exposure and toxicity scores. A chemical with a toxicological impact value of eight, or a chemical which is not listed in 67/548/EEC is considered as contributing to human toxicity in the environment, and thus requires further analysis. For details of the screening method, refer to the EDIP methodology [50]

The screening factor for benzene is calculated here as an example:

| Chemical Name : Benzene | CAS Number: 00071-43-2 |
|---|---|
| 67/547/EEC Risk Phrase | Human Toxicity Score (from EDIP method) |
| F; R11 | |
| Carc. Cat. 1; R45 | 8 |
| Muta. Cat. 2; R46 | 8 |
| T; R48 | 8 (when present with R23,R24,R25) |
| T; R23 | 4 |
| T; R24 | 4 |
| T; R25 | 4 |
| Xn; R65 | |
| Xi; R36 | 1 |
| XI; R38 | 1 |

| |
|---|
| Highest Toxicity Score : 8<br>Exposure Score : 4 (risk phases R; 53 and R; 58 are not listed)<br>Toxicological impact score : 4 x 8 = 32<br>Conclusion : The toxicological impact score is greater than 8, so the characterization analysis should continue. |

*Characterization - Partitioning emissions into environmental compartments*

Assuming that the results of the screening step indicated further analysis is required, the next step is to determine which environmental compartment, air, water, or soil, a substance will finally settle. The EDIP method for partitioning is simple and requires only a few basic chemical properties in order to guarantee that the greatest number of chemicals can be included. These chemical properties and those required for the remainder of the characterization process are shown in Table 3.13 below with their sources.

| Chemical Property | Data Source<br>(all models are available in the EPA's EPIWIN v3.12 software) |
|---|---|
| Atmospheric half-life | BIOWIN v4.02 (Level III Fugacity Model) |
| Henry's Law Constant | HENRY v3.10 Model |
| Octanol-Water Partitioning Coefficient (Kow) | STP Fugacity Model |
| Molecular Weight | Available from a variety of sources |
| Soil Sorption Coefficient (Koc) | PCKOC v1.66 Model |

**Table 3.13** Chemical properties required for human toxicity potential

The fraction of the chemical that is partitioned to each compartment is represented by a value from 0 to 1, and is given by $f_a$ (fraction partitioned to air), $f_w$ (fraction partitioned to water, and $f_s$ (fraction partitioned to soil). Refer to the EDIP method instructions for a more detailed explanation of the partitioning calculations [50].

The method used by this program for calculating partitioning is demonstrated here using the examples of benzene emissions to air, water and soil.

| |
|---|
| Chemical Name : Benzene CAS Number: 00071-43-2<br>Atmospheric half-life : 208.7 hours<br>Henry's Law Constant (H) : 0.00539 atm m3/mol<br>Ratio of surface water area to total regional area (a) : 0.2 (assumed constant for U.S.)<br>For emissions to air: Is atmospheric half-life greater than 24 hours?<br>Yes. Therefore, fa = 1, fw = a = 0.2, fs = 1-a = 0.8<br>For emissions to water: Is H > 10-3 atm $m^3$/mol?<br>Yes. Is atmospheric half-life greater than 24 hours?<br>Yes. Therefore, fa = 1, fw = a = 0.2, fs = 1-a = 0.8<br>For emissions to soil: Is H > 10-3 atm $m^3$/mol?<br>Yes. Is atmospheric half-life greater than 24 hours?<br>Yes. Therefore, fa = 1, fw = a = 0.2, fs = 1-a = 0.8<br>Note that in this case, because benzene is volatile (H>10-3 atm $m^3$/mol) and relatively long-lived, it is able to transfer easily between the compartments so that the partitioning results are the same regardless of the compartment into which the chemical is released. Also, the sum of the various partitioning coefficients can be greater than 1 in this case because benzene emitted to air can cause inhalation exposure in addition to ingestion exposure after it is deposited to soil and water. |

*Characterization - Estimating exposure*

After a chemical is present in an environmental compartment, humans can be exposed by either directly ingesting or inhaling it, or by consuming food products to which the chemical has been transferred. The type and amount of food an average person consumes, expressed as an intake factors (I), will therefore influence the exposure to toxic chemicals. Table 3.14 summarizes the intake factors used by this program.

| Compartment | Exposure Route | Intake Factor (I) | Units |
|---|---|---|---|
| Air | Direct | 1 | - |
| Water | Fish | 3.71x10-4 | kg fish/kg bw·day |
| Soil | Direct | 2.86x10-6 | kg soil/kg bw·day |
| | Plants | 9.30x10-3 | kg plant/kg bw·day |
| | Meat | 1.53x10-3 | kg meat/kg bw·day |
| | Dairy products | 1.32x10-2 | kg dairy products/kg bw·day |
| Groundwater | Direct | 2.86x10-2 | kg water/kg bw·day |

**Table 3.14** Human toxicity - Intake factors from EDIP method[29] [50]

The transfer of a chemical to food products depends such factors as the octanol-water partitioning coefficient (Koc) to estimate the likelihood of substances binding to food and the coefficient of adsorption (kd) to estimate how easily a chemical in the soil will be taken up by a plant. For a more detailed explanation of the exposure calculation methods, refer to the EDIP documentation [50]. The example of benzene partitioned to the air, water, and soil compartments is continued here.

Chemical Name : Benzene CAS Number: 00071-43-2

Soil organic carbon content ($f_{oc}$) : 0.002 kg/kg (EPA Region III default value) [67]

Soil Sorption Coefficient ($K_{oc}$) : 165 l/kg

Octanol-water partitioning coefficient ($K_{ow}$) : 134.90

The bioconcentration (BCF) factor, to estimate the tendency of a chemical to accumulate in fish:

$$BCF = 8.7 \text{ L water/kg fish}$$

Stem Concentration Factor (SCF) : for organic, non-ionic substance at pH 7 :

$$SCF = \left(0.82 + 10^{(0.95 \log K_{ow} - 20.5)}\right) \cdot \left(0.748 e^{-\left[\left(\log K_{ow} - 1.78^2\right)/2.44\right]}\right)$$
$$= 2.92718$$

Meat (beef) transfer factor ($B_b$) : for organic, non-ionic substance :

$$B_b = \log P_{ow} - 7.6$$
$$= 3.4 \cdot 10^{-6}$$

Milk transfer factor ($B_m$) : for organic, non-ionic substance :

$$B_m = \log P_{ow} - 8.1$$
$$= 1.1 \cdot 10^{-6}$$

Coefficient of adsorption ($k_d$) : for organic, non-ionic substance at pH 7 :

$$k_d = f_{oc} \cdot K_{oc}$$
$$= 0.33 \text{ L/kg}$$

Transfer factor from direct soil consumption ($T_{s,d}$) :

$$T_{s,d} = 1$$

Transfer factor from soil to plants ($T_{s,p}$) :

[29] The EDIP intake factors are determined from average food consumption in Denmark (Danish National Food Agency, 1990). Intake factors more suitable for the U.S. could also be easily calculated.

$$T_{s,p} = \frac{SCF}{k_d + \frac{0.4}{1.5}}$$

$$= 4.9059 \text{ kg dry matter soil/kg plant}$$

Transfer factor from soil to meat (beef) ($T_{s,b}$) :

$$T_{s,b} = \frac{16.9 \cdot B_b \cdot SCF}{k_d + \frac{0.4}{1.5}} + 0.41 \cdot B_b$$

$$= 2.82 \cdot 10^{-4} \text{ kg dry matter soil/kg meat}$$

Transfer factor from soil to milk ($T_{s,m}$) :

$$T_{s,m} = \frac{16.9 \cdot B_m \cdot SCF}{k_d + \frac{0.4}{1.5}} + 0.41 \cdot B_m$$

$$= 8.93 \cdot 10^{-5} \text{ kg dry matter soil/kg dairy products}$$

Transfer factor from water to fish ($T_w$) :

$$T_w = BCF$$

$$= .0087112 \text{ m}^3 \text{ water/kg fish}$$

*Characterization - Calculating Human Toxicity Factors*

A toxicity factor represents the volume of an environmental compartment required to dilute one gram of a chemical to a sufficiently low concentration so that exposure would result in no toxic effects. For the air compartment, the Human Toxicity Factor ($HTF_a$) is the reciprocal of the Human Reference Concentration (HRC), which is the highest concentration of a substance in air expected not to cause any toxic effect from life-long inhalation by humans. For the water and soil compartments, the Human Toxicity Factors (HTFw, HTFs) are the reciprocal of the Human Reference Dose (HRD), which is the largest quantity of a substance expected not to cause any toxic effect from life-long ingestion by humans.

Values for HRD and HRC are obtained from the U.S. National Library of Medicine's online database, TOXNET, through which the Hazardous Substances Data Bank (HSDB) is available. Because studies of the human effects are not available for most chemicals, these databases are mainly composed of animal test data. The EDIP method assigns various uncertainty factors based on the type of toxicity test data in order to take into account the difficulty in extrapolating animal test data to humans.

| Uncertainty Factor | Available Toxicity Test Data |
|---|---|
| $10^5$ | Extrapolation from $LC_{50}$ or $LD_{50}$ from tests on animals |
| $5x10^4$ | Extrapolation from $LC_{LO}$ or $LD_{LO}$ from tests on animals |
| $10^4$ | Extrapolation from LOAEL from sub-chronic (duration < 1 year) tests |
| $5x10^3$ | Extrapolation from $LC_{LO}$ or $LD_{LO}$ in observations of acute toxicity to humans |
| $10^3$ | Extrapolation from NOAEL from sub-chronic tests or extrapolations from LOAEL from chronic tests for toxicity (duration ≥ 1 year) |
| $10^2$ | Extrapolation from NOAEL from validated chronic tests on animals (duration > 1 year) or extrapolated from LOAEL studies on humans or extrapolated from lowest irritant concentration when inhaled by humans |
| 10 | Extrapolation from NOAEL found in validated experimental chronic studies on humans |

**Table 3.15** Human Toxicity - Uncertainty Factors for HRC and HRD [50]

For the example of benzene:

Chemical Name : Benzene CAS Number: 00071-43-2

From the Hazardous Substances Data Bank (HSDB), the LD50 for rats though inhalation is 10,000ppm/7hr, or 31947 $mg/m^3$. If other test data were available, the minimum value would be selected. However, there is no additional test data of any type for inhalation, and because this data is an LD50 result from animal testing, an uncertainty factor of $10^5$ is used.

To calculate the Human Reference Concentration (HRC):

$LD_{50,inhalation} = 31947\ mg/m^3$

Uncertainty Factor = $10^5$

$$HRC = {LD_{50,inhalation}} \big/ {Uncertainty\ Factor}$$

$$= 0.31947 mg/m^3$$

Also from the HSDB, the $LD_{50}$ for rats through ingestion is 3306 mg/kg body weight. And again, because this is $LD_{50}$ data from animal testing an uncertainty factor of $10^5$ is used.

To calculate the Human Reference Dose (HRD):

$LD_{50,ingestion} = 3306\ mg/\ (kg\ bw \cdot day)$

Uncertainty Factor = $10^5$

$$HRD = {LD_{50,ingestion}} \big/ {Uncertainty\ Factor}$$

$$= 0.3306\ mg/kg\ bw$$

Finally, the Human Toxicity Factor for air ($HTF_a$) is calculated as:

$$HTF_a = 1 \big/ HRC$$

$$= 3130.2\ m^3/g$$

And the Human Toxicity Factors for water and soil ($HTF_w$, $HTF_s$) are:

$$HTF_w = HTF_s = 1 \big/ HRD$$

$$= 30248\ kg\ bw \cdot day/g$$

*Characterization - Calculating Human Toxicity Potential*

This program's method for calculating the final indicator for human toxicity departs slightly from the EDIP method. The EDIP method only indirectly considers the lifespan of a substance in water and soil by multiplying $HTF_w$ and $HTF_s$ with a biodegradation probability factor, *BIO*, which ranges from 0 to 1. The final indicator results are presented in terms of the contaminated volumes for each compartment. This program's method considers the substance lifespan directly with the inclusion of the substance half-life in each compartment, estimated using a level III fugacity model[30]. For each compartment, the indicator is determined by the product of the mass of emissions and the compartment-specific values for the fraction emissions partitioned, intake factors and transmission factors, human toxicity factor, and substance half-life. The indicator results are presented in terms of the number of the days that a chemical will be present in a volume of an environmental compartment sufficiently large to cause no toxic effect to exposed humans. The example of 1 gram of benzene emitted to air is completed here.

Emissions to air:

Q = 1.0 g

From the level III fugacity model, the half life of benzene is:

[30] The model used is BIOWIN v4.02, which is available as part of the U.S. EPA's EPIWIN v3.12 software.

in air: $t_{1/2,a}$ = 8.70 days
in water: $t_{1/2,w}$ = 37.5 days
in soil: $t_{1/2,s}$ = 75.0 days
The bulk density of dry soil ($\rho_b$) is [67]:

$$\rho_b = 1.5 \cdot 10^3\,\text{kg/m}^3$$

For the air, water, and soil compartments, using the values given above, the Human Toxicity Potential ($HTP_a$, $HTP_w$, $HTP_s$) is determined by:

$$HTP_a = Q \cdot f_a \cdot I_a \cdot T_a \cdot HTF_a \cdot t_{1/2,a}$$
$$= 2.72 \cdot 10^4\ \text{m}^3\ \text{air} \cdot \text{days}$$
$$HTP_w = Q \cdot f_w \cdot I_w \cdot T_w \cdot HTF_w \cdot t_{1/2,w}$$
$$= 0.733\,\text{m}^3\ \text{water} \cdot \text{days}$$
$$HTP_s = \frac{Q \cdot f_s \cdot \left(I_{s,d} \cdot T_{s,d} + I_{s,p} \cdot T_{s,p} + I_{s,b} \cdot T_{s,b} + I_{s,m} \cdot T_{s,m}\right) \cdot HTF_s \cdot t_{1/2,s}}{\rho_b}$$
$$= 55.2\,\text{m}^3\ \text{soil} \cdot \text{days}$$

*Normalization*

To estimate the extent and duration of the contamination of the three environmental compartments that results from the consumption activities of Americans, the normalization factor would ideally include a mass-weighted sum of the HTP values for all chemical emissions. However, this would require that HTP values for all major chemicals be calculated using the methods above. Since those calculated values are not yet available, an alternate approach is used at this time.

The U.S. EPA publishes data for the annual emissions in the U.S. for 528 chemicals and compounds grouped according to several emissions categories in a Toxic Release Inventory (TRI) [68]. Of the chemicals which have TRI data available, 186 have human toxicity potentials available using the methods of Hertwich [69]. These HTP values have been calculated using the CalTOX model, which is a multimedia environmental fate model with multiple exposure pathways similar to the volTOX model developed for this program.

The method used by Hertwich to calculate *HTP* estimates the individual lifetime risk resulting from a unit emission of 1 kg/day of a chemical (*c*) into the various environmental compartments (*n*). The risk of an each chemical, $H_{cn}\ (s_{cn}=1)$, is normalized by the individual lifetime risk from the emission of a reference chemical, $H_{refchem,air}(s_{refchem,air}=1)$, which is benzene for cancer effects, and toluene for noncancer effects.

$$HTP_{cn,Hertwich} = \frac{H_{cn}\left(s_{cn} = 1\right)}{H_{refchem,air}\left(s_{refchem,air} = 1\right)}$$

The total human toxicity potential can be summed across all chemical releases, and all environmental compartments.

$$HTP_{Total,Hertwich} = \sum_{c\ \text{chemicals}} \sum_{\substack{n\ \text{release} \\ \text{compartment}}} HTP_{cn} s_{cn}$$

For this program, to estimate the human toxicity potential of U.S. emissions, the EPA TRI data are first converted into benzene and toluene equivalents using Hertwich's HTP method. These values are then added for all chemicals in the TRI data, to obtain an estimate for total benzene and toluene equivalent emissions in both the total air emissions and total surface water discharges categories.

A detailed table of the year 2000 TRI data, $HTP_{Hertwich}$ values, and the calculated total benzene and toluene equivalents is shown in the appendix. For the year 2000, the results of those calculations are shown in Table 3.16.

2000 U.S. emissions
(from US EPA TRI data for which $HTP_{Hertwich}$ values were available)

| | |
|---|---|
| Total air emissions ($Q_{to\ air}$) | $1.7639 \cdot 10^{4}$ g benzene equivalents (or) |
| | $4.9806 \cdot 10^{14}$ g toluene equivalents |
| Total surface water emissions ($Q_{to\ water}$) | $1.4815 \cdot 10^{9}$ g benzene equivalents (or) |
| | $6.4879 \cdot 10^{12}$ g toluene equivalents |

**Table 3.16** Human Toxicity – Converted U.S. Total emissions in 2000

Using the this program's method of calculating human toxicity potentials, the $HTP_a$ , $HTP_w$ , and $HTP_s$ values for benzene and toluene can be added within each compartment to give total indicator values for air, water and soil.

For emissions to air,
$HTP_{a,benzene\ to\ air} = 2.72 \cdot 10^{4}$ $m^3$ air·days / g emitted to air
$HTP_{w,benzene\ to\ air} = 0.733$ $m^3$ water·days / g emitted to air
$HTP_{s,benzene\ to\ air} = 55.2$ $m^3$ soil·days / g emitted to air
$HTP_{a,toluene\ to\ air} = 5.94 \cdot 10^{3}$ $m^3$ air·days / g emitted to air
$HTP_{w,\ toluene\ to\ air} = 0.108$ $m^3$ water·days / g emitted to air
$HTP_{s,\ toluene\ to\ air} = 3.72$ $m^3$ soil·days / g emitted to air
And for emissions to water,
$HTP_{a,benzene\ to\ water} = 2.72 \cdot 10^{4}$ $m^3$ air·days / g emitted to water
$HTP_{w,benzene\ to\ water} = 0.733$ $m^3$ water·days / g emitted to water
$HTP_{s,benzene\ to\ water} = 55.2$ $m^3$ soil·days / g emitted to water
$HTP_{a,toluene\ to\ water} = 5.94 \cdot 10^{3}$ $m^3$ air·days / g emitted to water
$HTP_{w,\ toluene\ to\ water} = 0.108$ $m^3$ water·days / g emitted to water
$HTP_{s,\ toluene\ to\ water} = 3.72$ $m^3$ soil·days / g emitted to water

These human toxicity potentials per gram emitted are then be multiplied by the estimated total US emissions to calculate total human toxicity potentials for substances emitted in the year 2000.

$$Normalization\ Factor_{Human\ Toxicity,air,US\ 2000} = \frac{\begin{pmatrix} HTP_{a,benzene\ to\ air} \cdot Q_{benzene\ equiv.to\ air} + HTP_{a,toluene\ to\ air} \cdot Q_{toluene\ equiv.to\ air} \\ +HTP_{a,benzene\ to\ water} \cdot Q_{benzene\ equiv.to\ water} + HTP_{a,toluene\ to\ water} \cdot Q_{toluene\ equiv.to\ water} \end{pmatrix}}{365 days \cdot 281{,}421{,}906\ persons}$$

$$= 2.92 \cdot 10^{7}\ m^3\ air \cdot day$$

$$Normalization\ Factor_{Human\ Toxicity,water,US\ 2000} = \frac{\begin{pmatrix} HTP_{w,benzene\ to\ air} \cdot Q_{benzene\ equiv.to\ air} + HTP_{w,toluene\ to\ air} \cdot Q_{toluene\ equiv.to\ air} \\ +HTP_{w,benzene\ to\ water} \cdot Q_{benzene\ equiv.to\ water} + HTP_{w,toluene\ to\ water} \cdot Q_{toluene\ equiv.to\ water} \end{pmatrix}}{365 days \cdot 281{,}421{,}906\ persons}$$

$$= 5.32 \cdot 10^{2}\ m^3\ water \cdot day$$

$$Normalization\ Factor_{Human\ Toxicity,soil,\ US\ 2000} = \frac{\begin{pmatrix} HTP_{s,benzene\ to\ air} \cdot Q_{benzene\ equiv.\ to\ air} + HTP_{s,toluene\ to\ air} \cdot Q_{toluene\ equiv.\ to\ air} \\ + HTP_{s,benzene\ to\ water} \cdot Q_{benzene\ equiv.\ to\ water} + HTP_{s,toluene\ to\ water} \cdot Q_{toluene\ equiv.\ to\ water} \end{pmatrix}}{365 days \cdot 281{,}421{,}906\ persons}$$

$$= 1.83 \cdot 10^4\, m^3\, soil \cdot day$$

***Ecotoxicity***

*Description of indicator*

The release of chemicals as a result of human activities can cause harm to natural ecosystems through many different mechanisms. Exposure to a substance that is acutely ecotoxic can cause the immediate death of an organism, while chronic toxicity refers to toxic effects that result after repeated or long-term exposure to a substance. As with human toxicity, the properties of a chemical and the conditions under which it was released will determine its ecotoxicity. As with humans, an organism's exposure to toxins can occur via inhalation, ingestion, and direct contact. However, the contamination of water and soil are more significant contributors to ecotoxicity, so the inhalation route is not considered.

*Characterization*

The release of release of toxic substances can cause damage to ecosystems at both local and regional levels. Although this substance may reside in each of the environmental compartments, only the water and soil compartments are considered for the calculation of the ecotoxicity indicator. As human toxicity, this program estimates ecotoxicity using a substance's toxicity data combined with a multimedia fate model. The resulting ecotoxicity indicator includes some consideration of potential exposure and harm, without the intensive modeling required to conduct a full risk assessment. Like human toxicity, the calculation method has been adapted from the EDIP method.

*Characterization - Screening*

The method for screening substances for ecotoxicity is similar to the process used for human toxicity, with the screening score determined by weighting the risk phrases from directive 67/548/EEC on dangerous substances. Aquatic ecotoxicity is determined by the use of Risk Phrases R50, R51, and R52, and taking the maximum of their weighted values, which are 4, 2, and 1, respectively. Terrestrial ecotoxicity is given a value of 4 if any of the risk phrases R54, R55, R56, or R57 are used, and a value of 0 otherwise. The total ecotoxicity score is the sum of the substance's aquatic ecotoxicity and terrestrial ecotoxicity scores. The risk phrases related to ecotoxicity are shown in Table 3.17, with their meanings.

| R | Risk phrases (from 67/548/EEC) |
|---|---|
| 50 | Very toxic to aquatic organisms |
| 51 | Toxic to aquatic organisms |
| 52 | Harmful to aquatic organisms |
| 53 | May cause long-term adverse effects in the aquatic environment |
| 54 | Toxic to flora |
| 55 | Toxic to fauna |
| 56 | Toxic to soil organisms |
| 57 | Toxic to bees |
| 58 | May cause long-term adverse effects in the environment |
| 59 | Dangerous for the ozone layer |

**Table 3.17** 67/548/EEC dangerous substance risk phrases for ecotoxity

As with human toxicity, an exposure score 8 is given if the risk phrases R53 or R58 are applied to the substance, and a value of 4 otherwise. Finally, the ecotoxicological impact score is the product of the ecotoxicity and exposure scores. The screening process is demonstrated for chlorpyrifos, a common pesticide, is given below.

| Chemical Name : chlorpyrifos | CAS Number: 002921-88-2 |
|---|---|

| 67/547/EEC Risk Phrase | Aquatic ecotoxicity score | Terrestrial ecotoxicity score |
|---|---|---|
| T; R25 | | |
| N: R50 | 4 | |
| N: R51 | 2 | |
| N: R52 | 1 | |
| N: R53 | | |
| Maximum value | 4 | 0 |

Total ecotoxicity score : 4
Exposure Score : 8 (risk phases R; 53 is listed)
Ecotoxicological impact score : 4 x 8 = 32
Conclusion : The ecotoxicological impact score is greater than 8, so the characterization analysis should continue.

*Characterization - Partitioning emissions into environmental compartments*

The method of partitioning emissions into the environmental compartments is similar to the method for human toxicity described earlier. The only exceptions are that the air compartment is not considered, and the water compartment is divided into acute toxicity, and chronic toxicity, depending on the substance's longevity. For a more detailed explanation of the partitioning method, refer to the text for the EDIP method. [50]

The example for chlorpyrifos emitted to soil is continued here.

Atmospheric half-life : 208.7 hours
Henry's Law Constant (H) : $2.52 \cdot 10^{-6}$ atm $m^3$/mol
Ratio of surface water area to total regional area (a) : 0.2 (assumed constant for U.S.)
For emissions to soil: Is H > 10-3 atm m3/mol?
No. Therefore, $f_{wa} = 0$, $f_{wc} = 0$, $f_{sc} = 1$
Note: Unlike benzene, which was used as an example to estimate the partitioning for human toxicity, chlorpyrifos is not highly volatile (H<10-3 atm $m^3$/mol), and therefore it is assumed to stay entirely in the soil compartment, regardless of the longevity of the substance. This multimedia model ignores transport by other means such as by water in the soil.

*Characterization - Calculating Ecotoxicity Factors*

As with human toxicity factors, this program uses ecotoxicity factors to represent the volume of an environmental compartment required to dilute one gram of a chemical to a sufficiently low concentration so that exposure would result in no toxic effects. For the water compartment, the acute Ecotoxity Factor ($ETF_{wa}$) is the reciprocal of the Potential No Effect Concentration ($PNEC_{wa}$) , which is the concentration of a substance at which no harmful acute effects to aquatic organisms should occur. The chronic Ecotoxicity Factor for water ($ETF_{wc}$) is the reciprocal of $PNEC_{ws}$, which is the concentration at which chronic exposure should cause no harmful effects. For the soil compartment, the Ecotoxicity Factor ($ETF_{sc}$) is the inverse of $PNEC_{sc}$, which is the concentration that does not impact soil organisms.

Toxicity data for aquatic organisms is available for many chemicals in the ECOSAR v.99 database, which is packaged with the EPA's EPIWIN v3.12 software. The ECOSAR model was developed by the Syracuse Research Corporation for use by the U.S. EPA. It is a structure-activity relationships (SARs) model, which means that for substances for which no aquatic toxicity exists, the toxicity is predicted by comparing the chemical structure to substances that do have toxicity data. Most of the calculations in the ECOSAR model are based upon the octonol-water partitioning coefficient (Kow) [70]..

Uncertainty factors to adjust toxicity values based on specific test data should be assigned by toxicity experts. This program will initially adopt the uncertainty factors given as an example in the EDIP method and shown in Table 3.18 and Table 3.19 below.

| Uncertainty Factor | Available Toxicity Test Data (to estimate chronic toxicity, $PNEC_{wc}$) |
|---|---|
| 1000 | Some data for acute ecotoxicity ($LC_{50}$) available, but data for species from one or more of the classes fish, Crustacea and algae are missing. |
| 100 | Data available for acute ecotoxicity ($LC_{50}$) for at least one species from each of the classes fish, Crustacea and algae. |
| 20 | Data available for chronic ecotoxicity (LOEC) for at least one species from each of the classes fish, Crustacea and algae. |
| 10 | Data available for chronic ecotoxicity (NOEC) for at least one species from each of the classes fish, Crustacea and algae. |

**Table 3.18** Ecotoxicity - Uncertainty Factors for $PNEC_{wc}$ [50]

| Uncertainty Factor | Available Toxicity Test Data (to estimate chronic toxicity, $PNEC_{wa}$) |
|---|---|
| 100 | Some data for acute ecotoxicity ($LC_{50}$) available, but data for species from one or more of the classes fish, Crustacea and algae are missing. |
| 10 | Data available for acute ecotoxicity ($LC_{50}$) for at least one species from each of the classes fish, Crustacea and algae. |

**Table 3.19** Ecotoxicity - Uncertainty Factors for $PNEC_{wa}$ [50]

An example for calculating the ecotoxicity factors for chlorpyrifos is given below.

From the ECOSAR v0.99 database, two test $LC_{50}$ test results are available for fish, the lowest of which is 2.003 mg/L. One test result is available for *daphnid* (a member of the class *Crustacea*), with $LC_{50}$ = 1.057 mg/L, and one result for green algae, with $EC_{50}$ = 0.176 mg/L. No test results for chronic toxicity were available. Therefore, the lowest value is selected for use in further calculation, which is 0.176 mg/L. Since test data for at least one species from each of the classes fish, Crustacea, and algae are included, the uncertainty factors are for acute ecotoxicity in water, $Uncertainty\ Factor_{wa}$ = 10 and for chronic ecotoxicity in water, $Uncertainty\ Factor_{wc}$ = 100.

To calculate the Potential No Effect Concentration for acute toxicity in water ($PNEC_{wa}$):

$$LD_{50,minimum} = 0.176\ \text{mg/L}$$

$$PNEC_{wa} = LD_{50,minimum} / Uncertainty\ Factor_{wa}$$

$$= 0.0176\ \text{mg/L}$$

And for the Potential No Effect Concentration for chronic toxicity in water ($PNEC_{wc}$):

$$LD_{50,minimum} = 0.176\ \text{mg/L}$$

$$PNEC_{wc} = LD_{50,minimum} / Uncertainty\ Factor_{wc}$$

$$= 0.00176\ \text{mg/L}$$

Toxicity data for soil organisms is not usually readily available, so this program will use the calculation suggested by the EDIP method, which uses the value for $PNEC_{wc}$ and the soil's coefficient of adsoption ($k_d$) to estimate $PNEC_{sc}$.

Soil organic carbon content ($f_{oc}$) : 0.002 kg/kg (EPA Region III default value) [67]

The bulk density of dry soil ($\rho_b$) is [67]:

$$\rho_b = 1.5 \text{ kg/L}$$

For chlorpyrifos:
Soil Sorption Coefficient ($K_{oc}$) : 6830 l/kg

$$k_d = f_{oc} \cdot K_{oc}$$
$$= 13.66 \text{ L/kg}$$
$$PNEC_{sc} = PNEC_{wc} \cdot (K_d + 0.27) \cdot \rho_b$$
$$= 0.036775 / \text{ mg/L}$$

Finally, the acute Ecotoxicity Factor for water ($ETF_{wa}$) is calculated as:

$$ETF_{wa} = 1/PNEC_{wa}$$
$$= 56.818 \text{ m}^3\text{/g}$$

The chronic Ecotoxicity Factor for water ($ETF_{wc}$) is:

$$ETF_{wc} = 1/PNEC_{wc}$$
$$= 568.18 \text{ m}^3\text{/g}$$

And the chronic Ecotoxicity Factor for soil ($ETF_{sc}$) is:

$$ETF_{sc} = 1/PNEC_{sc}$$
$$= 27.192 \text{ m}^3\text{/g}$$

*Characterization - Ecotoxicity Potential*

As with the human toxicity potential calculation, this program's method for calculating ecotoxicity potential differs from the EDIP method. Again, this program will use substance lifespan directly, in the form of the substance half-life, whereas the EDIP method used a biodegradation probability factor, *BIO*. The results for ecotoxicity potential are presented in terms of the number of days that a substance will be present in a volume of an environmental compartment sufficiently large to cause no toxic effect to exposed organisms. The example for 1 gram of chlorpyrifos emitted to soil is completed here.

Emissions to soil:
$Q$ = 1.0 g
From the level III fugacity model, the half life of chlorpyrifos is:
in water: $t_{1/2,w}$ = 180 days
in soil: $t_{1/2,s}$ = 360 days
For the water compartment, using the values given above, the ecotoxicity potentials ($ETP_{wa}$, $ETP_{wc}$) are determined by:

$$ETP_{wa} = Q \cdot f_{wa} \cdot ETF_{wa} \cdot t_{1/2,w}$$
$$= 0 \text{ m}^3 \text{ water} \cdot \text{days}$$
$$ETP_{wc} = Q \cdot f_{wc} \cdot ETF_{wc} \cdot t_{1/2,w}$$
$$= 0 \text{ m}^3 \text{ water} \cdot \text{days}$$

The water compartments for $ETP_{wa}$ and $ETP_{wc}$ are combined into one ectotoxicity potential for the total water compartment ($ETP_w$):

$$ETP_w = ETP_{wa} \cdot ETP_{wc}$$
$$= 0 \text{ m}^3 \text{ water} \cdot \text{days}$$

For the soil compartment, the chronic ecotoxicity potential ($ETP_{sc}$) is given by:

$$ETP_{sc} = Q \cdot f_{sc} \cdot ETF_{sc} \cdot t_{1/2,s}$$
$$= 9789.1\,\mathrm{m}^3\ \mathrm{soil} \cdot \mathrm{days}$$

***Land use***

*Description of indicator*

Land that is occupied by activities related to consumption becomes at least partially unavailable for other critical uses, such as serving as habitat for wildlife, or producing food for humans.[31] Loss of habitat has been identified as one of the main drivers of biodiversity loss, in addition to overexploitation, pollution, climate change, and invasive alien species [71][70].

> Why only consider habitat loss as a factor for biodiversity?
> Although there are many factors that contribute to a loss of biodiversity, loss of habitat is possibly the most critical. Other drivers, such as climate change and ecotoxic effects of pollution, are already considered in other indicators of this program. Overexploitation, which is the unsustainable harvesting of biotic resources directly from nature, is difficult to measure at this time using life cycle assessment methods because of the lack of information for characterizing the level of threat to individual species according to particular locations. Because overexploitation is highly dependent on the resource management practices of the parties involved, information is better provided at this time by ISO Type I declaration programs such as the Marine Stewardship Council (MSC), and Forest Stewardship Council (FSC).

This indicator considers both the loss of available land to serve as habitat for the support of biodiversity, and the loss of available land to produce food for humans.

*Characterization*

This program applies an original method for characterization land use, which is based on the idea of assigning spatially specific weighting factors for a particular land area's ability to support biodiversity and agricultural productivity. This characterization method relies on the availability of digital maps, which have become increasingly available as Geographic Information Systems (GIS) become more advanced.

*Characterization - Biodiversity*

Measuring biodiversity in a consistent way is challenging because of the difficulty in assigning a value to various combinations of species over the wide variety of ecosystem types around the world. After excluding from consideration previous attempts to measure biodiversity in terms of monetary value of the services provided[32], the only existing method of consistently measuring biodiversity on a global scale is to identify ecosystem types, evaluate the presence of key species, and compare the results to targets for ecosystems of that type.

The Biodiversity Support Program (BSP) conducted biodiversity studies which were published in a series according the continents studied [72][71]. The results can be presented in the form of a digital map,

[31] Although food production is also considered by this program as a consumption activity, the occupation of productive agricultural land is considered an adverse environmental impact here since it will eventually limit the capacity for food production, or cause agricultural activity to shift to a larger area of less productive land.

[32] In addition to being highly subjective, the practice of economic valuation is explicitly identified by ISO as being inconsistent with the principles of life cycle assessment.

with classifies regions into four types according to their *biological value*[33]: globally outstanding, regionally outstanding, regionally significant, and locally important. This classification method used by the BSP was developed by Conservation International and the Wildlife Conservation Society. The methods used involved [73][72]:

1) Identifying habitat regions
   Within the seven Major Habitat Types (MHT) used globally, Regional Habitat Units (RHU) were identified considering the common characteristics for the habitat of six difference taxonomic groups of plants, mammals, birds, insects, herpetofauna, and fish. The size of an RHU can vary, but for the study of Latin America and the Caribbean, which includes both Central and South America, 35 RHU's were defined. (see Figure 3.5)
2) Identifying biological values for six taxonomic groups
   For each of the six taxonomic groups, each RHU was assigned a rating of "regionally outstanding", "regionally significant", or "locally important", with biological values of 3, 2, and 1, respectively, based on specific criteria for each group. Generally, these criteria included species richness, phyletic diversity, number of endemic species, beta diversity, and presence of rare/endangered species.
3) Determining total biological value for each RHU
   The total of all biological values within each RHU was calculated as the sum of five of the taxonomic groups (fish are excluded because of the difficulty in correlating RHU's with the other groups). These totals were then ranked within the Major Habitat Type, and finally, each RHU was assigned a cumulative biological value, again using the categories of regionally outstanding, regionally significant, and locally important. An example of this ranking method is shown in Table 3.20.

| RHU (within MHT) | Plants | Insects | Birds | Herps | Mammals | Total | Rank | Biological Value |
|---|---|---|---|---|---|---|---|---|
| **1. Tropical Moist Lowland Forests** | | | | | | | | |
| 1.1 Atlantic | 3 | 3 | 3 | 3 | 3 | 15 | 1 | R |
| 1.2 Upper Amazon | 3 | 3 | 3 | 3 | 2.5 | 13.5 | 2 | R |
| 1.3 NE Amazon | 3 | 3 | 2 | 2 | 1 | 11 | 3 | S |
| 1.4 SE Amazon | 1 | 1 | 1 | 1 | 2 | 7 | 5 | L |
| 1.5 Choco-Darien | 2 | 3 | 3 | 3 | 1 | 11 | 3 | S |
| 1.6 Central American Lowland | 2 | 2 | 2 | 2 | 1 | 8 | 4 | L |
| **2. Tropical Moist Montane Forests** | | | | | | | | |
| 2.1 Tropical Andes | 3 | 3 | 3 | 3 | 3 | 15 | 1 | R |
| 2.2 Central American Montane | 2 | 2 | 2 | 3 | 1 | 10 | 3 | S |
| 2.3 Caribbean Moist | 2 | 2 | 3 | 3 | 1 | 11 | 2 | S |
| 2.4 Venezuelan Moist | 2 | 2 | 2 | 2 | 1 | 9 | 4 | L |
| 2.5 Guyana Montane | 2 | 2 | 3 | 3 | 1 | 11 | 2 | S |
| … | … | … | … | … | … | … | … | … |

**Table 3.20** Calculation of biological value – Central and South America
R = Regionally Outstanding; S = Regionally Significant; L = Locally Important [73][72]

[33] The BSP also classified regions according to the potential for conservation, in terms of: 1) conservation threat and opportunity; 2) policy/institutional feasibility; and 3) human utility. However, these items are not considered by this program since they are drivers of, rather than consequences of the consumption activity addressed by the declaration.

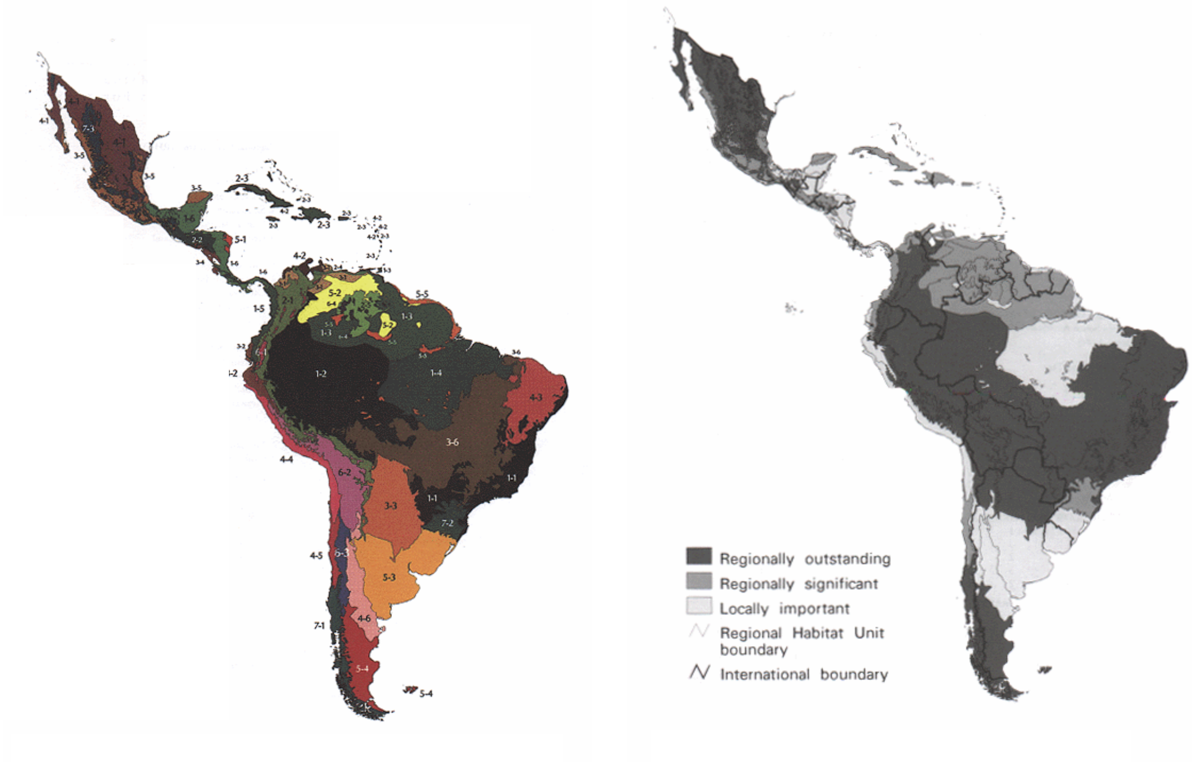



**Figure 3.5** Map of the biological value for Latin America and the Caribbean
35 Regional Habitat Units in Central and South America (left); Biological value for those RHU's (Right) [73][72]

This program will use the original numerical biodiversity values as characterization factors, as shown in Table 3.21.

| Biodiversity Value Category | Characterization Factor |
|---|---|
| Globally outstanding | 4 |
| Regionally outstanding | 3 |
| Regionally significant | 2 |
| Locally important | 1 |

**Table 3.21** Land use - Biodiversity characterization factors

*Characterization - Agricultural productivity*

The Food and Agriculture Organization (FAO) of the United Nations has created a geospatial model of potential agricultural productivities around the world. The program, called the Global Agro-Ecological Zones System (AEZ) incorporates spatial data for grid cells with a resolution of 0.5 seconds considering the factors of:

- Soil type
- Elevation
- Terrain slope
- Climate

These spatial parameters are then combined with models of crop yield to calculate a suitability index for various crop combinations and level of management [74]. This program will apply the suitability index for a mix of crops under rain-fed (non-irrigated) conditions. The suitability index assigns a productivity value to a grid cells that ranges from 0 to 100. The spatial data presents the index categorized according to eight suitability levels as shown in the example in Figure 3.6. This program will use the middle values of these suitability categories as characterization factors for agricultural productivity as shown in Table 3.22.

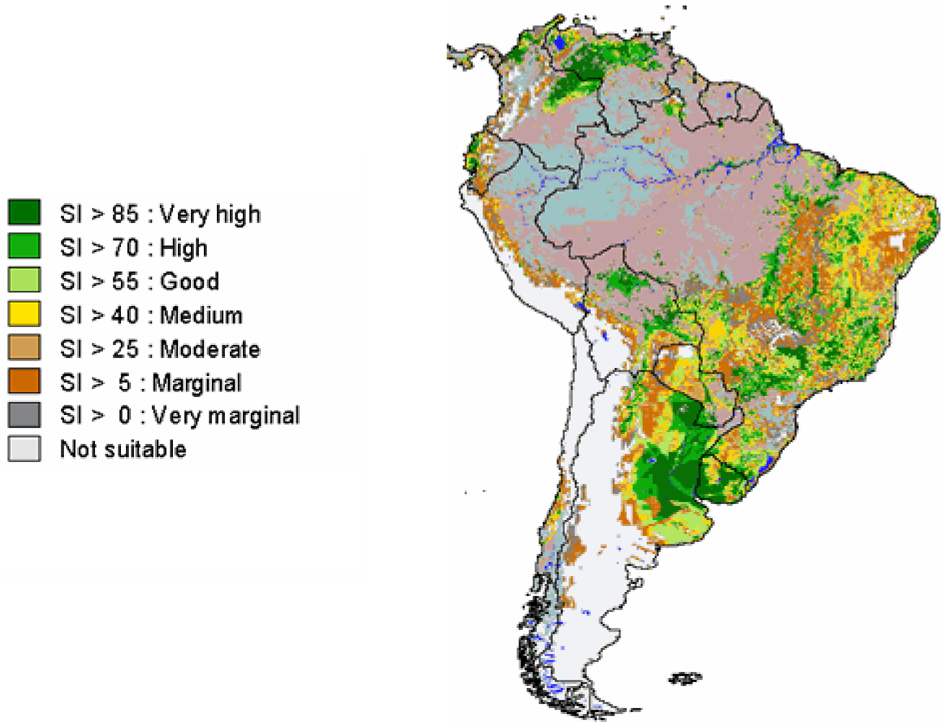



**Figure 3.6** FAO agricultural productivity suitability index – South America
FAO Global AEZ spatial data for the suitability for rain-fed crops excluding forest systems [74][73]

| Suitability Index Category | Characterization Factor |
|---|---|
| Very high | 92.5 |
| High | 77.5 |
| Good | 62.5 |
| Medium | 47.5 |
| Moderate | 32.5 |
| Marginal | 15 |
| Very marginal | 2.5 |
| Not suitable | 0 |

**Table 3.22** Land use – Agricultural productivity characterization factors

### *Water depletion*

*Description of indicator*

Water can be consumed at any stage during a product's life cycle, but especially for products such as home appliances, the use phase is responsible for the greatest share. Access to clean, abundant sources of freshwater is critical to supporting human life. Water withdrawal from groundwater aquifers can occur faster than the aquifer is able to recharge, resulting in a loss of freshwater resources. Additionally, water that is diverted from surface waters to another watershed or evaporated to the atmosphere will not be available for other uses. The lack of freshwater in arid and high population regions has led to number of large scale projects to divert freshwater over long distances. Additionally, concerns about contamination of local drinking water sources in some regions has resulted in a dramatic increase in the consumption of bottled water imported from elsewhere. Therefore, water depletion is a global environmental concern, and its use should be monitored even where freshwater resources are plentiful.

*Characterization*

This program's indicator for water depletion is original, since it only considers water that is not returned to its original source as depleted. The characterization factors shown in Table 3.23 have been adopted define the proportion of water used that is considered depleted.

| Water withdrawn from: | Water returned to: | Characterization Factor (Fraction of water depleted) |
|---|---|---|
| Groundwater | Any | 1 |
| Surface water (Lakes, rivers) | Same watershed | 0 |
| | Different watershed | 1 |
| | Atmosphere (evaporated) | 1 |
| Ocean (desalinated) | Any (except atmosphere) | -1 |
| | Atmosphere (evaporated) | 0 |
| Mixed (ground and surface) | Same watershed | Ratio of surface : total |
| | Different watershed | 1 |
| | Atmosphere (evaporated) | 1 |
| Unknown | Unknown | 0.32 |

**Table 3.23** Water depletion characterization factors

In order to select the appropriate characterization factor, it is first necessary to identify the water source and discharge types. For the production phase, this can be determined from the information collected about the manufacturing site. However, for the use phase, the actual water depleted will depend on the location of the user. For products destined for the United States, the characterization factor can be estimated as 0.32, with is the fraction of groundwater use to total water use, presented in Table 3.24.

*Normalization*

Withdrawals of freshwater in the U.S. are estimated by the USGS every five years. The summary of the year 20000 estimate is shown in Table 3.24. To calculate the normalization factor, this program assumes that total water depletion in the U.S. is equal to groundwater withdrawal. In the future, a more accurate estimate of actual water depletion should be made by considering the percentage of surface water withdrawals that result in depletion, especially considering the large volume of water used for irrigation.

| | Ground water withdrawals ($m^3$) | Surface water withdrawals ($m^3$) |
|---|---|---|
| Public Supply | 7.53110E+10 | 3.76847E+10 |
| Domestic | 4.14283E+09 | 4.59407E+07 |
| Industrial | 4.93863E+09 | 2.05714E+10 |
| Irrigation | 7.86492E+10 | 2.96642E+11 |
| **Total** | **1.63042E+11** | **3.54944E+11** |

**Table 3.24** USGS estimate of freshwater withdrawals in the U.S. in 2000 [75][74]

Based on the withdrawal of groundwater within the U.S. in the year 2000,

$$\text{Normalization Factor}_{\text{Water Depletion,US2000}} = \frac{1.6304 \cdot 10^{11} m^3 \, groundwater}{365 days \cdot 281{,}421{,}906 \; persons} = 1.587 \; m^3 (person \cdot day)^{-1}$$

## 3.4. LIMITATIONS OF LCA

When LCA is used to make a choice between alternatives, these limitations of LCA should be considered and, if possible, compensated for by the inclusion of additional information. ISO has identified several limitations of LCA as [35]:

- Choices and assumptions made may be subjective (e.g. system boundaries, data sources, and impact categories).
- Models may not be available for all applications or potential impacts.
- LCA studies for global and regional issues may not be appropriate for local applications.
- The accuracy of LCA studies is dependent on the availability of data, and the data quality.
- The lack of spatial and temporal data used for impact assessment introduces uncertainty in the results.

# 4. DATA PUBLICATION

Making the results publicly available in a useful manner is critical to the success of an environmental declaration. To facilitate the inclusion of a large number of products, the program should only require the disclosure of information that many companies are willing to provide. The results should be published in a range of media and arranged in a format that can effectively summarize the product profiles to a large number of people. Certainly, in some cases, the interests of applicant companies are different from those of consumers and the program administrator. It is therefore critical that any program policies for data publication consider the needs of all parties involved.

## 4.1. SELECTING INFORMATION TO PUBLISH

In the competitive marketplace, producers will go to great lengths to avoid disclosing the details of the processes and materials used to manufacture a product. Attempts to force mandatory disclosure of information through regulation are frequently resisted by industry groups that claim such requirements are too costly, or are in violation of international trade law [76] [77]. Non-industry observers have pointed out that the reluctance to collect and share information may also be due to the lack of market benefits gained by actors that gather information about the long-term effects of their activities, partly because negative information tends to be penalized more strongly than positive information is rewarded, especially when positive results are tempered by uncertainty in the data [78]. Others have noted that simply collecting information about products can be risky for companies, as demonstrated by several mass toxic court cases brought about when companies concealed the results of their own voluntary testing that revealed negative safety results [79]. Therefore, it is important that this program provides a level of information that is useful for consumers without discouraging the participation of producers. Additionally, the data requirements for producers should not subject them to undue legal liability risk. In practice, if a company is concerned about incurring a legal risk by explicitly stating the environmental impacts of their activities, this program will allow direct submission of LCI so that the program administrator is solely responsible for the estimation of category indicators.

> Key Recommendation: Program applicants will be given the option of submitting LCI data directly to the program administrator for calculation of category indicators of environmental impacts.

Producers will be reluctant to share LCI data with the program administrator in some cases, even if given assurance that the information will be kept confidential. The level of secrecy will vary for different companies and product categories, but it is expected to be of particular concern to companies that depend upon proprietary formulations (e.g, processed foods, personal care products, cleaners). Therefore, during the establishment of the product category rules, criteria will be set for the number of LCI items that can be withheld from the program administrator, to be replaced with environmental impacts calculated by the applicant.

> Key Recommendation: The Product Category Rules (PCR) shall state the number of LCI items that can be withheld from submission to the administrator for that particular product category, to be replaced with category indicator results calculated by the applicant.

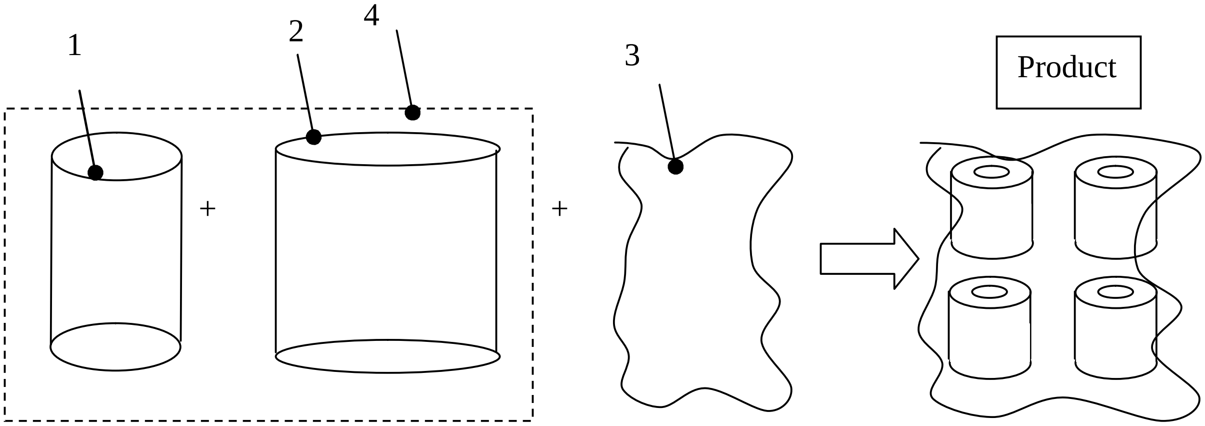
The collection of product information occurs in several stages, which can be divided into a) data that is kept confidential, and b) data that is made publicly available.

### 4.1.1 Data Publication Policies of This Program

***Product information to be kept confidential***

4) General product information

At the beginning of the life cycle assessment process, the applicant must gather some general information which should be summarized in a flow chart showing the processes of all the life cycle stages, and a component structure diagram from which one can understand the physical structure of the product. The flow chart should include the flow of materials into and out of the processes, and specify whether the LCA will use generic data or product-specific data for those materials and processes. This flow chart will form the basis for collecting LCI data. Other additional information, such as description of main function of the product, may be presented if it is necessary to verify LCA results and explain condition of the product. The detailed structure of the product may very complex, and/or be considered confidential by the applicant. Therefore, the component structure diagram can be a simplification of the detailed structure as long as it provides enough information to allow the program administrator to verify the LCI data.




Product Component Diagram

| Fig. No | Level (mark with "O") | | | | | | | | Unit Name or Assy/Part Name | Qty (per Final Product) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | |
| 3 | O | | | | | | | | Package-Plastic Wrap | 1 |
| 4 | O | | | | | | | | Roll Assy | 4 |
| 2 | | O | | | | | | | Tissue Paper | 4 |
| 1 | | O | | | | | | | Roll | 4 |

Structure table

**Figure 4.1** Figure Example of structure diagram for toilet paper

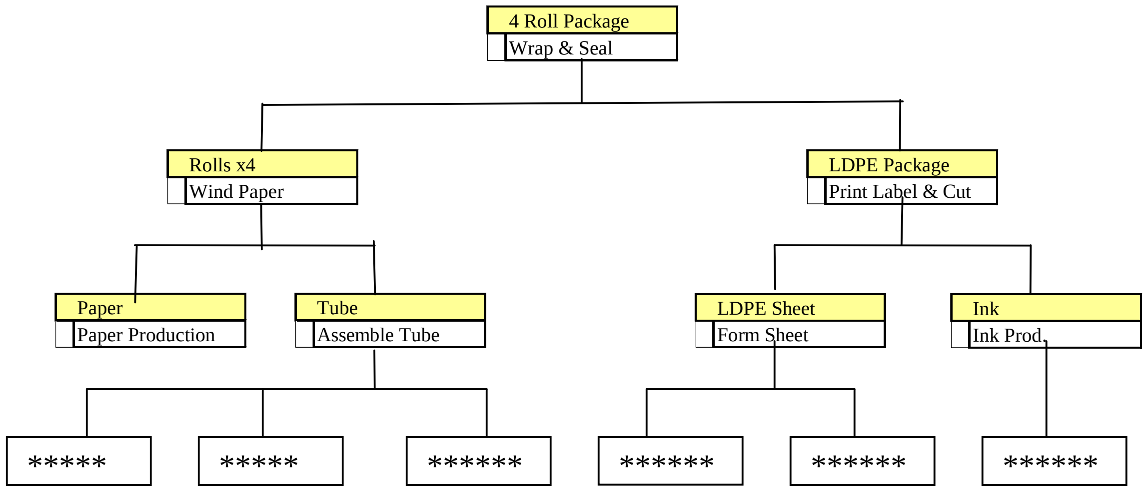



**Figure 4.2** Example of flow chart for toilet paper

5) Life cycle inventory (LCI)

The Life cycle inventory (LCI) is a list of values for emission and resource use items in all life cycle stages that are created by the applicant at the beginning of the LCA process. As mentioned earlier, the LCI can be either submitted in its entirety to the program administrator, or submitted with items replaced by their estimated environmental impacts per the PCR at the applicant's discretion. The submitted LCI shall be kept confidential by the program administrator, and not be made available to the public, other participating companies, or any other party.

| Item Name | Input Type | Value/are | Units |
|---|---|---|---|
| Surflan 4 AS | To Soil | 2.4 | pint, liquid |
| Roundup Ultra Max | To Soil | 1.1 | pint, liquid |
| Dusting Sulfur | To Soil | 30 | pound |
| UN 32 Applied | To Water | 50 | pound |
| Nitrogen Removed when Harvesting | To Water | -2.1 | pound |
| Water | Water Input | 36 | acre inch |
| Gibberelic Acid (ProGibb) | To Soil | 9 | gram |
| Ethrel | To Soil | 1 | pint, liquid |
| Land | Land Input | 1 | acre |
| ….. | ….. | ….. | ….. |

**Table 4.1** Example of confidential data - LCI data

6) The contribution of individual resource use and emission items to the total indicator result for each environmental impact category

Software provided by the program administrator will calculate the environmental impact of each resource input and emission item separately based on the LCI data collected by the applicant. Based on these calculations, the applicant might identify material or process changes that would improve their product's environmental performance. The applicant might also request the program administrator review the results to recommend such changes. As mentioned earlier, the indicator results may be calculated either by the applicant, or by the program administrator if requested. In both cases, the results for individual resource use and emission items will be kept confidential by the program administrator.

| | | | Global Warming | Eutrophication | Ecotoxicity From All Emissions | |
|---|---|---|---|---|---|---|
| | | | | | Contaminated Water Volume | Contaminated Soil Volume |
| Item Name | Value | Unit | gram CO2 equiv | gram NO3- equiv | cubic meter Water*day | cubic meter Soil*day |
| Surflan 4 AS | 2.4 | pint, liquid | 0 | 0 | 0 | 102.1612154 |
| Roundup Ultra Max | 1.1 | pint, liquid | 0 | 0 | 0 | 3.464249075 |
| Abound | 12 | fluid ounce | 0 | 0 | 0 | 3.017247918 |
| Mirothiol Special | 11 | pound | 0 | 0 | 0.101068919 | 1.805205073 |
| Dusting Sulfur | 30 | pound | 0 | 0 | 0.33766207 | 6.03102604 |
| UN 32 Applied | 50 | pound | 0 | 5.287932103 | No Data | No Data |
| Nitrogen Removed when Harvesting | -2.0938 | pound | 0 | -0.221437445 | No Data | No Data |
| Gibberelic Acid | | | 0 | 0 | 0 | 0.003243607 |
| … | … | … | … | … | … | … |

**Table 4.2** Example of confidential data - impact of individual LCI items

***Product information to be made publicly available***

7) The total results for each impact category in terms of midpoint indicator units

The environmental impact of a product is estimated to be the sum of the environmental impacts of the individual resource use and emission item. The summed results will be made publicly available as numerical values presented separately for each life cycle stage of the product.

| | Production | Transportation | Use | Disposal | Total | Unit |
|---|---|---|---|---|---|---|
| **Global Warming** | 7.535444316 | 24.59492164 | 0 | 0 | 32.13037 | gram CO2 equiv |
| **Acid Rain** | 0.061591198 | 0.102903848 | 0 | 0 | 0.164495 | gram SO2 equiv |
| **Eutrophication** | 5.074612363 | 0.039898994 | 0 | 0 | 5.114511 | gram NO3- equiv |
| **Photochemical Smog Creation** | 0.000728621 | 0.001737222 | 0 | 0 | 0.002466 | gram C2H4 equiv |
| **Ozone Depletion** | 2.24502E-05 | 2.08499E-05 | 0 | 0 | 4.33E-05 | gram CFC11 equiv |
| **Human Toxicity** | | | | | | |
| Finally To Air Compartment | 40564.68882 | 37.90235084 | 0 | 0 | 40602.59 | cubic meter Air*day |
| Finally To Water Compartment | 4.27588E-05 | 4.36878E-08 | 0 | 0 | 4.28E-05 | cubic meter Water*day |
| Finally To Soil Compartment | 1.392675999 | 8.87837E-07 | 0 | 0 | 1.392677 | cubic meter Soil*day |
| … | … | … | … | … | … | … |

**Table 4.3** Example data to be published – Total category indicator results
The results for each indicator, for every life cycle stage, in terms of mid-point indicator units

8) The total category indicator results for each life cycle stage after normalizing relative to an average individual's daily impacts

Using normalization factors determined by the program administrator, either the applicant, or the program administrator will calculate normalized indicator results for each life cycle stage, in every environmental impact category. These normalized results will be made publicly available as numerical values presented separately for each life cycle stage of the product.

| | Production | Transportation | Use | Disposal | Total |
|---|---|---|---|---|---|
| **Global Warming** | 0.01% | 0.04% | 0.0% | 0.0% | 0.05% |
| **Acid Rain** | 0.02% | 0.04% | 0.0% | 0.0% | 0.06% |
| **Eutrophication** | 3.09% | 0.02% | 0.0% | 0.0% | 3.11% |
| **Photochemical Smog Creation** | 0.00% | 0.00% | 0.0% | 0.0% | 0.00% |
| **Ozone Depletion** | 0.00% | 0.00% | 0.0% | 0.0% | 0.01% |
| **Human Toxicity** | 0.15% | 0.00% | 0.0% | 0.0% | 0.15% |
| Finally To Air Compartment | 0.14% | 0.00% | 0.0% | 0.0% | 0.14% |
| Finally To Water Compartment | 0.00% | 0.00% | 0.0% | 0.0% | 0.00% |
| Finally To Soil Compartment | 0.30% | 0.00% | 0.0% | 0.0% | 0.30% |
| … | … | … | … | … | … |

**Figure 4.3** Example data to be published – Normalized category indicators
The results for each indicator, for every life cycle stage, after normalizing relative to an average individual's daily impacts

9) The total normalized category indicator results for all life cycle stages

Finally, the total environmental impact of the product is calculated by impact category as the sum of the life cycle stage impacts for each category. These results will be made publicly available in a single percentage value for each category, and are the most simplified level of product information. Further aggregation of the data shall be explicitly forbidden (e.g, a single indicator that combines the results of all categories.)

> Key Recommendation: Applicants shall be forbidden to publish any product declaration that simplifies (aggregates) the LCA results further than a single normalized value for each impact category. Similarly, users of the product declaration should be cautioned about the validity of this practice.

10) Optional information

Applicants may want to include other information in the environmental declaration which they think consumers will find appealing, such as attainment of environmental certification by another organization approved by the program administrator. The environmental declaration should have the flexibilty to allow such information as long as it can be verified by the administrator. However, information that can not be verified, is contrary or irrelevant to the goals of this program, or already represented by the minimum declaration requirements will not be included.

> For example, information about certification from the Forest Stewardship Council (FSC) or the USDA Organic label could be presented since they indicates the use of land-management practices that are otherwise not included in the environmental declaration. However, a claim regarding a "chlorine-free" bleaching process would not be allowable as additional information, since it falsely implies an additional benefit beyond the information for ecotoxicity, human toxicity, and resource depletion already contained in the environmental declaration.

When the Product Category Rules (PCR) are developed, a definition of allowable additional information should be included, such as a list of which outside environmental certification organizations can be referenced.

Key Recommendation: Additional information may be included in the environmental declaration only if it is consistent with the program goals, is verifiable, and not completely accounted for in the minimum declaration requirements. The Product Category Rules (PCR) shall include a description of allowable additional information for that category.

If applicants are willing to provide additional, the program may allow it if is verified, and consistent with program goals. Applicants may want to present LCI data so it can be used by other companies in supply chain management, or in order to announce that they do not use a certain materials. For example, they may want to demonstrate that the product complies with the European Unions's Restriction of Hazardous Substances Directive (RoHS) [17], which restricts the use of certain materials in electrical and electronic equipment.

A primary goal of this program is to make the environmental impacts of a product visible to consumers in a way that they understand. To achieve this, it is not necessary to publish the itemized life cycle inventory information in items 4), 5), and 6) above, especially since exposing that information might violate the confidentiality of the applicant. This program will designate the information from items 7), 8), 9), and 10) as the minimum information requirement which maintains the usefulness of the environmental declaration, without exposing any proprietary information that applicant might wish to keep confidential.

The companies applying for this program should be in agreement with the information practices outlined by the program administrator, and both the applicant and the program administrator will be bound to the constraints of a mutually acceptable confidentiality agreement.

#### 4.1.2 Data publication policies of other programs

Degree of disclosure of LCA information is varied for each program. Swedish EPD does not determine a single standard of environmental declaration format because the characteristic of the program is flexibility. Companies can arbitrary chose which information is publicized as long as they are verified by verifiers and comply with PCR. They generally disclose general product information (size, weight, etc.) and information of resource input and emissions, and any other environmental attributes of products they want to show. Korea EDP publicizes general product information (size, weight. accessories) and six environmental indicators (Resource depletion, Global warming, Ozone depletion, Acidification, Eutrophication, Photochemical ozone creation). In the three exiting programs, LCA calculation reports are submitted to the administrator, but they are not disclosed and used only for verification of the publicized environmental declaration as the background data of LCA.

Ecoleaf disclose the most information of the three existing program. The summarized environmental indicators shown in the environmental declaration are only "Global warming", "Acidification" and "Energy consumption". However, Ecoleaf presents very detailed product environmental attributes. It discloses detailed product information (main component parts), LCI data for major material/energy input and emissions (approximately 50 items), production site information (e.g. energy consumption in a factory), detailed condition of each life cycle stage (transportation, use, recycle/disposal stages). This level of disclosure is generally accepted by Japanese companies, but it is doubtful that this publicity level can be accepted by American companies because this level may be sensitive to confidentiality.

The publicity level of this project's program is generally similar to the Korea EDP rather than Ecoleaf in that it publicizes environmental impacts in ten environmental indicators but does not disclose detailed LCI information and site specific data. It does not also adopt very flexible formats like Swedish EPD because that can cause lack of consistency between products. [22] [23] [24] [21]

| | Ecoleaf | Korea EDP | Swedish EPD |
|---|---|---|---|
| Submitted documents for investigation by the administrator | LCA calculation reports<br><br>Draft of Type III environmental declaration | LCA calculation reports<br><br>Draft of Type III environmental declaration | LCA calculation reports<br><br>Draft of Type III environmental declaration |
| Contents of Type III environmental declaration (published information) | Environmental impact (as 3 midpoint indicators),<br><br>LCI data for each life cycle stage (resource/energy input and emissions) | Environmental impact (as 6 indicators) | Arbitrary (the format is not standardized), but generally:<br><br>Environmental impact (various indicators)<br><br>Material content, Resource input, Emissions |

**Table 4.4** Data publication policies of existing Type III programs

## 4.2. GRAPHICAL DATA PRESENTATION

An important goal of this program is to convey the product information to consumers in an easy to understand way. Although detailed information is generated during the life cycle assessment process, issues of confidentiality and usability require that consumers be provided only data that has been highly aggregated. A variety of both graphical and numerical data presentation were considered for this program. The "radar area" graph was selected based on the considerations below. The radar area format was developed for this program based upon the more commonly used spider graph (also referred to as a "radar graph") and supplemented with printed numerical values. In this format, the results for the environmental indicator categories are presented as individual wedges, with the area of each being proportional to that category's environmental impact and extending from the center of a circle radially outward over a grid of concentric circles, not unlike the CRT display of a radar. Three basic criteria were used when selecting this format. This program has defined the requirements of a good graphical data presentation design to be:

1) Easy to read
   The design should allow consumers to easily understand the environmental impacts of the product, and to compare the environmental impacts between several products in a store. Even if it contains good information, a presentation format which is too complicated is not useful to consumers if they are unwilling to read it.
2) Compact
   The format should be compact enough to be displayed directly on the packaging of most types of consumer products. This criterion is in direct conflict with the first requirement, so it is important that the size not be reduced beyond the point where the level of the environmental impact and other necessary information can not be easily read.
3) Explicitly describe the environmental impact
   The currently existing Type III environmental declaration programs do not provide any way for the participating producers to display quantitative results directly on the product packaging. Instead, they provide a printed logo to indicate that the product has been certified by a third-party, and that the environmental information is available on the program administrator's website. The proposed program will give participating producers some flexibility to decide what, if any, information is printed on the product packaging, the general goal is provide some method for consumers to make comparisons of environmental information in the store where most purchase decisions are made.

### 4.2.1 Description of the "radar area" graph

An example of the graphical format used by this program to present product environmental declarations is shown in Figure 4.4. In this example, ten white, wedge-shaped segments are each shaded red in an area that is proportional to that category's environmental impact. The total segment area represents the average American individual's Total Daily Consumption Impact (TDCI) (See Chapter 3) for that category, as indicated by the 100% label at the outermost grid circle. The red shaded area extends radially to a distance that is the square root of that shaded area. It represents the category percentage of the TDCI for this product. This square root relationship arises from the geometry of a circle where

$$Area = \pi \cdot r^2$$

and from a wedge of that circle, where

$$Area = \frac{\pi \cdot r^2}{number\_of\_wedges}$$

The numerical values for environmental impacts are printed around the circumference of the wedges and shown as a percentage of TDCI, rounded to the nearest 0.1%. The category names are also shown around the perimeter of the graph, immediately outside of the numerical values. These impact category names are grouped into three main impact groups; "People", "Nature", and "Resource Depletion". Because of their multiple effects on both humans and the natural environment, the impact categories of "Global Warming" and "Land Use" are positioned at the top of the graph and lie between the "People" and "Nature" groups.

Illustrations have also been provided within each wedge to facilitate a more rapid understanding of each indicator's meaning. For instance, the sketch of a sweating penguin readily conveys the idea of global warming while at the same time making the graph more visually interesting and possibly improving the consumer's identification with the program. The illustrations might also help consumers intuitively understand the meaning of those indicators even though they may not know the exact definitions.

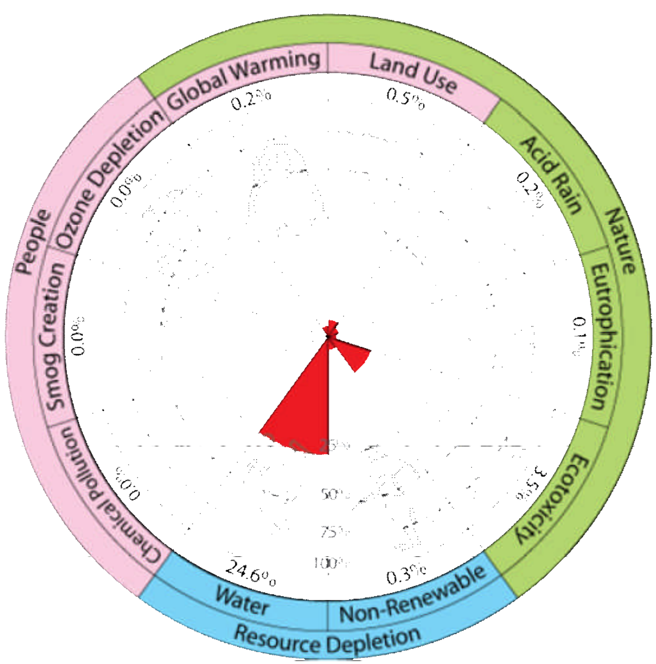



**Figure 4.4** The proposed program's environmental declaration logo

### 4.2.2 Proportion of shaded area as a representation of environmental impacts

The effective graphical presentation of numerical values is not simply a matter of aesthetics. The human brain perceives visual information in complex ways, and although little is known about these psychological processes, the perceived distortion of images as visual illusions is a well-established phenomenon, and the subject of significant research. This research is relevant here because in order for users to be able to accurately assess the relative difference between two figures, the graphic must be designed to avoid these visual illusions. For example, Tufte (1983) critiqued the use of 2-dimensional area graphs to represent one-dimensional values because of people's tendency to underestimate an increase in area. This distortion of perception can be quantified experimentally by "power laws", which for the area of circles has been found to be :

$reported\_perceived\_area = (actual\_area)^x$ where x = 0.8 +/- 0.3 (Tufte 1983).

The term "radar area" is slightly misleading because it implies that the graph conveys information primarily by the area of the shaded region. In fact, it is through a variety of visual cues that this graph, and nearly every other format, conveys information about the data to the user. Cleveland and McGill [80] identified ten "elementary perceptual tasks" that can be used to interpret graphical information. These are shown in the Figure 4.5.

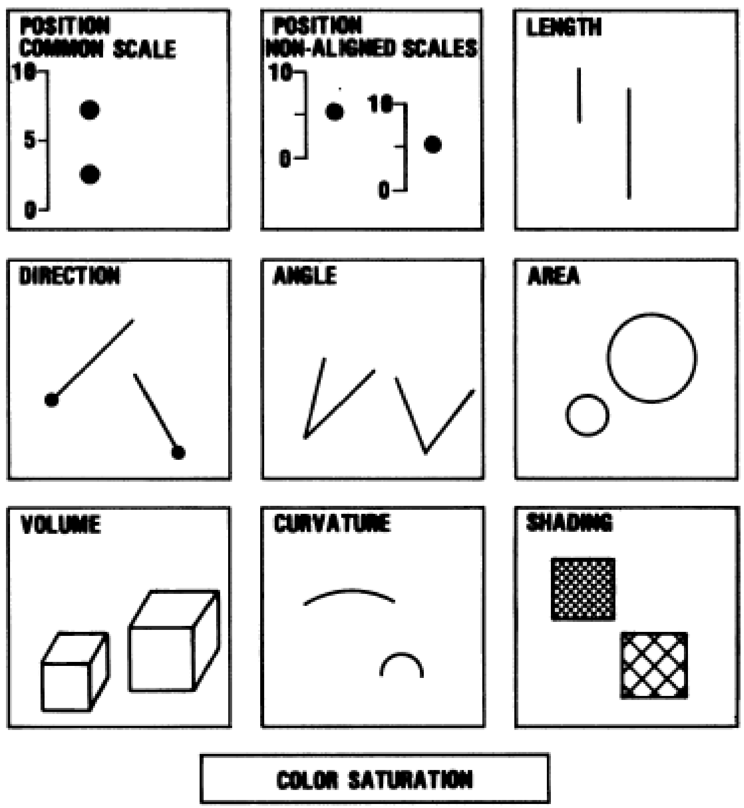



**Figure 4.5** The ten elementary perceptual tasks [80]

Cleveland and McGill ranked these elementary perceptual tasks based on the ability of test participants to accurately identify differences between images. The results indicate that people's ability to accurately distinguish differences in area is not as great as other perceptual tasks. From most to least accurate, these elementary perceptual tasks are:

1) Position along a common scale

2) Positions along nonaligned scales
3) Length, direction, angle
4) Area
5) Volume, curvature
6) Shading, color saturation

For comparisons between environmental impact categories, this program's area radar format employs mainly the elementary tasks of:

- Position along a common scale (i.e, where the shaded area extends relative to the concentric grid circles) and
- Area (i.e, how the size of the shaded area compares with the unshaded area).

However, this program aims to provide information that allows comparison between products across the whole range of environmental impact categories. And if environmental declarations are to be presented directly on product packaging, variations in product size will require different labels sizes, thus precluding the use of nearly all of Cleveland and McGill's elementary perceptual tasks except for the relatively ineffective color saturation and shading tasks. (Note: In addition to their poor perceptual accuracy, shading and color saturation should be not be used to distinguish data because of the difficulty and cost of accurately printing colors. Use of color also limits accessibility for color-blind users.) Therefore, to allow the comparison of graphs of different sizes, radar area graph will depend on the *proportion* of the shaded area to unshaded area to provide the main visual cue.

Although it can be an effective method of graphical comparison, some research has shown that even proportional comparisons can be hindered by unequal graph size and small differences in data [81]. Therefore, the radar area graph used by this program will include printed numerical values in addition to the graphical representation.

#### 4.2.3 Units of the radial axis

To facilitate comparison between products, it is desirable to present the data relative to a common axis for all products. In the case of this program, that would require the TDCI on the radial axis cover the same range of values. (For example, 0% to 100% as shown in the figure) However, this presents some difficulty when some products will have vary large impacts compared to an average individual's activities (e.g, a refrigerator or a computer) while other products will have a very small impact (e.g, a pen or a candy bar). Therefore, presenting the results on a common scale would require are range as wide as from 0% to 10,000% or more for large durable goods. This would result in environmental impact area in the graphical representations of more frequently consumed items being reduced in size, and made nearly indistinguishable from other small and medium-impact items.(see note) To avoid this, the program administrator will define the appropriate range of values in the PCR so that the results for all products in that category will be presented using the same range of values.

> Key Recommendation: The PCR shall define the range of TDCI values to be presented on the radar area graph considering the possible range of environmental impact results for that product category.

> Note: The use of a logarithmic scale would allow one to distinguish between environmental impacts of small value. However, this program will not adopt the use of a logarithmic scale because it exaggerates the importance of these small impacts, and minimizes the importance of large impacts. Allowing users to intuitively evaluate, along a linear scale, the cumulative environmental impact of various activities is a critical feature of this program.

### 4.2.4 Limitations of the "radar area" format

Although the radar area format provides a relatively simple and accurate method of conveying information graphically, it has a few disadvantages. The primary disadvantage is that, because it encourages the user to visually aggregate the various categories, the format implies that all categories are of equal importance. As discussed in the life cycle impact assessment section, this aggregation of categories is neither warranted, nor possible considering the difference in values and beliefs held by individual users. To compensate for this limitation, the program will allow users who access the web-based information to customize according to their personal preferences which of the impact categories are represented in the radar area graph, and the relative areas of each.

### 4.2.5 Details of the selection process for the "radar area" graph and alternative formats

In addition the "radar area" graph, two other formats were considered: the bar graph and the numerical table. The selection of the radar graph format was made considering the attributes described above, prior research, and the results of a consumer survey conducted specifically using the three formats studied by this program. The results of that consumer survey are summarized here, with the detailed results and methods attached as Appendix A.

***Bar chart***

The bar chart presents multiple one-dimensional values simultaneously relative to a common axis. The format is familiar to average consumers, and allows accurate comparison within the graph because it employs what Cleveland and McGill identified as the most effective of the elementary tasks: position relative to a common axis. Like the radar area graph, the comparison of charts of different size can cause difficulty to the user, even if a proportional comparison technique is employed (i.e, the proportion of the bar length to the total axis length). This deficiency can also be offset with the addition of printed numerical values. Unlike the radar area graph, the layout of the bar chart format does not easily accommodate supplemental illustrations.

The bar chart format has been used previously in the U.S. to present Type III environmental declarations for consumer products. In the early 1990's, Scientific Certification Systems (SCS) conducted a trial environmental declaration program and presented an "Environmental Report Card" on the product packaging in the form of a bar graph of the LCI data. Because the data were not normalized relative to any reference data, the LCI results of two products were shown on the packaging: "this product" and an "average product". However, the presentation format used by SCS would only be possible for products that have a large area available for printing on the package. (An additional weakness of the SCS Report Card label was the fact that although the bars represented different LCI units, they were presented on the same, single-axis graph, thus misrepresenting the significance of the various LCI categories.)

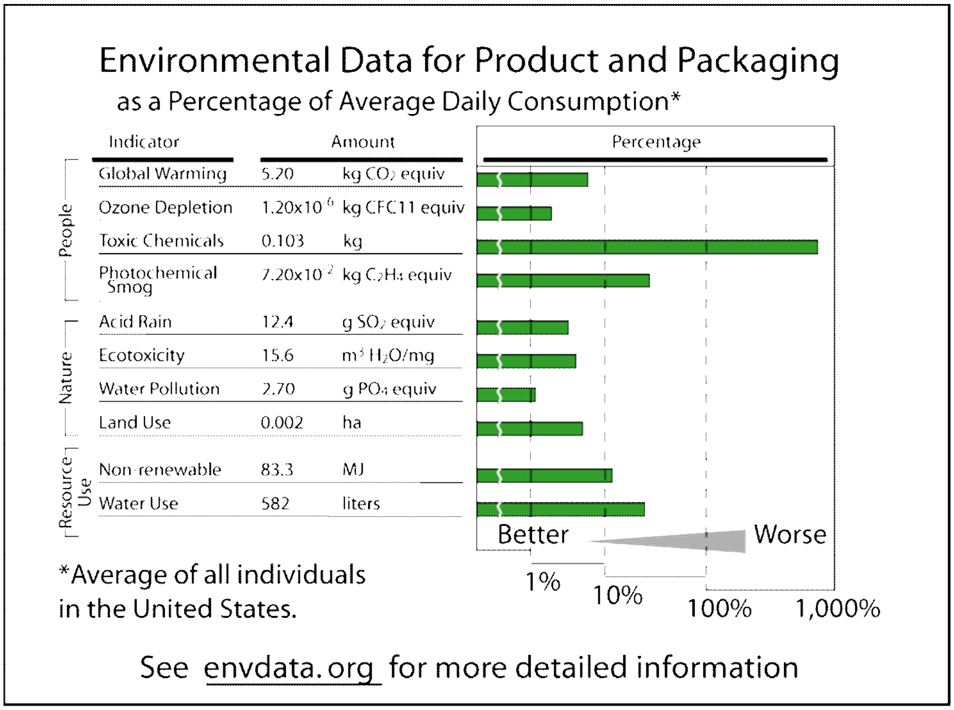
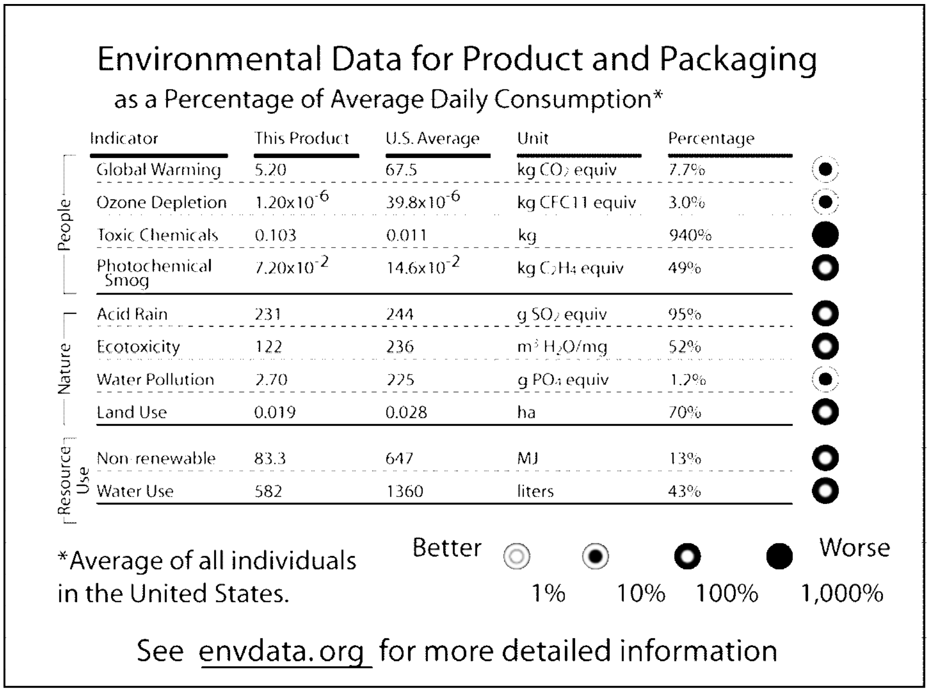



**Figure 4.6** Example of Bar chart format

***Numerical Table***

The numerical table format uses only numerical values to present environmental impact results. For this program, a numerical table might display three values simultaneously for each indicator category; the product's absolute environmental impacts, an average individual's impacts (TDCI), and the product's impacts as a percentage of TDCI. Like the bar chart, this format does not allow for the inclusion of supplemental illustrations. To present nutritional information on packaged food, use of the numerical table format is currently required in the U.S., and American consumers are already quite familiar with it. Because numerical data can seem overwhelming, it may be beneficial to add some graphical aid similar to the summary circles used by Consumers Union in their Consumer Reports magazine product comparisons [82]. This summary circles could be used to expresses the environmental impact levels; from fully shaded circles for categories with high environmental impacts to circles with progressively less shading for categories with lower environmental impacts.



Environmental Data for Product and Packaging

as a Percentage of Average Daily Consumption*

| | Indicator | This Product | U.S. Average | Unit | Percentage |
|---|---|---|---|---|---|
| People | Global Warming | 5.20 | 67.5 | kg $CO_2$ equiv | 7.7% |
| | Ozone Depletion | $1.20 \times 10^{-6}$ | $39.8 \times 10^{-6}$ | kg CFC11 equiv | 3.0% |
| | Toxic Chemicals | 0.103 | 0.011 | kg | 940% |
| | Photochemical Smog | $7.20 \times 10^{-2}$ | $14.6 \times 10^{-2}$ | kg $C_2H_4$ equiv | 49% |
| Nature | Acid Rain | 231 | 244 | g $SO_2$ equiv | 95% |
| | Ecotoxicity | 122 | 236 | $m^3$ $H_2O$/mg | 52% |
| | Water Pollution | 2.70 | 225 | g $PO_4$ equiv | 1.2% |
| | Land Use | 0.019 | 0.028 | ha | 70% |
| Resource Use | Non-renewable | 83.3 | 647 | MJ | 13% |
| | Water Use | 582 | 1360 | liters | 43% |



**Figure 4.7** Example of Numerical table format

***Consumer survey to compare data presentation formats***

When a combination of values are compared, as is the case with this program (e.g, A + B on one graph, with C + D on another graph), experiments by Spence and Lewandowsky (1991) [83] found that the accuracy of reading a pie chart, for which segment areas can be easily added, exceed the accuracy of a bar chart, and far exceeded the accuracy of a numerical table. Although the radar area graph used by this program is not entirely analogous to a pie chart, it is similar in that the contiguous wedge areas can be more easily grouped allowing multiple categories to be compared more easily among products. A survey was conducted to compare the three potential data presentation formats. Based on those survey results and the background information presented above, the radar area format was selected as most appropriate for use by this program.

The survey was given to 100 consumers on-site at a retail store. Participants were asked to make pair-wise comparisons of two fictitional products for each of the three possible label formats. The same environmental impact data for the two products was used consistently for all three formats. Furthermore, the environmental performance of one product was unambiguously superior to the other product, which had the same or higher environmental impacts in each impact category. The results of the survey are presented in their entirety as Appendix A, and summarized here.

When asked to identify which of the two products had a lower overall environmental impact, survey participants were generally able to correctly identify the correct product regardless of the presentation format. 92% of respondents correctly identified the better product using the radar area format, while the bar chart and numerical table formats each yielded 89% correct responses.

Survey participants were also asked which format they felt was easiest to understand. The percentage of respondents who chose the radar area graph as "the easiest to understand" was almost the same as for the bar chart (36% for radar area and 37% in the bar chart). However, the percentage of those who chose the radar area graph as "the most difficult" was higher than for the bar chart (33% for radar area and 18% for bar chart). The numerical table format was highly unpopular, with only 16% of survey participants classifying it as "the easiest to understand" and 43% as "the most difficult to understand". One possible explanation for why more consumers think the radar area graph is more difficult to understand than the bar chart may be that they are not accustomed to this type of format. In fact, some survey respondents who did not choose the radar area graph as "the easiest" said, after further questioning, that it was the easiest to understand once they knew how to read it.

The survey results clearly support the evidence discussed earlier that a numerical table format is not suitable for this application. The survey did not provide any clear evidence to support the use of the radar area graph over the bar chart format. However, other considerations, such as smaller minimum size as discussed later, tend to favor the radar area graph.[34]

***Consumer survey to select terminology***

The consumer survey used to select the graphical presentation format also contained questions about what type of environmental data should be presented, and what terminology most appropriately describes the environmental impact categories. The detailed survey results of the survey are presented in Appendix A.

Regarding the type of environmental data to be presented, survey respondents preferred "a numerical estimate of the environmental impact" based on scientific calculation methods, such as Global Warming Potential or Human Toxicity Potential, to "mass of resource used or chemical emission" such as Carbon Dioxide released (kg of CO2) or Wood Used (kg of woods). In other words, the use of midpoint indicators was preferred to the use of direct LCI data. Additionally, the respondents preferred that this information be presented as separate indicators rather than combined into several summary indicators. Specifically, the use of Global Warming, Ozone Depletion, Photochemical Smog, and Toxic Chemicals categories was preferable to the use of a single category, such as "Human Health", to summarize those indicators. These results are consistent with this program's life cycle assessment methodology, and the use of midpoint indicators.

Survey participants were also asked what kind of reference information they would find the most useful in order to evaluate and compare a product's environmental impacts. Half of the respondents answered that "comparison to the damage of the average product in the same category" would be the most helpful to present the environmental impact. However, this program will not adopt this data presentation method because of the uncertainty involved when identifying average product impacts, and the program's goal of providing information about the absolute environmental impacts of products. Therefore, this project will employ the respondent's second choice for data normalization, which is "a comparison to the damages that result from the average individual American's daily consumption".

Finally, the survey asked respondents to identify the terminology that both accurately describes environmental impacts and is easy to understand. For example, "Global Warming", "Climate Change" and "Greenhouse Effect" all describe the same phenomenon, but people's understanding of those words may be different. For the ten main indicators used by this program, the final terminology is:

Global Warming, Land Use, Acid Rain, Eutrophication, Ecotoxicity, Non-Renewable Resource Depletion, Water Resource Depletion, Chemical Pollution, Smog Creation, Ozone Depletion.[35]

[34] The final version of the radar area graph has been improved from the survey version. In addition to rephrasing a few of of the impact category names, the environmental impact of each indicator is now directly proportional to the area of a shaded wedge instead of the "shaded star" pattern, whose shaded area depends on the distance of the data point from the center of the circle.

[35] Respondents actually preferred the term "Water Pollution" to "Eutrophication," but we decided that the term "Water Pollution" could confuse users because of possible overlap with other indicators such as Ecotoxicity. The term "Human Toxicity" is generally preferred by life cycle assessment practitioners, but as one survey participant responded, "I would never buy a product with any human toxicity (impact)". It was decided that the term "Chemical Pollution" can avoid the perception that using or consuming a product is necessarily toxic to the purchaser.

## 4.3. USE OF PRINT AND INTERNET MEDIA

This program will use a variety of means to provide information to users. Therefore, the use of the terms “label” and “ecolabel” are intentionally avoided when discussing this program’s environmental declarations since they can create the perception that a printed product label is the primary means of communication. While printed product labels are still one method that will be employed, it is expected that internet and related technologies will offer the greatest opportunities to quickly provide useful information that can be customized to suit each individual’s needs.

### 4.3.1 Printed media and on-product labels

When comparing products in-store, printed media is likely to remain a main source of information for consumers considering the convenience and immediacy of information provided by the format. However, the usefulness of printed media for environmental declarations is impaired by several obstacles, including:

- The printed area is too small to contain the necessary information.
- The distance between printed declarations is too great to allow for convenient product comparison.
- User-specific conditions, such as location of purchase, can not be easily included.
- Some program participants may choose not to print quantitative results directly on product packaging.

Still, printed information is a good way to gain wider recognition for this program, and in combination with web-based media, should be employed to the greatest extent possible. Two types of printed media are considered separately here: on-shelf signs and on-product labels. The decision of whether the information will be presented on the shelf, directly on the product, or both will depend on the participating producer and retailer.

*On-shelf signs*

Printed information can not be shown directly on small products (pencils) or products without packaging (vegetables). Even some large products, such as refrigerators and computers, are often displayed in the store without packaging. In these cases, printed information can only be displayed on a sign that is posted near the product. The size of the sign may vary depending on the type of product and retailer preference, but a 13 x 18 cm (5 x 7 in) card size would be generally acceptable. The product name must be prominently shown on the sign so that it is clear to the consumer to what the information is referring. The advantage of the on-shelf sign is its relatively large size that can be easily read without omitting detail and explanation. However, if the consumer wants to compare products that are not immediately adjacent to each other, they will need to remember the information from one sign as they walk to the other product’s sign. Also, if the package does not contain any reference to the program, the consumer will be less likely to remember the program’s name, or the internet URL address, after they return to their home.

*On-product Labels*

As stated earlier, the term “label” is generally not to be used to describe this program’s environmental declarations, except when referring to printed on-product labels. Using the radar area format the minimum label size is 25mm x 40 mm (1.0 in x 1.6 in). This format was selected partly because the circular layout, and the use of illustrations to supplement the text allow for a smaller label than the alternatives (see Table 4.5).

| | | Size | Orientation | Illustrations | Text |
|---|---|---|---|---|---|
| **Radar Area Chart** | Medium | 50 x 70 mm (2.0" x 2.8") | Portrait | Yes | 6 point |
| | Small | 25 x 40 mm (1.0" x 1.6") | Portrait | Yes | 3 point |
| **Bar Graph** | Medium | 70 x 50 mm (2.8" x 2.0") | Landscape | No | 6 point |
| | Small | Impossible (text too small) | | | |
| **Numerical Table** | Medium | 70 x 50 mm (2.8" x 2.0") | Landscape | No | 6 point |
| | Small | Impossible (text too small) | | | |

**Table 4.5** Dimensions for medium and small format on-product labels

This program will not require participating producers to print any information on the product packaging. However, participants will be encouraged to publicize the fact that their product has undergone a life cycle assessment by an independent party. Ideally, this will be in the form of the radar area chart displayed as an on-product label. However, some participants may wish to advertise the fact that their product has been subject to a life cycle assessment, but do not want to show the results on the product packaging. This might be case when the product's environmental impacts are high relative to alternative products. Participating companies therefore will be given to choice to display a logo with only the program administrator's URL web address and a product identification number on the product packaging so that consumers can access the environmental declaration data using the internet.

Key Recommendation: While the display of environmental declaration data directly on their products will be encouraged, participating producers shall have the flexibility to display a logo-only label, or no label at all.

### 4.3.2 Web-based Media

The internet is an essential communication tool for any Type III environmental declaration program because it provides a single access point to the entire range of the program's publicized data, and it enables users to interact more actively with the data than printed labels. Using the program administrator's website, a consumer can compare the environmental impacts of the products they are considering, learn more about the methods used to calculate the environmental impacts, and create a personal database that allows them to track the impacts of their consumption activity.

***This program's web publication method***

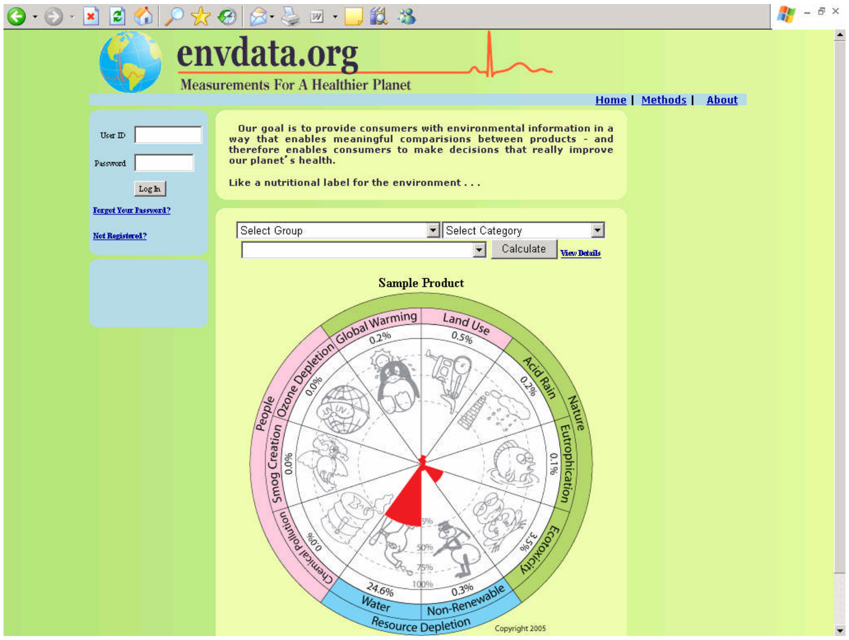



**Figure 4.8** Main page of the proposed program's website

This program's website has three main purposes; 1) to present environmental impact data for comparison between products, 2) to provide each registered user access to a personal database of their consumption history, and 3) to provide general information about the program principles and methods, and 4) to provide information for potential program applicant companies about how they can submit their products for inclusion in the program.

*Environmental impact data for product comparison*

Even when environmental impact data is displayed as on-product labels, consumers may still have some difficulty making product comparisons for reasons explained earlier. By selecting various products on the website, the user can make side-by-side comparisons of products using either the radar area graph format, or a numerical tabular data format. Using a numerical table, it is also possible to provide the category indicator results in other ways:

- By life cycle stage
- Before normalization (midpoint indicators).

Users are also given the option to download a file (in .pdf format) for each product's summary life cycle assessment results.

*Personalized database for individual users*

One of the greatest benefits of a web-based data publication system is the flexibility it provides for users to interact with the data. The program's web site uses an application server hosting a read/write database that allows registered users to access information that they have saved during a previous session. Such saved information can include personal preferences about the way the user wants to display product data, to a list of their prior purchases of registered products. There are many potential uses for application-based websites, so only a few under consideration for use by this program are discussed here.

*Personalized data presentation format*

The radar area graph presentation format may not be suitable for all users. For example, more advanced users, or those with some background in life cycle assessment, may wish to see the data automatically presented in a tabular format of midpoint indicators every time they access the website. This can be accomplished by allowing the user to save this preference as a personal setting. The radar area graph itself can also be modified to suit each individual user. As discussed earlier, one of the limitations of this presentation format is the implication that all impact categories are of equal importance. By allowing users to select the categories that are most important to them, a customized radar area graph can be presented with any combination of three to ten categories. It would even be possible to allow users to assign a percentage value to represent the relative importance of each category. These values could then be used to customize the radar area graph by increasing or decreasing the included angle of the various indicators' shaded wedges. The user could then accurately evaluate the total environment impacts of a product by considering the total shaded area.

*Personalized transportation phase impact results*

As discussed in the life cycle assessment methods section, because program applicants do not know the final destination of every product, an assumption for the average purchase location must be made when calculating the transportation impacts. However, the end user does know the purchase location, and therefore the environmental declaration results presented to the user on the website can reflect the actual transportation scenario. This can be accomplished by allowing users to register their zip code as a personal preference. The web application would then employ a zip code-based distance calculator whose results would be used in a transportation formula for each impact category.

*Personalized use phase impact results*

Environmental impacts in the use phase of a product's life cycle can be dependent upon the conditions under which the product is used. For example, based on this program's calculation method, the value of the indicator for water depletion will be different for a user who lives in an area where water is drawn from an underground aquifer than for someone who lives where water is drawn from a rain-fed reservoir. Users who know the source of their home water supply can edit their personal settings so that the web application will automatically calculate the environmental indicator based on this information. The web site will also allow users to modify a few of this program's standard assumptions for calculating use phase impacts in order to provide more useful information for product comparison. As discussed earlier, when deciding what materials and processes should be included in a product's life cycle assessment, the product boundary is drawn so as not to overlap with other products in a product system. This is mainly relevant for deciding the use phase boundaries, since it is in this phase that multiple products interact with each other.

> For example, the product boundaries of a laundry detergent might be drawn to include the water used to wash clothes. That means that the product boundary for a laundry machine would not include water use since it is part of the same product system as the detergent. A consumer shopping for laundry machines, however, might want to include the use phase water depletion in the environmental declarations for two machines. Although this would not be acceptable for a printed label in this case (because the product functional unit can not reliably predict the product's durability), by allowing the web user to select the exact basis of comparison, (e.g. one year typical use, 500 normal loads, etc. ) environmental declarations can be customized to present the results in a manner that is more useful to the user.

*Personalized disposal phase impact results*

The website can also allow users to select options that will customize the disposal phase impacts to more closely reflect their individual scenario. Normally, disposal phase impacts will be calculated using average data, such as the relative proportions of waste landfilled, incinerated, or recycled in a particular region. Consumers who wish to select their personal disposal conditions for a product will be able to view an environmental declaration that more accurately reflects their personal decisions. This information might be useful to consumers who would like to know the effect of their recycling efforts relative to their other consumption activities.

- Aggregating environmental impacts of product consumption

One of the unique aspects of this program is the emphasis, as a program goal, on providing consumers with information about a product's environmental impacts in absolute terms. This goal, combined with the practice of minimizing the double-counting of impacts resulting from the overlap of different products, was established in order makes it possible for consumers to aggregate product results so that they could estimate the total environmental impacts of their consumption activities. This original feature of this program is made possible only by the application of web-based database technology. However, several obstacles must be addressed before this feature is useful for consumers. Several proposals to overcome these obstacles are presented here:

Obstacle 1 - Incomplete product coverage: During the initial stages of a program, there may only be a few hundred registered products, and a consumer's purchases may only include a few of these. Even as the program gains popularity, the registered products will likely never exceed a small fraction of what the average individual consumes. To compensate for this, the web site will allow users to extrapolate the impacts of their consumption of registered products to estimate the impacts of all their purchases. Such an extrapolation might be made using a mass or cost-based adjustment of all purchases.

> For example, if registered products accounted for $40 of $400 total purchases, the registered products might be multiplied by a factor of 10 to estimate total environmental impacts.

Of course the results can only provide a very rough estimation of total impacts, and will be presented with an uncertainty factor. This uncertainty factor will decrease as the proportion of registered products consumed increased, thus providing some additional incentive for the user to choose registered products.

Obstacle 2 – Difficulty for users to input purchase data: Even if data were made available for every product, it would be unreasonably time consuming for consumers to input the data to the web database manually. By applying internet-based technologies, there are several alternatives to overcome this obstacle.

> Example A: Retailers may wish to act as a program partner if they believe that by providing information as a service, they will be rewarded by increased customer loyalty. These partner retailers will be asked to add environmental declaration data to their inventory tracking systems so that when a customer goes shopping, the tally of their environmental impacts can be presented to them (e.g, printed on a receipt, or accessible via the retailer's website). The consumer's purchases from partner retailers can then be either input manually to the program's website using the printed receipts, or input by downloading purchase data from the retailer web page.

Example B: New technologies accessible via handheld devices such as cell-phones and PDA's enable consumers to view electronic product information at the point of purchase. (see new technologies section) By connecting automatically to the program web page, the user can also choose to add the item to their purchased products database while viewing the product data. The use of a 2-dimensional bar code that is readable by the handheld devices' built-in digital camera can greatly simplify this task of data input.

Key Recommendation: A program's website should allow users to aggregate the data from their purchases, and provide an estimate the total environmental impacts of their consumption activities.

- Aggregating environmental impacts of product consumption with other activities

Although the environmental impacts of an individual's activities are due in large part to their consumption and use of products, other activities, such as personal transportation and home energy use, also make a significant contribution. By providing the means to compare dramatically different activities, this program will allow users to prioritize their efforts to reduce environmental impacts according the effectiveness of various options.

Example: Some environmentally conscious consumers in the U.S. may be willing to spend more on a product based only on the characteristics of the product packaging, such as its recyclability, since that is one of the only clearly visible environmental features of a product. On the other hand, the same consumer may decide not to pay extra for a slightly more efficient vehicle. For consumers who are willing to spend a certain amount of money or time to improve their environmental performance, a relative comparison between these different activities will allow them to distribute their limited resources more effectively.

For this task, the program's web page will enable users to input information about their other activities, such as miles driven, or gasoline purchased for their personal vehicle, and energy and water use data from home utility bills. The web-based application will then calculate environmental impacts based on this information. It is likely that only a small percentage of the web site's visitors will take advantage of this feature. However, even users who are unwilling to take the time to input their own data might benefit from viewing activity impact summaries for users who do input personal data and are willing to share it. The technique of aggregating information from product environmental declarations with that of other activities might result in overlap, and double-counting of environmental impacts. This could occur, for example, when adding the impacts of home electricity and water use to product consumption impacts that include the use of a laundry machine. To avoid this double counting when calculating environmental impacts from an individual's entire range of activities, energy and water consumption impacts during the use phase of consumer products will be excluded.

*General program information*

The graphical data presentation format and environmental indicators are the highly simplified results of a complicated life cycle assessment process. But in order for users and applicant producers to maintain a high level of trust in the program's integrity, it is important that the methods used to calculate the environmental impacts are clearly explained. The program's web site provides a good forum to publish this information because of the quantity of information that can be transmitted through downloadable reports, and the ease with which users can navigate through on-screen explanations of methodology which is indexed at various levels of complexity. The program's web site will also present information to companies that are considering registering their products. Potential applicants can then see the fee structure and other requirements for product registration, and submit a request for more information.

With the advance of web-based information technologies, some organizations, individuals, and pubic agencies have attempted to foster an increase in awareness of the individual's role in preventing environmental problems by providing websites which calculate environmental impacts of an individual's activities. This section presents examples from a few of these websites to demonstrate the potential such environmental impact calculators have as part this program to help consumers understand the environmental impacts caused by their purchasing activities.

***Examples of existing web-based impact calculators***

*The Ecological Footprint Quiz (www.myfootprint.org )*

Since the concept of an "Ecological Footprint" was introduced by Mathias Wackernagel in 1996, the concept of converting the environmental impacts of human activities to a cumulative land area based unit has gained in popularity and is now employed by internationally respected organizations like the World Wildlife Fund (WWF). Specifically, ecological footprint represents the land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology. Although Wackernagal makes some reference to the possibility of applying the concept to consumer products in the form of an ecolabel, the ecological footprint is typically used to compare the environmental impacts of an entire population such as a country, a continent, or an aggregation of all developed nations [83]. WWF publishes an ecological footprint in terms of the number of planet Earths required to sustainably support the entire world population in their annual Living Planet report [84].

"Ecological Footprint Quiz" (www.myfootprint.org) is a web-based environmental calculator that is maintained by two nonprofit organizations; Earth Day Network and Redefining Progress. Visitors to the web site are asked to select their country of residence, a reference city in the region with the same climate, and respond to 16 multiple choice questions about their food, housing, transportation, and consumption habits. The results are then presented in terms of absolute land area for four categories: food, mobility, shelter, and goods/services categories. The footprint is also presented in terms of the number of planets required if all humankind adopted the same lifestyle as the respondent. For respondents who want to learn how to reduce their ecological footprint, the website provides another page where for the food, mobility, and housing categories, they can adjust the specific values for several activities to see the change in their footprint value.

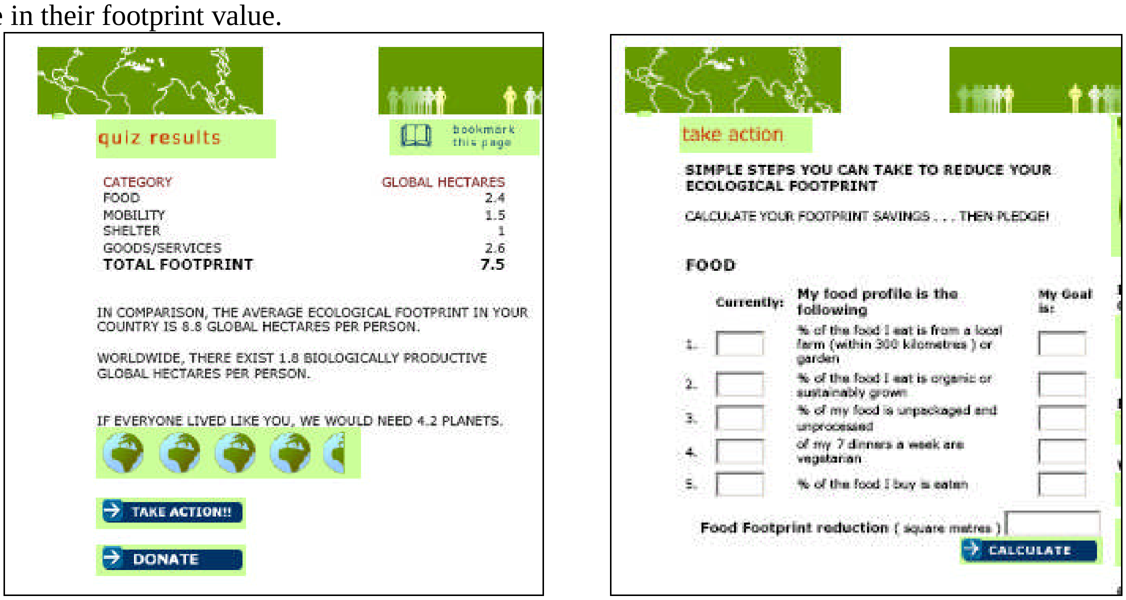



**Figure 4.9** Website for the Ecological Footprint Quiz

Website calculator presents the user's personal Ecological footprint in terms of the number of planets (left), and the change in their footprint after allowing adjustment of the values for several activities (right).

*The Canadian government's One Tonne Challenge (www.climatechange.gc.ca/onetonne )*

The One-Tonne Challenge is a concept created by the Canadian federal government in an effort to help meet the greenhouse gas (GHG) reduction targets set by the Kyoto Protocol by encouraging Canadian citizens to each reduce their annual greenhouse gas emissions by one metric ton. According to the web site (2006), the Canada's per capita annual GHG emissions are more 5 metric tons, so the challenge is not an insignificant one. To assist Canadian's in this voluntary challenge, the website asks 21 multiple choice and numerical value questions (some with sub questions) to calculate the total mass of GHG emissions. The results are also broken down in 9 categories in a pie chart format (transportation, heating & cooling, water heating, lighting, appliances, gardening, household waste, recreation and other) and the total mass is presented in a bar chart format with along with the national average and the provincial/territorial average for reference. Like the Ecological Footprint Quiz, the One-Tonne Challenge calculator also encourages users to see the effect of changing specific activities so that they can effectively achieve the reduction goal. By incorporating a user registration feature with database access, participants can create and edit a "reduction plan" that in addition to saving the specific actions committed to, also displays a thermometer-like graphic that with a falling mercury level, tracks their progress towards meeting the reduction goal.

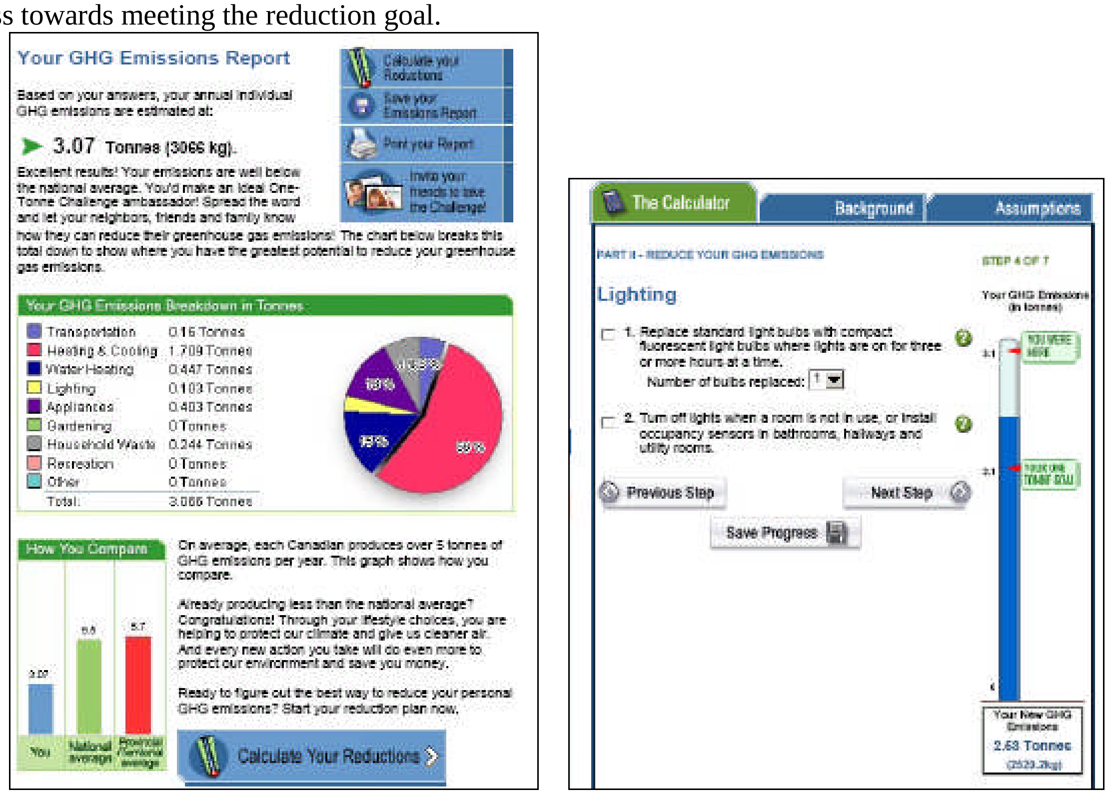



**Figure 4.10** Website for Canada's One Tonne Challenge
The site calculates GHG emissions from individual's activities (left), and the effect of changing specific activities (right).

*City of Tampa, Florida Water Department Water Usage Calculator*

*(*http://www.tampagov.net/dept_water/conservation_education/Customers/Water_use_calculator.asp*)*

In an effort to educate the residents of Tampa, Florida about the main activities responsible for individual water use, the city provides a web-based calculator that estimates the total water usage. The web-based calculator asks 18 numerical response questions which are separated into six categories (bathroom, toilets, faucets, washing dishes, laundry, and lawn watering & other uses). The results are presented for each of the six categories in terms of the number of gallons used per person per day in the household. The household total water consumption per day, per month, and per year is also calculated and presented with the Tampa average household results for reference. Unlike the other calculators discussed above, there is no page provided for calculating reductions. However, a page with water usage reduction advice is provided, and the numerical data input easy to understand, so little additional explanation is required.

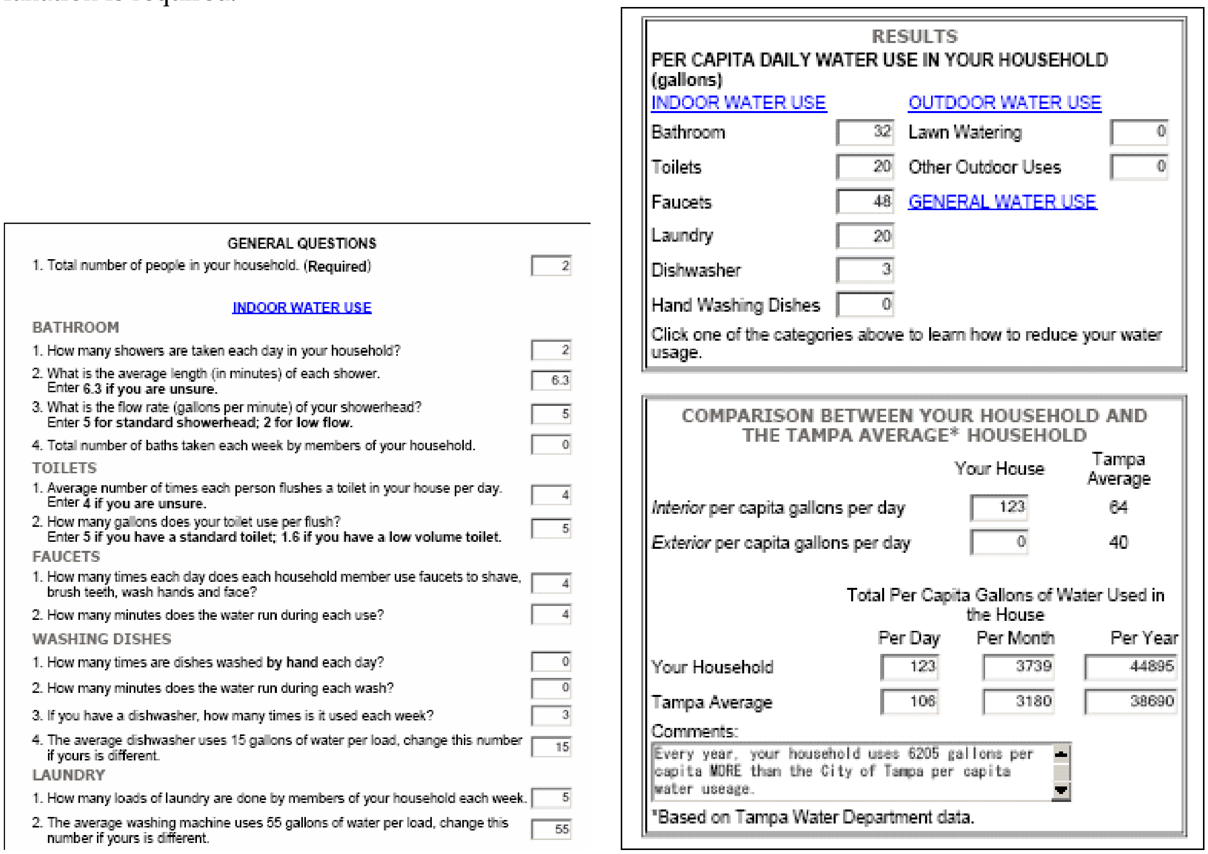



**Figure 4.11** Website of the City of Tampa's water use calculator
The calculator asks for numerical responses to questions (left). The results are compared to the city's average household (right).

*Hybrid Vehicle User Fuel Efficiency Database (www.greenhybrid.com)*

Although hybrid vehicles (combined fossil fuel and electric power) have been gaining in popularity and are touted for their potential to save fuel, they been subject to some criticism for failing to provide the levels fuel efficiency advertised by manufacturers. The GreenHybrid website, and Real Hybrid Mileage Database were created by Jason Siegel, an individual attempting to increase awareness of hybrids and promote their potential to save fuel. A unique feature of this site is that owners of hybrid vehicles can register with the site, and input the mileage and fuel consumed into the site's database. As of March 2006, over 1600 users had submitted information for 14 different vehicle models. The web application automatically calculates the average fuel efficiency reported for each model, and presents the results of all 14 models on a bar chart for comparison. The aggregate data for all models is also presented by vehicle model in a numerical table format, with values for median, mean, range of middle 50% values, standard deviation, standard error, and number of cars in sample. The vehicle model list provides a link to a page with data for a single model type. On this page, the individual user's average data is presented as a histogram to graphically show the distribution of fuel efficiency for that model, and also as a numerical table of fuel efficiency ordered from most to least efficient. By ranking the results of registered users, the Real Hybrid Mileage Database introduces an element of competition that might encourage users to continue participating in the database, and even change their driving habits in an effort to improve their position within the ranking. The database is still useful for consumers who do not yet own hybrid vehicles, or hybrid owners who do not want to take the time to input their own data, because it provides quantitative information that is not available elsewhere.

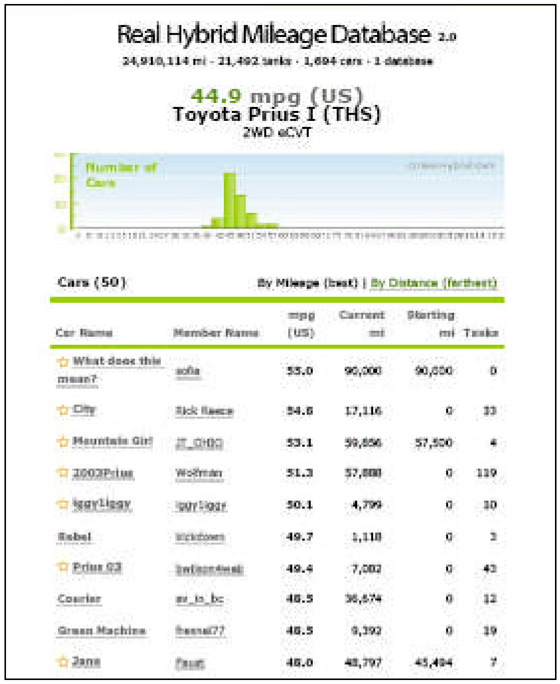



**Figure 4.12** Website for greenhybrid.com - User fuel efficiency database

*Other Web-Based Calculators*

Although not exactly environmental impact calculators, there are some web sites that provide consumers information about the potential health effects of specific products. An interesting example is the "produce scanner" presented by the Environmental Working Group (EWG), which describes itself as an investigative industry "watchdog organization". Using data from U.S. Department of Agriculture (USDA) and California Department of Food and Agriculture for the chemical residue on fruits and vegetables, the web site selects results randomly from thousands of lab tests to simulate the uncertainty in selecting an item of produce. Results are presented in terms of the number of pesticides found in that random test, their chemical names, and there association known health effects. (www.foodnews.org )

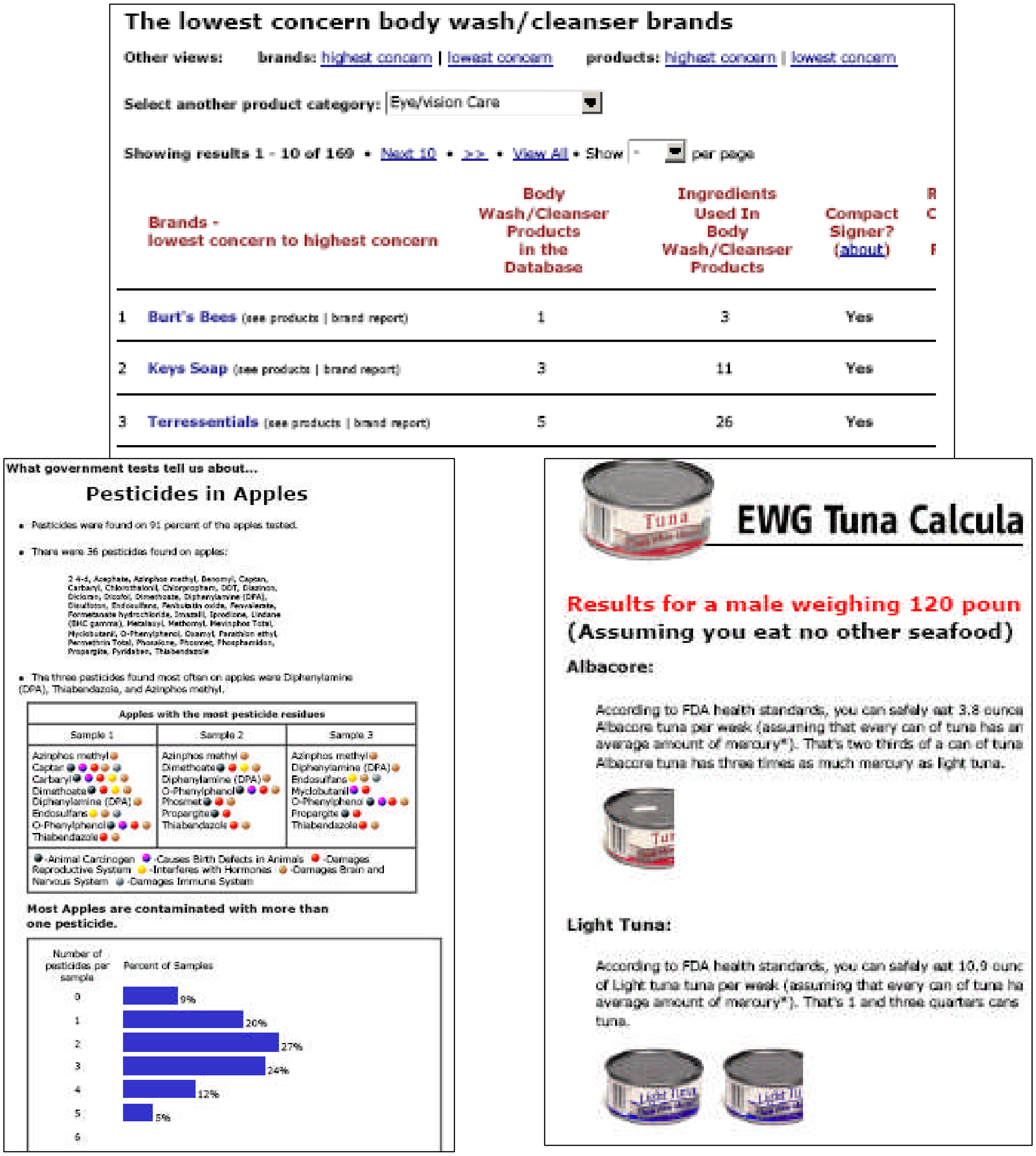



**Figure 4.13** EWG's product toxicity information websites
"Skin deep" evaluates the ingredient lists of personal care products (top), "Produce scanner" provides information about pesticide residue of vegetables (bottom left), and the "Tuna mercury calculator" presents the number of cans of tuna that can be safely consumed (bottom right)

Also from the EWG is "Skin Deep" internet-accessible database for personal care products. (www.ewg.org/reports/skindeep/) Based on the printed ingredients information for more than 13,000 ingredients, and using a hazard based scoring system for each ingredient, the products are given a relative score, and assigned a "safety score" from 0 to 5 which is segmented into "low", "moderate", or "higher" levels of concern for that product type. Visitors to the web site can search for products by name and are presented with the safety score and the publicly available list of ingredients for that product. Alternately, visitors can search by product type, in which case the results are presented as a list of brand names which are ranked by the average safety scores of the products they sell.

Finally, the EWG offers a "Tuna mercury calculator" that is intended to provides some guidance to those concerned about the mercury that accumulates in larger predatory fish, such as tuna, as a result of air pollution from coal-burning power plants. (www.ewg.org/issues/mercury/20031209/calculator.php) The web site asks users to input their body weight, and select their gender. Then, based on data from US Food and Drug Administration (FDA) tests of the amount of mercury in canned tuna, and the FDA's recommended safe dose of mercury, the web site calculates the masses of albacore tuna and light tuna that can be safely consumed. The results are also presented graphically as images showing the number of cans of tuna that correspond to these masses. All of the EWG calculators presented here are similar in the fact that they are based on publicly available data, and do not rely on the cooperation of retailers. This is possible because these calculators only consider the toxic effects of consumption, not the environmental impacts of production processes, and therefore can be estimated using ingredient lists and product test data. Without the cooperation of producers, the EWG calculators are able to cover a wide range of products, but are unable to present environmental impacts as comprehensively as this program's environmental declarations.

## 4.4. FUTURE TECHNOLOGY

The data presentation methods proposed for this program are all limited in their usefulness in large part because of the limitations of the media by which they are presented. Printed labels and on-shelf signs are limited by the available space and issues of portability, while access to the program's internet database is limited by the consumer's ready access to a personal computer. Therefore, there is currently no perfect method that will allow all consumers to conveniently view the data for all registered products at the time they are making purchase decisions. However, as new information technologies (IT) become available, this program's environmental declarations can be made more accessible, and more useful. In the early 1990's, before the internet was widely accessible, the only method of presenting the environmental declaration data was as a printed label on the product packaging. Features such as this program's aggregation of individual consumption impacts, or customization of results and presentation format, would have been impossible. At that time, it would have been difficult to predict the tremendous impact that the internet would have on information availability, and the potential for environmental declarations to be presented on personal computers rather than on printed labels. Similarly, future advances in technology can be expected to dramatically improve the effectiveness of this program's data publication. Although we cannot predict the future with perfect accuracy, it is still useful to consider how this program will take full advantage of future technology.

### 4.4.1 Internet accessibility via handheld devices

A growing number of people in the U.S. currently have cell phones which are capable of accessing the internet. In 2005, of the 194 million wireless service subscribers in the U.S. [85], 48% have multimedia service. And the penetration of internet-capable cell phones is increasing rapidly; up 11% from 2004[86]. According to this trend, it can be assumed that even more people in the future will be able to access the internet via cell phone. The personal digital assistant (PDA) is another handheld device that can connect to the internet, but the sales of PDA's are declining as a result of the popularity of multimedia cell phones and industry observers have predicted that the cell phone will continue towards a dominant position among internet-capable handheld devices. [4 Gilroy, A].

Using a cell phone, consumers can access this program's webpage to view detailed LCA results as they are purchasing products in a store. This method offers a major advantage over internet access via a home computer, because the use of a handheld device in-store does not require that consumers write down or memorize the web site's URL address and the product identification number. Also, the comparisons are more useful when made in the store, as the consumer is making a purchase rather than requiring the use of time at home when the individual would not normally be thinking of shopping.

The process for using a cell phone for in-store product comparison is:

- The user connects to the internet, and types the program web address, or follows a link to the program home page.
- The user selects a "compare products" option, and navigates through pull-down menus to select two or more products for comparison.
- (optional) The user adds the selected products to their purchased items database in order to calculate total environmental impacts.

Even with the use of a handheld internet device, product comparisons in-store are still somewhat inconvenient for consumers because of the device's small screen size, and the time required to perform the steps above, especially inputting the web address and the product identification information. This procedure might be dramatically improved with the use of a product scanning technology, as described below.

### 4.4.2 Product scanning with two-dimensional codes

The adoption of two dimensional (2D) codes printed on product labels would dramatically improve the convenience of comparing environmental declarations for consumers who use a handheld device capable of scanning the label. A 2D code containing the web address for the web page containing that product's data would eliminate the inconvenience of manually typing the address and navigating through a series of menus to find the product. Several standard formats for 2D codes are already in use, and are becoming increasingly popular because of their greater capacity to store data than the traditional one dimensional bar code. In Japan, the "QR Code [87]" is a typical format, while the U.S. and Canada tend to use the "DataMatrix" and "Semacode [88]" formats, respectively. The advantage of the 2D code arise from the fact that information is contained in both the vertical and horizontal directions, whereas bar code contain data in one direction only. As a result, the DataMatrix format can contain up to 2355 alphanumeric characters and the QR code up to 4296 whereas the typical bar code (Code 39/Code 128) can contain only 20-40 alphanumeric characters depending on the length [89]. Furthermore, the 2D code can be printed in a smaller area than the barcode. For example, QR Code is capable of encoding the same amount of data in approximately one-tenth the space of a traditional bar code.

**Figure 4.14** Picture of QR code

In Japan, QR Code is becoming increasingly popular as a means of directing internet-capable cell phones to web pages by using the cell phone's built-in digital camera function to capture and process the 2D code image. A number of advertisements in magazines and websites display a QR Code symbol, which contains the URL information for websites targeted towards mobile users. After capturing the image, cell phone software decodes the symbols, and directs the phone's browser to the associated web page. Currently, companies in Japan are using this feature to provide consumers with more detailed product information than can be found in the printed advertisement. In order to perform this function, a cell phone must be equipped with a camera and internet capability as well as the software to read the code. This is currently not an obstacle in Japan, were in 2005 an estimated 83% of cell phones have internet capability, and 85% of them are equipped with a built-in camera [85]. The software can be download free-of-charge. While it is difficult to predict if the market penetration of this technology in the U.S. will ever match that of Japan, the prominence of both camera phones and multimedia services are rapidly increasing in the U.S., so that it is reasonable to assume that in the near future a large percentage of consumers in the U.S. will be able to access the internet using 2D codes.

In addition to its potential usefulness for in-store product comparisons, using a handheld device and 2D code would greatly simplify the management of the user's individual consumption database compared to using a home PC. After scanning the product 2D code to view the environmental declaration, the web page can provide the option of adding the product to their consumption database.

Because of the 2D codes ability to store a large amount of information, it would be possible for a mobile user to scan environmental declarations even without a connection to the internet. Incorporating the detailed environmental declaration data in the code would provide information to the user more quickly than relying on the wireless internet connection, and it might be an advantage to users who are charged for internet access based on the time spent online. It would also allow the handheld device to be used everywhere, even if the wireless signal were limited. To provide this information, the program administrator would need to develop software for the cell phone to interpret the code and manage product information, and to provide that software to users. To allow for users to add to their individual consumption database, the purchasing decision could still be registered using the cell phone in the same way as with a direct internet connection, but the data would need to be stored temporarily on the cell phone to await a transfer to the web-based database, where it could be more easily viewed and managed.

### 4.4.3 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a generic term that is used to describe a system that transmits the identity of an object wirelessly, using radio waves. RFID was designed to transmit a signal to a reader that captures the data on tags and sends it to a computer system, thus eliminating the time and potential error involved with manual data entry. A typical RFID tag consists of a microchip attached to a radio antenna mounted on a substrate and can store as much as 2 kilobytes of data. Information about a product or shipment, including the date of manufacture, serial number, sell-by-date, and shipping destination can be written to a tag. [90] [91]. This technology is already employed by many industries, and it is particularly useful in supply chain management for production facilities. Cost is the major obstacle to the technology's penetration to general products: $0.20 to $1.00 per chip. However, the competition to improve RFID systems has resulted in rapidly decreasing size and cost for the chips. The size of the smallest chip is now 0.4 mm (Picture), and the price is estimated to be less than 5 cents. It is expected that RFID technology will be a viable replacement for the bar code when the price becomes sufficiently low, for example, less than $0.01 per chip.

For this environmental declaration program, the fact that the data contained on the tag is rewritable makes RFID uniquely suited for storing information that might vary between products. For example, the chip can be used to identify the source location of a product that might come from several sites, such as produce. This advantage is significant because with all other, methods it is only possible to know the exact distance between a producer to a retailer when the production site can be identified by the product packaging or UPC code.

Although RFID technology can store and manage environmental information, its ability to present information is limited because RFID readers are not available to customers. The only way to present the environmental information is, with the cooperation of the retailer, on the printed sales receipt.

> <u>Providing information to customers on a printed sales receipt</u>
> When a product is purchased, a register can automatically read all information contained in RFID. If the register has software to process the contained environmental information, the printed receipt can display the individual and total environmental impacts of the purchased products. Universal Product Codes (UPC), instead of RFID, may be used for the same presentation method, but it cannot rewrite information. While this method can be used to present a summary of environmental impacts after purchases are made, it is not useful to compare the environmental impacts of different products in a store.

Information on an RFID chip, similar to a 2D code, can be read directly by scanning with a mobile device. If consumers have devices to read the information, they can view the environmental information at the retail site, and directly add the data to their personal database. The RFID code is potentially better than the 2D code because more specific product data can be stored. However, this method is not currently possible because there are no such mobile devices for general consumers to read the information. However, if the demand for this function arises in the future, it might be incorporated in handheld devices such as cell phones.

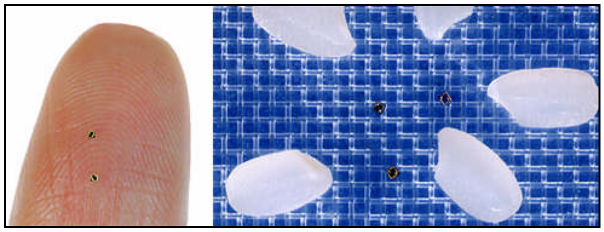


**Figure 4.15** RFID chip
The smallest RFID chip is 0.4mm square. Compared to a finger (left) and rice (right).

## 4.5. SCENARIOS OF DATA PUBLICATION

The various methods of presenting environmental declaration data each have different advantages, and when used in combination with each other, can give consumers the flexibility to choose the format that is most convenient and useful for them. **Error! Reference source not found.** summarizes the advantages and disadvantages of the different presentation methods, and the extent to which the technology to support those methods has penetrated the U.S. market.

| | | Assuming technology is available, | | | | | Penetration in U.S. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ability to provide data for: | | Convenience for Consumer to analyze data for: | | Ability to include: | Current | | Future | |
| Customer Interface | Data transmission medium | Product Comparison | Total Purchase Summary | Product Comparison | Total Purchase Summary | Product Specific Data | Availability of Technology to consumers | % of Consumers with Access | Availability of Technology to consumers | % of Consumers with Access |
| Printed label | Product package | High | Low | High | Low | Low | High | High | High | High |
| Printed label | Shelf signage | High | Low | High | Low | Low | High | Moderate | High | Moderate |
| Home PC | Internet | High | High | Moderate | Moderate | Moderate | High | High | High | High |
| Handheld device | Internet (type URL) | High | High | Moderate | Moderate | Moderate | High | Low | High | High |
| Handheld device | Internet (via QR code) | High | High | High | High | Moderate | Moderate | Low | High | Moderate |
| Handheld device | QR code (embedded data) | High | High | High | High | Low | Moderate | Low | High | Moderate |
| Handheld device | RFID (embedded data) | High | High | High | High | High | Low | Low | Moderate | Moderate |
| Printed receipt | UPC code | Low | Moderate | Low | High | Low | Moderate | Moderate | High | Moderate |
| Printed receipt | RFID | Low | Moderate | Low | High | High | Low | Low | High | Moderate |

**Table 4.6** Various presentation technologies

The usefulness of the presentation formats depends not only on availability of technology, but also upon the level of involvement of producers and retailers. For example, printed product label declarations are only possible if the producer decides to display the quantitative values on the packaging. In this section, four different scenarios are described separately under current and future technologies, considering different levels of producer and retailer involvement. The final eight data publication scenarios are summarized in Table 4.7.

### 4.5.2 Current Technology

Currently available technologies include printed declarations, both on-product label, and on-shelf signage, home PC and handheld device internet access (manually typing URL), and printed receipt via UPC code. The blue shaded boxes in Table 4.7 indicate current technologies.

(i) Administrator only

If both the retailers and producers are unwilling to publish product information, consumers will only be able to access environmental declarations through the program's web site. Consumers will need to type the internet address, and manually navigate through the web site to find the product information that is interesting to them. Users will be able to manage their private consumption database with both home PC internet and mobile devices.

(ii) Administrator and producer

In addition to (i), if producers are willing to present the environmental declarations, they will print them on the product package according to the format guidelines provided by the program administrator.

(iii) Administrator and retailer

In addition to (i), if retailers are willing to present the environmental declaration data, they can place signs on the shelf next to the products. Retailers would print out the environmental declarations from the program administrator's database, or they could purchase pre-printed signs directly from the administrator.

(iv) Best case (Administrator, producer, and retailer)

If all stakeholders are willing to present the environmental declarations, data could be available on the product packaging, on-shelf signage, home PC or handheld device internet by typing the URL, or the printed receipt via product UPC code.

In this scenario, producers and retailers would negotiate through the program administrator the best method to present product data considering the product type. For example, for products displayed in the store without packaging, such as vegetables or refrigerator, shelf signage is better. Consumers could then read the printed summary of a product's environmental impacts in the store to compare products. They could also connect to the program's webpage using a home PC or mobile device to learn more detailed information. Additionally, if retailers add the environmental declaration data to their inventory tracking system, it would be possible to display environmental impact information on the printed sales receipt after tallying the results of products identified by their UPC code.

### 4.5.3 Future Technology

2D code and RIFD technologies may become more widely available in the future. In this scenario, they may replace UPC code. Those new technologies can be combined with currently available technologies. The orange boxes in Table 4.7 indicate future technologies.

(i) Administrator only

If only the administrator is willing to present the environmental declarations, the website is the only possible method. This is the same as the current technology "administrator only" scenario.

(ii) Administrator and producer

If producers are willing to present the environmental declarations, they may use a 2D code (both internet and embedded data) and RFID for handheld devices as well as product package labels. These presentation tools can be used simultaneously. Producers can display either a printed label or a 2D code, or both on the product package. In the 2D code case, consumers scan the code with their cell phones built-in camera, and either connect to the administrator's website page for that product, or directly read the embedded data. If hand-held devices have the ability to scan RFID in the future, they could read the data embedded in the RFID chip to view the detailed information at the retail site.

(iii) Administrator and retailer

If retailers are willing to present the environmental declaration, they may put a 2D code or RFID chip on-shelf signage which also present a radar area graph. When consumers have cell phone capable of scanning either 2D code, or RFID can access information in the same way as the “Administrator and producer” scenario above.

(iv) Best case (all stakeholders participate in the presentation)

If all stakeholders are willing to present the environmental declarations, information might be presented using any combination of product package labels, on-shelf signage, internet via home PC, internet via handheld device by typing URL, internet via handheld device by scanning 2D code, handheld device reading embedded data in 2D code, handheld device reading embedded data in RFID, or printed receipt via RFID.

In this scenario, producers and retailers cooperate to present the environmental declaration and choose which method, is best to present information for a particular product, as in “current technology-best case”. For example, consumers could read summary of the ten environmental impacts on product packaging or on-shelf signage. Then, they could scan the 2D code or RFID chip using their cell phone to learn more detailed information and compare products while still in the store. Additionally, they could record their purchase information in a personal database using either their cell phone or home PC internet. When they purchase the products at a register, a printed receipt might shows a summary environmental information for all purchased products.

| | | Data Presentation Scenarios | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Current | | | | Future | | | |
| Customer Interface | Data transmission medium | Data provided by Administrator Only | + Data provided by Producer | + Data provided by Retailer | + Data provided by Retailer and Producer | Data provided by Administrator Only | + Data provided by Producer | + Data provided by Retailer | + Data provided by Retailer and Producer |
| Printed label | Product package | | * | | * | | * | | * |
| Printed label | Shelf signage | | | * | * | | | * | * |
| Home PC | Internet | O | O | O | O | O | O | O | O |
| Handheld device | Internet (type URL) | O | O | O | O | O | O | O | O |
| Handheld device | Internet (via QR code) | | | | | | * | * | * |
| Handheld device | QR code (embedded data) | | | | | | * | * | * |
| Handheld device | RFID (embedded data) | | | | | | * | | * |
| Printed receipt | UPC code | | | | * | | | | |
| Printed receipt | RFID | | | | | | | | * |

* = Partial Product Coverage

O = Full Product Coverage

**Table 4.7** Scenarios for publication at different levels of technology

Blue boxes are current technologies and orange boxes are future technologies. O means all products are covered and * means limited number of products are covered by participants in the program.

# 5. ROADMAP FOR A TYPE III PROGRAM IN THE U.S.

## 5.1. NECESSARY STEPS TO ESTABLISH A TYPE III PROGRAM IN THE U.S.

Based on the proposed systems and methods explained above, we propose the steps that the program administrator should take to start the program.

1) Organizing "Program Establishment Committee" and determine program methods
At the program inception, the administrator shall create "Program Establishment Committee", and define the methods for evaluating the environmental impacts of products. This is the most important step at the beginning of the program because this committee determines all basic system of the program although any change is possible in the process of implementation of the program. The purpose of the committee is making objectiveness and consistency through the program. The administrator appoints the members of committee, which consists of representatives of consumers, industries, and academia, then coordinate the difference of their opinion to get agreement about the program. The administrator shall start the program cooperating with the Program Establishment Committee.
The program principles that Program Establishment Committee shall determine include:

(a) LCA methods

This report proposed possible LCA methods to assess environmental impacts of products mainly in the Chapter 3. These can be draft methods of the actual program, but the proposed methods are not the single best methods to assess environmental impacts of products. There are still controversial points to evaluate environmental impacts. For example, it may be difficult to define how to decide consistent system boundaries, or what is the most appropriate normalization factor for each indicator. In order to create objective and consistent LCA methods that satisfy the purpose of interest parties- consumers, companies, experts of environmental problems- , representatives of those interest parties should participate in the program when the program is established. LCA method is not the only thing that the committee defines.
We proposed 10 indicators are the best to present environmental characteristics of products. Some of those indicators, such as global warming and acidicity, have confirmed calculation methods scientifically agreed. However, the proposed calculation methods for some indicators, such as ecotoxicity and chemical pollution, are not yet confirmed methods. Therefore, in creating those methods, advice about LCA methods especially by LCA experts is necessary.

(b) Organizational structure of the program

The organization structure of the program, such as PCR reviewing committee and Judgment committee should be defined by the Program establishment committee. A structure like Japanese Ecoleaf's organizational structure is not the single organizational structure but committees which include several interest parties are essential for Type III environmental declaration programs. As is mentioned in Chapter 2, such committee should have the same number of each interest parties in order to guarantee the objectiveness.

(c) PCR criteria

Although each PCR is created by PCR committee, the criteria of PCR shall be determined by the Program Establishment Committee. The PCR criteria depend on how the committee thinks comparability among products. If comparability within product categories is regarded like Ecoleaf, PCR criteria are strictly constructed even in generic data used. On the other hand, LCA methods should be flexible like Swedish EPD, PCR criteria are less strictly constructed.

(d) Verification system

There are some possible methods of verification system. In Japanese Ecoleaf, the administrator assign LCA experts as verifiers, while in Swedish EPD, private independent companies have authority to verify the result. In addition, Swedish EPD and Korea EDP conduct on-site inspection whereas Japanese Ecoleaf does not usually conduct on-site inspection. Each system has advantage and disadvantage. The administrator may have option to conduct and verify LCA by itself with extra fee. The Program Establishment Committee shall determine what verification system can match the program to guarantee the objectivity of the results with realistic cost.

(e) Fee

Fee system has also some possible methods. "Market price based fee" or "size of company based fee" is better system than a universal fee. Both market price based fee and size of company based fee has advantage and disadvantage in terms of fairness. The Program Establishment Committee shall determine the fee system to the level that encourages companies to register their product and the revenue can sustain the program administration.

2) Organizing program committees such as PCR committee and Judgment committee
   After the Program Establishment Committee determines the organizational structure of the program, the administrator shall select the committee members and organize the committees composed of several interest parties. For example, those program committees may include PCR committee and Judgment committee (Chapter 2). The member of committee should take balance among interest parties- consumer, industry, academia. The administrator shall pay compensation to the members.
   The PCR committee shall created PCRs for each product categories requested by stakeholders when companies apply for registrations of products.

3) Creating a LCA database software
   In order to make LCA process consistent and easier, the administrator shall create LCA calculation database. The LCA methods and characterization factors used in the database software shall be based on the methods determined by the Program Establishment Committee. The administrator shall maintain the database and continue to add generic data when additional data is requested by applicants or new PCRs require the generic data. The administrator ideally provides applicants with the database software with free charge.

4) Creating data publishing methods
   The administrator shall create the data publication methods which are easier for consumers to understand and to access. This report proposed a "radar area" format is the best format to publicize. In addition, the administrator shall decide publication media. Currently available media are on-product label, on-shelf signage, and home PC and handheld device internet access (manually typing URL). The administrator shall publicize the environmental declarations in combination of those media. In the future, the publication media will include more usable technologies such as 2D code or RFID.A website is currently the best method to publicize detailed LCA data and have functions for consumers to arrange the environmental impacts to match their preferences and have personal database in their purchasing. The administrator shall make use of the interactivity of the website so that audiences have fun to access the webpage and get detailed useful information for them.

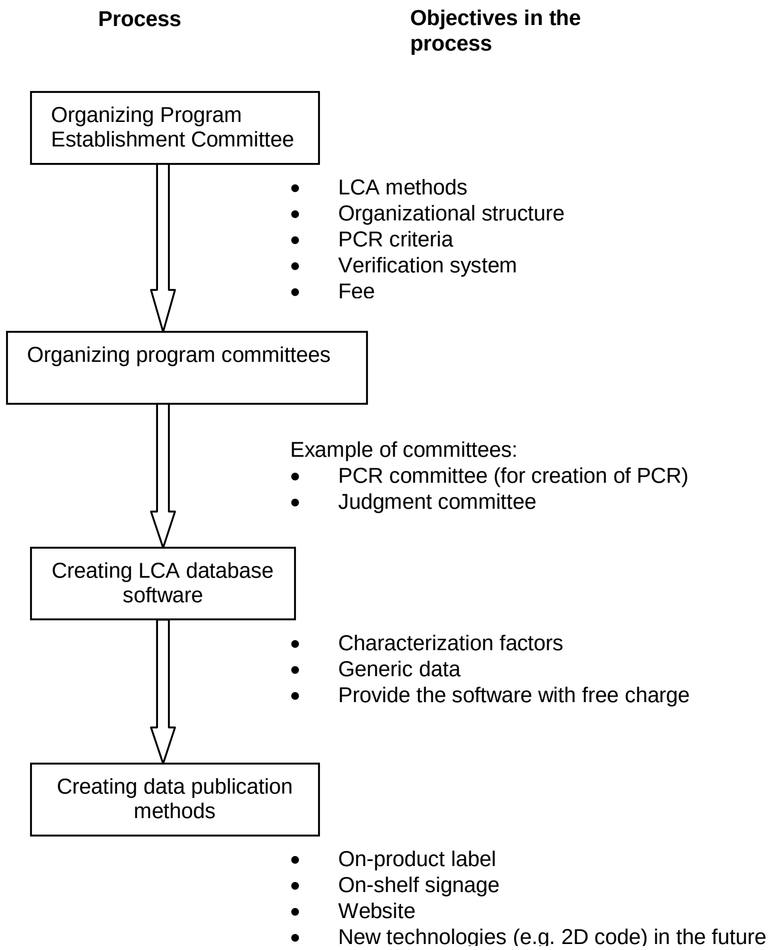



**Figure 5.1** Steps to start the Type III environmental declaration program

## 5.2. OBSTACLES AND STRATEGIES FOR SUCCESS

### 5.2.1 Challenges for Type III Declarations

In order to maximize the benefit of a Type III environmental declaration described above, some difficulties of Type III labels are needed to be overcome. The labeling administrator should continue to make the most effort to improve the program even after it is started. Additionally, the Type III environmental declaration program administrators in the world should cooperate together to overcome these difficulties. In the future, benefits of labels must exceed those difficulties and costs due to those efforts. [22]

- The number of applicants
  Because a Type III labeling program is very a new concept, there are still few applicants for Type III environmental declaration in any existing programs. Prevalence of the concept in companies and societies is necessary for this label to be more useful and sustain the administration system. One of the reasons of the unpopularity is that the history of each program is very short, therefore as time goes on, the number of product is expected to increase. In order to promote the concept, education for customers and some kind of advertisement by any stakeholders is necessary at the beginning of the program.

- Difficulty for applicant companies to collect LCI data
  As manufacturers try to collect more detail data in supply chain, they have more works to do. For the companies that are not accustomed to data collection in supply chains, this may be big a burden. Databases of Type III environmental declarations simplify calculation of environmental impacts, but companies still needs to educate their staffs and make them understand the concept of LCA.
- Difficulty for consumers to understand environmental information
  In order to understand the environmental impacts presented in a Type III environmental declaration, a certain level of knowledge about environment should be needed. This project's environmental declaration tries to make environmental impacts easier to understand using the benchmarking in ten environmental indicators and the explanation of each environmental indicator in the website. However, educational background of consumers about general environmental issues must be increased in the society.
- Internationalization
  Even if a company obtains a certification of their product in one country, they cannot use the environmental declaration in export region. This is inconvenient for global companies which export their product to the worldwide. In order to solve the problem, existing environmental declaration programs are discussing mutual certification, which allows them to use the Type III environmental declaration in other countries once companies obtain certification in one country. If mutual certification can be accomplished, each country needs to advertise more to enhance recognition of their own environmental declaration program in order to have the same condition between countries.
- Database creation and maintenance
  LCA databases needs to be continuously updated. This is a big burden for administrators. In addition, if mutual certification is implemented, the program administrators should cooperate to make common database to avoid large differences of generic data between countries because conditions, such as energy consumption, would be different in each country. Existing environmental declaration programs are discussing cooperating to create common international database as is mentioned above.
- Participation of inferior products
  Companies whose products have worse environmental impacts than others are not willing to participate in the environmental declaration program. It decreases comparability between products. Because mandatory participation is impossible, it is necessary to give those companies some incentive to participate in the program.

### 5.2.2 Strategies for Market Penetration

The administrator should strategically promote the program for getting popularity in public and companies. These are possible strategies for the administrator to advertise and popularize the Type III environmental declaration program.

1) From common goods to less common goods
   At the beginning of the program, the environmental declarations should be contained by the product which consumers very often see in store or they buy everyday in order to increase awareness of consumers, if the program targets BtoC. As they see the environmental declarations in stores, they would more aware of it and become interested in it.
   For example, vegetables, which this master's project used in retail test, are one of those candidates which people periodically buy. Vegetables would have different environmental characteristics depending on production location or whether they are organic or non-organic, therefore consumers can notice the difference of the product characteristics as well as they consider organic or non-organic. The commodities which consumers periodically buy are another good candidate. For example, a certain number of consumers prefer to buy "green" toilet paper or detergent, for example, products of Seventh Generation. Consumers would be

comfortable to buy the products knowing how green they are.

2) From green consumers to general consumers
Green consumers, such as customers of Whole Foods, are willing to consider environmental impact of products and enjoy reading environmental declarations while general consumers, such as customers of Walmart or Kroger, would relatively be unaware of environment. Therefore, at the beginning of the program, it should target green consumers, and after getting popularity in green consumers, try to trickle down the awareness. “Green” stores can give additional values to products in their stores, making them to have the environmental declaration and use this tool in their marketing strategy to improve their image. Thus, support by those green stores would be key issue of the program.
As more products have the environmental declaration in stores, companies would aware usefulness of it and more companies would participate in the program. General stores also have green products, and thus as those stores have more products having the environmental declaration, general consumers would aware it. They may not care about the environmental impact in their purchasing, but as they often see the environmental declaration, it has educational function because the environmental declaration has indicators which show they are important for environmental issues. In the long term, this educational function would promote general consumers’ awareness of environmental issues.

3) Recommend “green” retailers to push manufacturers to have environmental declaration
“Green” stores may require manufactures to have Type III environmental declarations in order to show they consider product environmental characteristics. Once manufactures register environmental declaration, they can use the environmental declaration in any stores. Manufacturers can expand market in green stores with the environmental declaration and improve their image.

4) Recommend for green purchasing from public sectors to private sectors
One of the most useful utilization of Type III environmental declaration is green purchasing of public sectors and private sectors, which means BtoB. As public sectors promote utilization of environmental declarations, companies cannot help considering containing environmental labels because public sectors are big customers for any industries. In addition, public sectors relatively tend to care about environment as their public role. Then, the impact of green purchasing would trickle down to private sectors from public sectors.
Existing Type III environmental declarations mainly target BtoB and recommend public sectors or companies to use green purchasing. Type I label such as Greenseal is currently used for green purchasing because it is easy to interpret as a relative measurement which shows “this good surpasses a certain criteria”. At the beginning of the program, Type III will lack comparability until the number of register become sufficiently large. Nonetheless, Type III environmental declaration is an objective reliable tool to consider how green the product is, showing the product considers life cycle assessment. Therefore, it is rational that public sectors and companies use Type III environmental declaration in their green purchasing decision.
For example, in Japan, a growing number of public sectors use environmental labels for green purchasing since Green Purchasing Act (2001). EcoMark (Type I) is used as criteria by 95.8% (1128/1177) of local governments and Ecoleaf is used by 4.0% (47/1177) of them (2005) [92]. The number of Ecoleaf is very low but more local government would use Ecoleaf if popularity of it increases as the Ecoleaf administrator is promoting it for public sector green purchasing.

5) Seminar/Symposium, education for consumers and students
Companies need to know the advantage of the environmental declaration as well as the way to

apply for the program and method of LCA. It is the role of an administrator to take place seminar about the program. These seminars may target industry associations or individual companies. In addition, educating consumers is important strategy in the long term. The administrator may hold symposiums about environmental labels and green purchasing. It should cooperate with other environmental label administrators and consumer groups/NGOs.

6) From leading companies to general companies
At the beginning of the program, it is expected that leading "green" companies are interested in the program. There are a number of companies which consider environmental impacts in their product life cycle and use good environmental characteristics for promotion of products. They use their own environmental declaration on their product but they may need more objective environmental information. Type III is a good tool to meet those companies' demand. Those leading companies would have knowledge about LCA and use this method for product design and manufacturing process. For those companies, the concept of Type III environmental declaration would easily be accepted. On the other hand, general companies or small companies may have difficulty to understand methods and concept of LCA and Type III environmental declaration. Nonetheless, those companies can get knowledge about LCA through applying and proceeding Type III environmental declaration registration. Therefore, general companies would have benefit to be accustomed to the LCA method through Type III environmental declaration.
Leading companies may participate in PCR creation process because companies can propose it. Therefore, their active participation would be a key to promote the program.

7) From international to local companies
Global companies should care about global and other countries' environmental regulation. For example, EU countries have implemented strong environmental regulation and are requiring manufactures meet a certain standard for emission and material use such as EuP. Public sectors of those environmental conscious countries would set green procurement criteria. In addition, in EU countries, more consumers strongly aware environmental issues and integrate environmental activities in their life style than the US. Therefore, global companies have to consider product environmental impact in life cycle to gain market in those countries. Global companies may get Type III environmental declaration registration in those countries. In addition, if an international mutual certification program of Type III environmental declaration start, it would be easy to get registration in several countries.

8) Developing relationship with IT
Innovation of information technology will improve the utility of Type III environmental declaration and its product database. For example, IC tag will be able to contain environmental information, and it makes management of product information easier. Utilizing IC tag, for instance, consumers may directly be able to know total environmental impact of the products which they use in store, when receipt show environmental information below the bill. If cell phone can connect to internet, consumers can see LCA information as soon as they go to the website and input a registration number.
IT innovation has made Type III environmental declaration more useful. Ten years ago, it was impossible to show LCA results in a small environmental declaration, but nowadays, it is easy to see all detail LCA results in website even though printed environmental declaration shows only summary of those. In the near future, Type III environmental information would develop along with information technology.

9) Cooperate with government and industry associations
Support from government and industry associations can authorize the program. Even if the

program cannot have direct support, such as financial or legislative support, including them in the program administration will give authority to the program.  For example, include them in the steering committee of the program would be the cheapest way to do that.

## APPENDICES

## APPENDIX A. SURVEY FOR DECLARATION PRESENTATION AND CONTENT

Place: People's Food Coop (PFC) (Ann Arbor, MI)
Date: August 9; 10; 11; 12, 2005
The number of samples: 100 customers in PFC
Method: Questionnaire distributed and completed in the store in the store

### A.1 Purpose

We conducted a customer survey at People's Food Coop (PFC) in Ann Arbor, from August 9th to 12th, 2005, in order to observe their attitudes for environmental labels and to determine which label design and description of environmental indicators are easiest to understand by them. The result of this survey was reflected in the label design, the proposed roadmap, and other chapters. Some chapters in this paper mention the results for evidence of the proposal. It does not intend statistical analysis, but percentage of answer in each question was useful to determine our label format.

### A.2 Method

The two team members set a table near the entrance in the store and randomly asked customers to answer 18 questions of an answer sheet (see the attached sheet), considering age and gender group of the sample can spread, until the number of respondents reached 100. Customers wrote the answers at the table, taking 10-15 minutes. We gave respondents two types of chocolate bars ($1.65 and $2 equivalent) as gifts: one had organically produced and had some ecolabels; another was conventionally produced but the size was larger than the organic chocolate: and checked customer's attitudes for "green" products.

### A.3 Results

The percentage of answer in each question is below. The number of respondents and the percentage is the same because sample size is exactly 100.

- Question 1-3

1. After you buy an item (CHECK ALL THAT APPLY)

   - ☐ a. Return bottles, cans
   - ☐ b. Recycle newspapers
   - ☐ c. Sort trash

**2.** When you purchase an item (CHECK ALL THAT APPLY)

   - ☐ a. Read labels
   - ☐ b. Use biodegradable plastic garbage bags
   - ☐ c. Use biodegradable soaps, detergents
   - ☐ d. Avoid buying aerosols
   - ☐ e. Avoid products from specific companies
   - ☐ f. Buy products made from, packaged in recycled materials
   - ☐ g. Buy products in refillable packaging
   - ☐ h. Avoid restaurants using Styrofoam containers

**3.** Other (CHECK <u>ALL</u> THAT APPLY)

- ☐ a. Contribute money to environmental groups
- ☐ b. Cut down on car use
- ☐ c. Write to politicians

| Question | Answer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | <u>a-91</u> | <u>b-90</u> | <u>c-73</u> | | | | | |
| 2 | <u>a-91</u> | b-19 | c-49 | <u>d-69</u> | <u>e-67</u> | <u>f-69</u> | <u>g-59</u> | h-25 |
| 3 | <u>a-44</u> | <u>b-81</u> | <u>c-41</u> | | | | | |

The purpose of Question 1-3 were to identity demography of customers in PFC, using the items which was used for categorizing five "environmental types" of customers for "Green Gauge Report" [93]. The items in these questions describe "environmentally friendly" consumer behavior and thus percentage of those items shows how "green" the customers are.

Consequently, it is said that most consumers in PFC behave in a manner considered "environmental friendly". When compared to the 1990 report, in (underlined) 11 of 14 items, the percentage of consumers in PFC exceeds that of "True Blue Greens", who are the most proactively "green" consumer group.

This consumer groups will be the main target of the label proposed by this project at the beginning of the program, thus customer of PFC can be a good candidate for target of the label.

- Question 4

*Recently, new labels have been developed with the intention of giving consumers information about the environmental attributes of products. Some of these labels are not yet widely recognized, and may be unfamiliar to even the most well-informed consumers. We would like to determine how familiar consumers are with these new labels.*

**4.** Look at each label and answer the two questions. (SEE BOXES BELOW)

| | Do you recognize this label from a product that you saw advertised or for sale? | If yes, which of the following do you think best describes the label's meaning? (Note: You do not need to guess the meaning if you do not know.) |
|---|---|---|
| **A.** | ☐ a. Yes →<br>☐ b. No → | ☐ a. I have seen this label, but am not exactly sure what it means.<br>☐ b. The product **is compatible with renewable energies** such as solar and wind power<br>☐ c. The product **uses less energy to operate** than some competing products<br>☐ d. The product **was produced using energy efficient technologies** |

| | | |
|---|---|---|
| **B.** | ☐ a. Yes →<br>☐ b. No ↓ | ☐ a. I have seen this label, but am not exactly sure what it means.<br>☐ b. The product **contains recycled material**<br>☐ c. The product **is generally environmentally preferable**<br>☐ d. The product **is recyclable** |
| **C.** | ☐ a. Yes →<br>☐ b. No ↓ | ☐ a. I have seen this label, but am not exactly sure what it means.<br>☐ b. The fish **was raised using aquaculture** (fish farms), and not caught from a wild population<br>☐ c. The fish **does not contain heavy metals, or harmful toxins**<br>☐ d. The fish **was caught from a wild population that is not threatened by overfishing** |
| **D.** | ☐ a. Yes →<br>☐ b. No ↓ | ☐ a. I have seen this label, but am not exactly sure what it means.<br>☐ b. The product **is made from recycled paper**<br>☐ c. The product **contains wood obtained from a sustainably managed forest**<br>☐ d. Some profits from the sale of this product are **donated to protection of old-growth forests** |
| **E.** | ☐ a. Yes →<br>☐ b. No | ☐ a. I have seen this label, but am not exactly sure what it means.<br>☐ b. This food product **was produced using methods that maintain or improve soil and water quality**<br>☐ c. This food product **was produced on a small-scale farm**<br>☐ d. This food product **was produced with natural irrigation** (precipitation), and not irrigated with water diverted from natural sources |

| Question | | | Answer | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | A | i | a-74 | b-26 | N/A-0 | | | | | | |
| | | ii | a-20 | b-0 | | c-47 | d-6 | | N/A-1 | | |
| | B | i | a-18 | b-79 | N/A-3 | | | | | | |
| | | ii | a-79 | b-2 | | c-4 | | d-0 | | N/A-0 | |
| | C | i | a-12 | b-87 | N/A-1 | | | | | | |
| | | ii | a-8 | | b-0 | | c-0 | | d-4 | | N/A-0 |
| | D | i | a-4 | | b-95 | N/A-1 | | | | | |
| | | ii | a-3 | | b-1 | | c-0 | | d-0 | | N/A-0 |
| | E | i | a-92 | b-7 | | N/A-1 | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | ii | a-22 | b-57 | c-3 | d-7 | N/A-3 |

This question analyzed how familiar customers are with Type I environmental labels. Though Type I labels have been developed with the intention of giving consumers information about the environmental attributes of products, some of those labels are not yet widely recognized, and may be unfamiliar to even the most well-informed consumers.

Underlined choices in each (ii) are correct answers. (A) “Energy Star” and (E) “USDA Organic” have high percentage of respondents who can recognized the labels, but other Type I labels- (B) “Green Seal”, (C) “Marine Stewardship Council” and (D) “Forest Stewardship Council” labels- were recognized by very few people (less than 20%). Even if they can recognize the labels, many of them can not know the exact meaning of the labels. About half of them chose wrong answer for Energy Star, and 40% did that for USDA Organic. The result seems surprising because they are the most popular ecolabels in the U.S. and many consumers may take the label into account when they purchase product. Moreover, in (B), (C), (D), less than 4% of respondents can identify the correct meaning of the label.

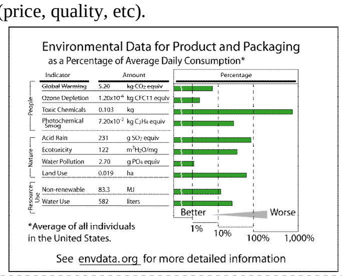
Even if consumers read the labels in purchasing products, labels do not make the most of their function unless consumers can understand the meanings of them. This result supported that Type I label may misrepresent the meaning of the label for many consumers, and therefore consistent quantitative Type III label may be more useful information tool to inform the environmental characteristics of products than Type I label.

- Question 5

*We would like to know how the label presentation format affects how easily information about environmental damages can be understood. Hypothetical information for digital cameras is used in the following question to show the label’s appearance in different formats.*

**5.** Considering the differences in environmental damage, select the product that you would most likely buy assuming that all other product attributes are the same (price, quality, etc).

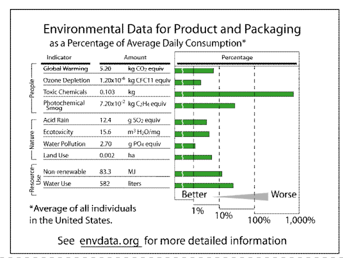
☐Product 1



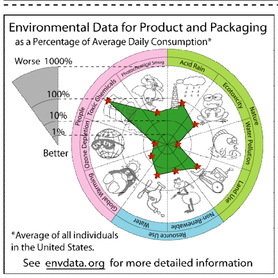

**A.** Product 1 or Product 2? (CHECK ONE BOX)

or

☐Product 2



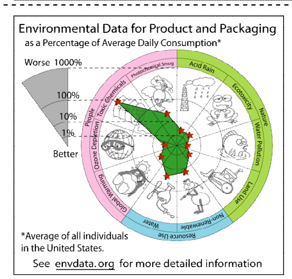

☐Product 3



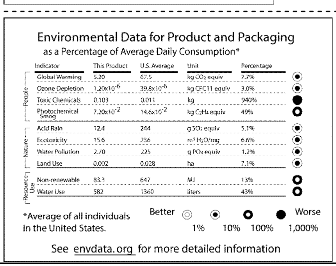

**B.** Product 3 or Product 4? (CHECK ONE BOX)

or

☐Product 4



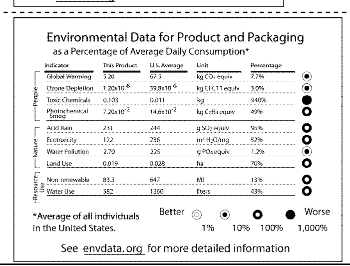

☐Product 5




**C.** Product 5 or Product 6? (CHECK ONE BOX)

or

☐Product 6



| Question | | Answer | | |
|---|---|---|---|---|
| 5 | A | a-7 | <u>b-89</u> | N/A-4 |
| | B | a-5 | <u>b-92</u> | N/A-3 |
| | C | <u>a-89</u> b-7 | | N/A-4 |

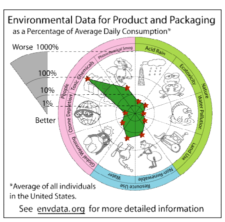
The purpose of this question was to know how the label presentation format affects how easily information about environmental damage can be understood. We assumed three types of label formats can be designed, considering limited space of product packages, in order to state 10 indicators. In this question, all three labels described the same environmental impact of hypothetical digital camera, and therefore showed the same information in different formats. For easy comparison, the impact of Acid Rain, Eutrophication, Land Use were explicitly less than others. The underlined item in the table was the one which has less environmental impact. It was assumed that customers could choose the product which had less environmental impact, and then the label which has high percentage of right answer is easy to read.

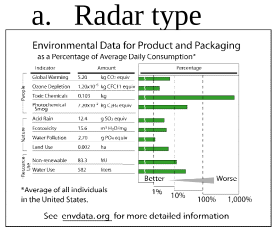
All three formats had almost same answer percentage, but the Rader format had a slightly higher percentage: the Rader format had 92% of right answer while the other two formats had 89%. The difference was not significant because most customers could understand this explicit difference. The detail of this question is referred to the chapter "Data Presentation" in order to decide the format of this project's label.

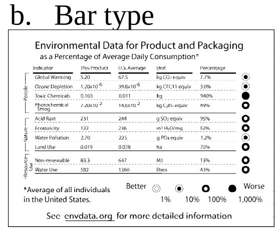
- Question 6

**6.** In question 5, which label did you find the easiest to understand? (SEE BOXES BELOW)

a. Radar type b. Bar type c. Table type




Easiest to understand (CHECK <u>ONE</u> BOX) ☐a. ☐b. ☐c.
Most difficult to understand (CHECK <u>ONE</u> BOX) ☐a. ☐b. ☐c.

| Question | | Answer | | | |
|---|---|---|---|---|---|
| 6 | A | a-36 | b-37 | c-16 | N/A-3 |
| | B | a-33 | b-18 | c-43 | N/A-6 |

This question directly asked which label format was the easiest to understand. The "Table type" format had the least percentage of respondents who chose "the easiest to understand" while the most percentage of respondents who chose "the most difficult to understand". In the choice of "the easiest to understand", the percentage of respondents who chose the "Rader type" and the "Bar type" was almost the same (1% larger in the "Bar type). On the other hand, in the choice of "the most difficult to understand", the percentage of respondents who chose the "Rader type" was almost twice as the "Bar type".

This result showed that the "Bar type" label can be the easiest to understand in a limited minute. However, some customers who did not choose the "Rader type" as "the easiest" said that once they knew how to read the "Rader type" format, that format could be the easiest, after they answered the question.

The reason why the "Rader type" was not chose as "the easiest" in this question might be that American consumers are not accustomed to this type of format, although such format is popular in other countries such as Japan.

Finally, this project adopted the "Rader type" format, considering other factors related to product description, although the result showed this type was the second one of the three. The detail of this question is referred to the chapter "Data Presentation" in order to decide the format of this project's label.

- Question 7

*The following questions will help us determine what type of information should be included on labels in order to help consumers consider the environmental attributes of a product in their purchasing decisions.*

**7.** What information would you prefer to see on a product label? (CHECK ONE BOX)

☐ a. A numerical estimate of the environmental damage caused by the production, use, and disposal of a product

For example, Global Warming Potential = x
Toxicity to Humans = y
Land Conversion = z

☐ b. A numerical estimate of the mass of resources used, and pollutants released during the production, use, and disposal of a product.

For example, Carbon Dioxide released = x kg
Benzene (a carcinogen) released = y kg
Wood used = z kg

| Question | Answer |
|---|---|
| 7 | a-72 b-23 N/A-5 |

The purpose of this question was to determine what type of information should be included on the label in order to help consumers consider environmental attributes of a product in their purchasing decisions. The purpose of this question was which methods should be used in indicating environmental impacts.

Item (a) expresses the environmental impact as a numerical estimate of the environmental impacts which are based on scientific calculation methods, such as Global Warming Potential or Human Toxicity Potential. Item (b) expresses the environmental impact as mass of resource used or chemical emission, such as Carbon Dioxide released or Wood Used, like inventories.

72% of respondents preferred (a) to (b). This may be because the mass is difficult to image the environmental impact from mass of them unless they know meaning of chemicals or resources, for example, how CO2 affects global warming or how benzene affects human health.

- Question 8

**8.** Read the descriptions of three different methods of presenting information about the environmental damage caused by products. Then rank the methods according to how much they help you understand the level of environmental damage caused by a product. (SEE BOXES BELOW)

a. A comparison to the damages that result from the average individual American's daily consumption
(for example, "This product's environmental damages are equal to 78% of the US individual daily average")

b. Absolute numerical values of the mass of resources used, and pollutants released
(for example, "This product is responsible for 3.2kg of CO2 emissions")

c. A comparison to the damages of the average product in the same category
(for example, "This product's environmental damages are equal to 124% of the average product in this category")

Most Helpful (CHECK ONE BOX) ☐a. ☐b. ☐c.
Least Helpful (CHECK ONE BOX) ☐a. ☐b. ☐c.

| Question | | Answer |
|---|---|---|
| 8 | A | a-29 b-18 c-50 N/A-3 |
| | B | a-17 b-63 c-19 N/A-1 |

The purpose of this question was to know which method of presenting information about the environmental impact caused by products is the best of three possible methods.

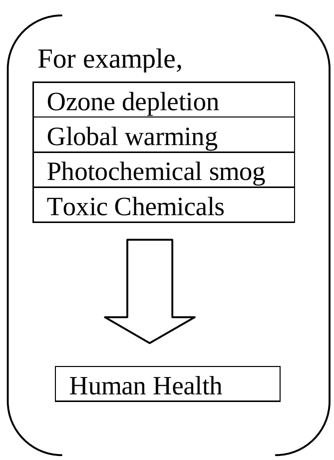
Half of them thought (c) "comparison to the damage of the average product in the same category" is the most helpful to present the environmental impact, and more than half of them thought (b) "absolute numerical values of the mass of resource used and pollutant released" is the least helpful. Then, (c) can be the best method to describe the environmental impact in the label, and (a) "a comparison to the damages that result from the average individual American's daily consumption" is the second. However, today it is impossible to estimate the environmental impact of "average" product in the same category, because it requires collecting the data of all product information. Therefore, this project applied the second best method "a comparison to the damages that result from the average individual American's daily consumption" in label description.

- Question 9

**9.** Would you rather have detailed information about the environmental damage caused by a product, or a summary of that same information? (CHECK ONE BOX)

☐ a. Detail

☐ b. Summary




| Question | Answer |
|---|---|
| 9 | a-61 b-37 N/A-2 |

The purpose of this question was to determine the description of the environmental indicator in the label: "detailed information" of the indicators or "summarized information" of those indicators. 61% of respondents preferred "detailed information" to "summarized information".

The project's label uses ten detailed indicator and present which indicators are categorized in which summarized indicator: People, Nature, Resource Depletion.

- Question 10

*In order to develop a label that is clear and easy to read, we are trying to select words that most customers are familiar with.*

**10.** Read the description of the environmental damage and answer the two questions. (SEE BOXES BELOW)

| Description of environmental damage | (i) Are you familiar with this concern? | (ii) Which word(s) are easy for you to understand? (CHECK ALL THAT APPLY) |
|---|---|---|
| **A.** The potential increase in the earth's temperature caused by a buildup of gases that trap heat from reflected sunlight. | ☐Yes→<br>☐No ↴ | ☐Global Warming<br>☐Climate Change<br>☐Greenhouse Effect<br>☐Other_____________ |
| **B.** The reduction of the protective ozone layer caused by emissions of ozone-depleting substances that leads to an increased exposure to damaging UV light. | ☐Yes→<br>☐No ↴ | ☐Ozone Depletion<br>☐Ozone Destruction<br>☐Ozone Layer Hole<br>☐Other_____________ |
| **C.** Ozone buildup in the lower level atmosphere from the reaction of certain air pollutants in sunlight which causes respiratory problems. | ☐Yes→<br>☐No ↴ | ☐Photochemical Smog<br>☐Ground Level Ozone<br>☐Smog Creation<br>☐Other_____________ |
| **D.** The increase in acidity of water and soil systems caused by air pollution that is harmful to forests, aquatic life, and man-made structures. | ☐Yes→<br>☐No ↴ | ☐Acid Rain<br>☐Acidification<br>☐Acid Precipitation<br>☐Other_____________ |
| **E.** The damage to the health of plant and animal species caused by chemical emissions from industrial systems. | ☐Yes→<br>☐No ↴ | ☐Ecotoxicity<br>☐Ecosystem Health<br>☐Nature Health<br>☐Other_____________ |
| **F.** The fertilization of surface waters by nutrients, resulting in increased algae growth and decreased oxygen available to other aquatic life. | ☐Yes→<br>☐No ↴ | ☐Eutrophication<br>☐Water Pollution<br>☐Algae Blooms<br>☐Other_____________ |
| **G.** The use of land or damage to an ecosystem that makes an area unsuitable as a wildlife habitat and contributes to species diversity loss. | ☐Yes→<br>☐No ↴ | ☐Habitat Conversion<br>☐Land Conversion<br>☐Land Use<br>☐Other_____________ |

| Question | | | Answer | | | |
|---|---|---|---|---|---|---|
| 10 | A | i | a-96 | b-1 | | N/A-3 |
| | | ii | a-79 | b-49 | c-68 | d-0 |
| | B | i | a-91 | b-2 | | N/A-7 |
| | | ii | a-74 | b-41 | c-49 | d-1 |
| | C | i | a-76 | b-19 | N/A-5 | |
| | | ii | a-26 | b-33 | c-52 | d-3 |
| | D | i | a-92 | b-3 | | N/A-5 |
| | | ii | a-84 | b-19 | c-23 | d-1 |
| | E | i | a-78 | b-16 | N/A-6 | |
| | | ii | a-51 | b-45 | c-21 | d-8 |
| | F | i | a-74 | b-20 | N/A-6 | |
| | | ii | a-15 | b-53 | c-41 | d-2 |
| | G | i | a-82 | b-11 | N/A-6 | |
| | | ii | a-44 | b-24 | c-45 | d-15 |

The purpose of this question was to define which wording is clear and easy to understand for each environmental indicator. In section (i), we asked whether they are familiar with those environmental impacts, and in section (ii), asked which word is easy to understand about those impacts.

Most environmental impacts were recognized by more than three-fourth of the customers. Only (F) was recognized by a little less than 75% of customers. According to the result of section (ii), the easiest words for customers were respectively: (A) Global Warming, (B) Ozone Depletion, (C) Smog Creation, (D) Acid Rain, (E) Ecotoxicity, (F) Water Pollution, (G) Land Use.

In the project label, we adopted the words which had high percentage in the survey except (E). “Water Pollution” can mislead readers about the meaning because the word has broad meaning, and it can be confused with other environmental impact such as Ecotoxicity. Therefore, for this indicator, we used “Eutrophication” instead of “Water Pollution” although this word is not common for general consumers.

We did not ask about “Water” depletion, “Non-Renewable” resource depletion, and “Chemical Pollution” of 10 indicators in this question. The word “Water” depletion, “Non-Renewable” resource depletion is easy word to be understood by people. On the other hand, “Chemical Pollution” can be replaced by other words such as “Toxicity”, but “Toxicity” is an emotionally charged word. That word may make people believe that the product is toxic for their health, and therefore producers and retailers may not be willing to use that word. Therefore, we decided to use the softer word which can be accepted even by companies.

- Question 11

11. Select how much more you would be willing to pay for that product if it were environmental friendly. (CHECK ONE BOX FOR EACH PRODUCT)

**a.** Paper products made out of recycled paper
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**b.** Household products such as kitchen and bedroom cleaners
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**c.** Garden products such as insecticides and fertilizers
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**d.** Plastic packaging or containers made of recycled plastic materials
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**e.** Detergents
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**f.** Automobile
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**g.** Plastic package or containers made with less plastic
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**h.** Gasoline
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**i.** Food produced with organic methods
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

**j.** Computer which uses less energy to operate
☐ No more ☐ 5% ☐ 10% ☐ 20% ☐ 30% or more

| Question | | Answer | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | A | a-12 | b-19 | c-36 | d-21 | e-15 | N/A-6 | | |
| | B | a-9 | | b-14 | c-36 | d-21 | e-15 | N/A-5 | |
| | C | a-9 | | b-7 | | c-15 | d-33 | e-27 | N/A-9 |
| | D | a-13 | b-16 | c-35 | d-21 | e-10 | N/A-5 | | |
| | E | a-10 | b-16 | c-35 | d-21 | e-11 | N/A-7 | | |
| | F | a-16 | b-7 | | c-16 | d-26 | e-23 | N/A-12 | |
| | G | a-17 | b-15 | c-29 | d-22 | e-9 | | N/A-8 | |
| | H | a-19 | b-12 | c-25 | d-16 | e-18 | N/A-10 | | |
| | I | a-4 | | b-4 | | c-22 | d-29 | e-35 | N/A-6 |
| | J | a-17 | b-11 | c-28 | d-24 | e-11 | N/A-9 | | |

The purpose of this question was to learn how much more customers are willing to pay for various "green" products. The result shows consumers are willing to pay higher cost to "green" products and these additional costs can be added to a "green" product's price as long as customers accept. The cost of the registration fee of the environmental labelling program may be absorbed in the price premium to some extent.

The items were extracted from the "Cambridge Reports Research International poll (July 15-27, 1993)"[94], and we added "Food produced with organic methods" and "Computer which uses less energy to operate".

Mean percentage[36] of acceptable additional cost for each "green" product is:

a=12.9%, b=13.7%, c=18.2%, d=12.1%, e=12.7%, f=16.0%, g=11.7%, h=13.0%, i=19.9%, j=12.6%

Consequently, customers were willing to pay more than 10% additional costs for all product categories. This means that at least 10% can be added to any "green" products as an acceptable premium price. Especially (c) "Garden products" and (i) "Food" had very high value (larger than 18%). This may be because many consumers already pay higher prices for those "organic" products.

[36] "30% or more" was assumed as "30%" in this calculation.

- Question 13-18

*General information about the respondents will help us determine if the information we are collecting correctly represents the average customers at this store. You are not required to answer any of the questions below.*

**13.** How old are you? (CHECK ONE BOX)

- ☐ a. 19 or younger
- ☐ b. 20-29
- ☐ c. 30-39
- ☐ d. 40-49
- ☐ e. 50-59
- ☐ f. 60 or older

**14.** What is your gender? (CHECK ONE BOX)

- ☐ Male
- ☐ Female

**15.** Including yourself, how many people live in your household? (FILL IN BLANK)

_____ person(s)

**16.** Which best describes your household current annual income?

- ☐ a. Less than $5,000
- ☐ b. $5,000 to $9,999
- ☐ c. $10,000 to $14,999
- ☐ d. $15,000 to $19,999
- ☐ e. $20,000 to $24,999
- ☐ f. $25,000 to $34,999
- ☐ g. $35,000 to $49,999
- ☐ h. $50,000 to $74,999
- ☐ i. $75,000 to $99,999
- ☐ j. $100,000 to $149,999
- ☐ k. $150,000 or more

**17.** Are you currently enrolled as a full-time college student? (CHECK ONE BOX)

- ☐ a. Yes
- ☐ b. No

**18.** What is the highest level of education you have completed? (CHECK ONE BOX)

- ☐ a. Middle School or less (grades 1-8)
- ☐ b. Some high school (grades 9-11)
- ☐ c. High school graduate or equivalent
- ☐ d. Vocational / technical training
- ☐ e. Some college
- ☐ f. B.A. / B.S. degree or equivalent
- ☐ g. M.A. / M.S. degree or equivalent
- ☐ h. Advanced degree (M.D., Ph.D., etc)

| Question | Answer |
|---|---|
| 13 | a-3 b-35 c-15 d-9 e-26 f-10 N/A-2 |
| 14 | a-41 b-57 N/A-2 |
| 15 | (1)-27 (2)40 (3)16 (4)7 (5)3 (6)1 N/A-6 |

| | |
|---|---|
| 16 | a-4 b-5 c-9 d-8 e-4 f-8<br>g-13 h-19 i-9 j-3 k-7 N/A-11 |
| 17 | a-19 b-78 N/A-3 |
| 18 | a-0 b-0 c-3 d-0 e-20 f-38 g-27<br>h-8 N/A-4 |

Those questions were optional question to identify the demography of respondents.

In the Question 13, the age group 20-29, and 50-59 were the majority of respondents. In Question 14, about 60% were female. In Question 15, more than 80% had less than three members in their households. In Question 16, the income groups were almost equally dispersed while about 40% of customers had more than $50,000 annual income. In Question 17, about 20% of respondents were full-time college students. In Question 18, more than 90% had high education (more than college).

- (Question 19) Choice of a gift

| | | | |
|---|---|---|---|
| (19) gift | conventional-58 | organic-36 | N/A-6 |

After finishing the survey questions, respondent chose a free gift from either “Organic” or “Conventional” chocolate. The size of the “Conventional” was bigger than the “Organic”, and “Organic” had several environmental labels such as “USDA Organic” on the package. The price of the “Conventional” was $2.27 while that of the “Organic” was $1.65, although price seal were not on the package, and the taste type was the same. The intention of this implicit question was to know how many customers were willing to pay “premium” for “green” products, assuming smaller size was a sort of “premium”.

36% of customers chose organic chocolates and 58% chose conventional chocolates. The percentage of 36% who chose a small organic chocolate rather than a larger chocolate is not small, although many customers did not deliberately watched the package. It can be said that many customers might be willing to choose “green” product, regardless of the size of the product.

## A.4 Table of the Result

| Question | | | Answer | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | a-91 | b-90 | c-73 | | | | | | |
| 2 | | | a-91 | b-19 | c-49 | d-69 | e-67 | f-69 | g-59 | h-25 | |
| 3 | | | a-44 | b-81 | c-41 | | | | | | |
| 4 | A | i | a-74 | b-26 | N/A-0 | | | | | | |
| | | ii | a-20 | b-0 | | c-47 | d-6 | | N/A-1 | | |
| | B | i | a-18 | b-79 | N/A-3 | | | | | | |
| | | ii | a-79 | b-2 | | c-4 | | d-0 | | N/A-0 | |
| | C | i | a-12 | b-87 | N/A-1 | | | | | | |
| | | ii | a-8 | | b-0 | | c-0 | | d-4 | | N/A-0 |
| | D | i | a-4 | | b-95 | N/A-1 | | | | | |
| | | ii | a-3 | | b-1 | | c-0 | | d-0 | | N/A-0 |
| | E | i | a-92 | b-7 | | N/A-1 | | | | | |
| | | ii | a-22 | b-57 | c-3 | | d-7 | | N/A-3 | | |
| 5 | | A | a-7 | | b-89 | N/A-4 | | | | | |
| | | B | a-5 | | b-92 | N/A-3 | | | | | |
| | | C | a-89 | b-7 | | N/A-4 | | | | | |
| 6 | | A | a-36 | b-37 | c-16 | N/A-3 | | | | | |
| | | B | a-33 | b-18 | c-43 | N/A-6 | | | | | |
| 7 | | | a-72 | b-23 | N/A-5 | | | | | | |
| 8 | | A | a-29 | b-18 | c-50 | N/A-3 | | | | | |
| | | B | a-17 | b-63 | c-19 | N/A-1 | | | | | |
| 9 | | | a-61 | b-37 | N/A-2 | | | | | | |
| 10 | A | i | a-96 | b-1 | | N/A-3 | | | | | |
| | | ii | a-79 | b-49 | c-68 | d-0 | | | | | |
| | B | i | a-91 | b-2 | | N/A-7 | | | | | |
| | | ii | a-74 | b-41 | c-49 | d-1 | | | | | |
| | C | i | a-76 | b-19 | N/A-5 | | | | | | |
| | | ii | a-26 | b-33 | c-52 | d-3 | | | | | |
| | D | i | a-92 | b-3 | | N/A-5 | | | | | |
| | | ii | a-84 | b-19 | c-23 | d-1 | | | | | |
| | E | i | a-78 | b-16 | N/A-6 | | | | | | |
| | | ii | a-51 | b-45 | c-21 | d-8 | | | | | |
| | F | i | a-74 | b-20 | N/A-6 | | | | | | |
| | | ii | a-15 | b-53 | c-41 | d-2 | | | | | |
| | G | i | a-82 | b-11 | N/A-6 | | | | | | |
| | | ii | a-44 | b-24 | c-45 | d-15 | | | | | |
| 11 | | A | a-12 | b-19 | c-36 | d-21 | e-15 | N/A-6 | | | |
| | | B | a-9 | | b-14 | c-36 | d-21 | e-15 | N/A-5 | | |
| | | C | a-9 | | b-7 | | c-15 | d-33 | e-27 | N/A-9 | |
| | | D | a-13 | b-16 | c-35 | d-21 | e-10 | N/A-5 | | | |
| | | E | a-10 | b-16 | c-35 | d-21 | e-11 | N/A-7 | | | |
| | | F | a-16 | b-7 | | c-16 | d-26 | e-23 | N/A-12 | | |
| | | G | a-17 | b-15 | c-29 | d-22 | e-9 | | N/A-8 | | |
| | | H | a-19 | b-12 | c-25 | d-16 | e-18 | N/A-10 | | | |
| | | I | a-4 | | b-4 | | c-22 | d-29 | e-35 | N/A-6 | |
| | | J | a-17 | b-11 | c-28 | d-24 | e-11 | N/A-9 | | | |

| | |
|---|---|
| 12 | - |
| 13 | a-3 b-35 c-15 d-9 e-26 f-10 N/A-2 |
| 14 | a-41 b-57 N/A-2 |
| 15 | (1)-27 (2)40 (3)16 (4)7 (5)3 (6)1 N/A-6 |
| 16 | a-4 b-5 c-9 d-8 e-4 f-8<br>g-13 h-19 i-9 j-3 k-7 N/A-11 |
| 17 | a-19 b-78 N/A-3 |
| 18 | a-0 b-0 c-3 d-0 e-20 f-38 g-27<br>h-8 N/A-4 |
| (19) gift | conventional-58 organic-36 N/A-6 |

# APPENDIX B. RETAIL TEST OF CONSUMER RESPONSE

Place: People's Food Coop (PFC) (Ann Arbor, MI)
Term: From February 22 to March 25, 2006
Method: LCA calculation with the original database software created by the team
Comparison of sales between in the test period and before the test period
Creating the program's website created by the team

## B.1 Purpose

We conducted a retail test at People's Food Coop (PFC) in Ann Arbor, from February 22 to March 25, 2006.

The purpose of this retail test is to assess how the availability of information on products' environmental impact changes consumers' behavior. In order to evaluate the potential success of an ecolabelling system and its effect on the environment, we quantified how consumers change their behavior. We conducted LCA on organic and conventional vegetables because they have the different environmental characteristics while the functions are the same as a food item. General "Organic" labels sometimes mislead consumers because their meaning is not well understood, as is shown in the customer survey (See Appendix A, Q4 (E)). The environmental impacts of organic vegetables had lower environmental impacts than conventional vegetables when LCA analyses on their life cycle stages were conducted. Therefore, we assumed quantitative environmental information may make organic vegetables more preferable. If the sales of organic vegetables increased compared to the term without the environmental declaration, it could be assumed that consumers changed their behavior to more environmental conscious purchasing.

Another purpose of the retail test is to confirm the feasibility of data presentation in the Type III environmental declaration program, from LCA calculation on some products through presenting information in a store and the website. The time taken for LCA calculation was also estimated for the simplest product case. Practicing this process, we could learn what was the limitation of the current system and what should be improved in the future as well as how feasible it was. The methods researched in this paper were reflected in this retail test, and the information and ideas acquainted in the practice of the retail test was in turn reflected in the entire chapter in this paper as backgrounds. This retail test could be a good start for the actual program even if the customers' behavior was not appreciable.

In this program, we named the program name "envdata.org" as the hypothetical program administrator and used the name in the labels and the website.

## B.2 Method

The retail test included three stages: (1) Conduct LCA using the original database, (2) Place the environmental declaration on shelf sign, and (3) Present the detailed LCA results in the program website.

- Conduct LCA using the original database

We conducted LCA on organic and conventional vegetables. Targeted vegetables are organic/conventional apples, organic/conventional avocados, and conventional grapes. We created LCA database software, which is attached to this report as a supplemental electronic file (see Excel files "*exLCA*" and "*volTOX*"). This software was created based on the methods which are explained in Chapter 3. Then, we input LCI data and transportation data into the LCA database software to calculated ten environmental indicators. The LCA results were presented as ten indicators and in proportion to the American average benchmark. There were clear difference between conventional and organizational vegetables, therefore the result could help consumers to distinguish those two types of the same vegetables.

The reason why we chose those vegetables was vegetables had clear difference in the environmental impacts between organic and conventional production. In addition, collecting LCI information was available in the University of California, Davis's website, and those vegetables were sold at PFC.

The LCI data in production stage referred to the life cycle analysis of the University of California, Davis, Department of Agricultural and Resource Economics Outreach [95], about vegetables made in California. Transportation stage is adjusted to exact production location to Ann Arbor, MI. The LCA data source in a production stage, production location, and estimated transportation distance are shown in Table B.1. We assumed vegetables sold in the test site had the same environmental impacts as the UC Davis studies, and distances were estimated using "MapQuest,com". Only for conventional grape produced in San Joaquin Valley, CA, we used an average distance from San Joaquin Valley to undetermined destination in the continental U.S. in order to estimate transportation impact for non-specific retailer.

Detail of LCA of Conventional Grape produced in San Joaquin Valley, CA is explained in Appendix C, as an example of those analyses.

| | Product Location | Production LCI data source | Transportation |
|---|---|---|---|
| Organic Avocados | Uruapan, Mexico | 2001 UC Davis Study (Ventura and Santa Barbara CA) [96]. Assume Organic does not use any pesticides and fertilizer and yield is 80% of conventional. | From Uruapan, Mexico to Ann Arbor, MI<br>Shipped by truck (HDDV 8a) |
| Conventional Avocados | Uruapan, Mexico | 2001 UC Davis Study (Ventura and Santa Barbara CA) [96] | From Uruapan, Mexico to Ann Arbor, MI<br>Shipped by truck (HDDV 8a) |
| Organic Apples | Orondo, Washington | 2001 UC Davis Study (San Joaquin Valley-North, CA) [97] | From Orondo, WA to Ann Arbor, MI<br>Shipped by truck (HDDV 8a) |
| Conventional Apples | Ypsilanti, Michigan | 1994 UC Davis Study (North Coast, CA) [98] | From Ypsilanti, MI to Ann Arbor, MI<br>by truck (HDDV 8a) |
| Conventional Grapes | San Joaquin Valley, CA | 2004 UC Davis (San Joaquin Valley, CA) [99] | From San Joaquin Valley, CA to an average, undetermined destination in the continental U.S. by truck |

**Table B.1.** LCI data for life cycle analysis of vegetables

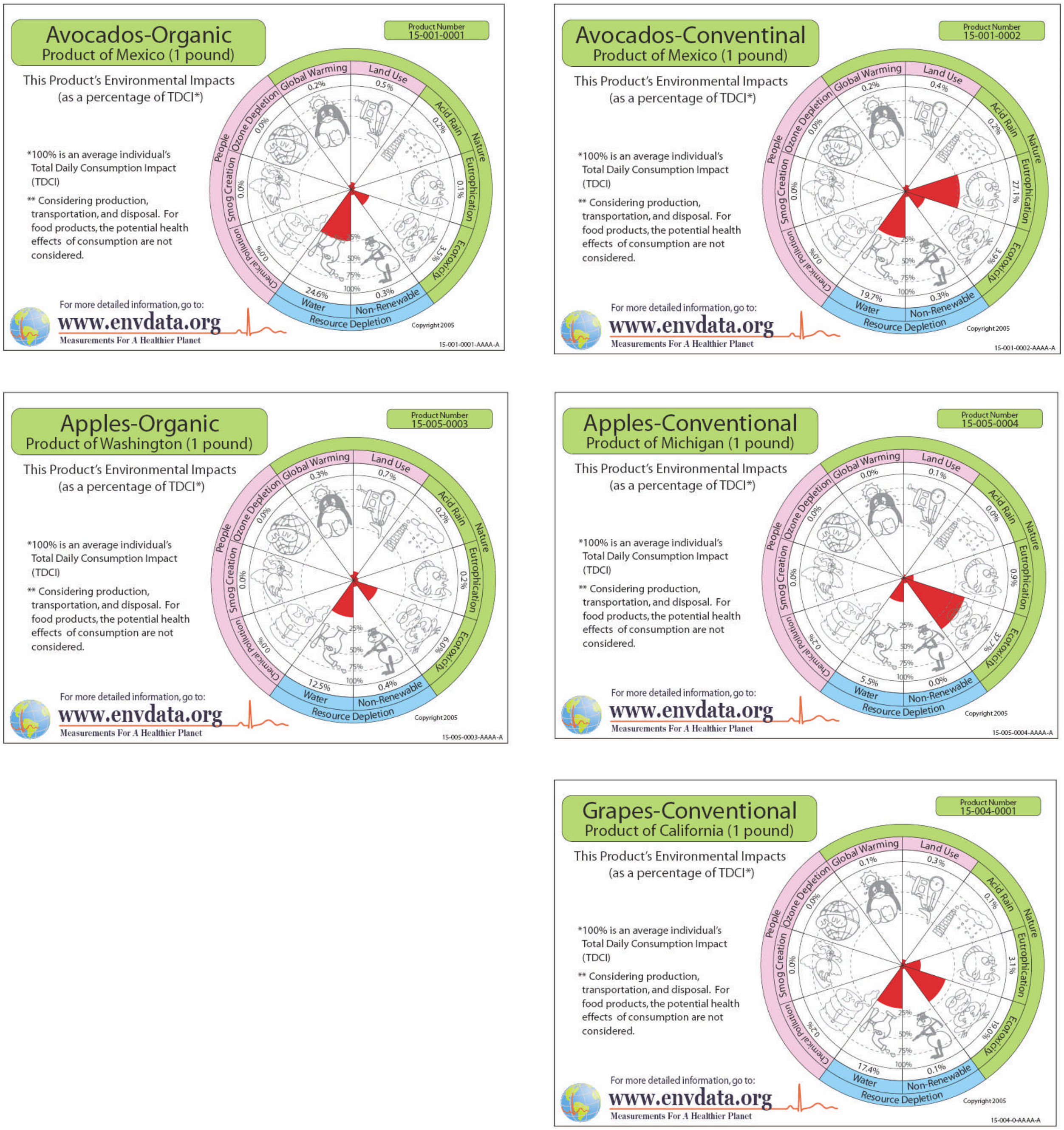



**Figure B.1.** Environmental declarations used in the retail test
Organic produce (left) and conventional produce (right)

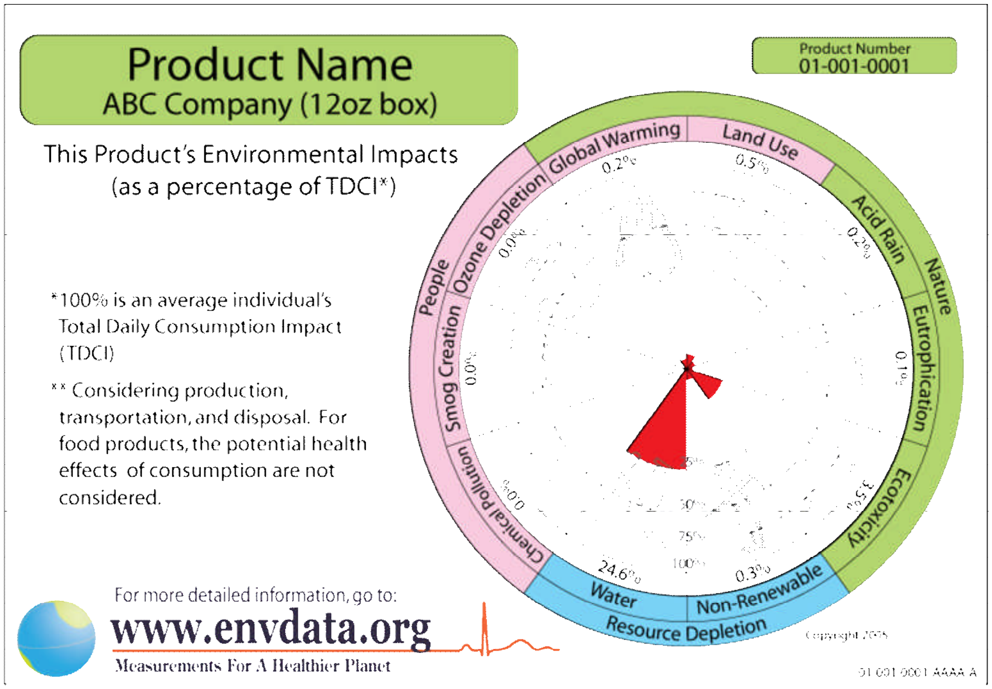



**Figure B.2.** Large picture example of on-shelf sign

Figure B.1. shows the result of LCA of the products. The format is the same as shelf signature used in the store. As is shown in Figure B.1, there were clear differences between organic and conventional types.

As for Avocado, organic one had much less "Eutrophication" impact than conventional one. This was because we assumed organic one does not use any pesticides and fertilizer, which mainly contribute "Eutrophication", "Ecotoxicity" and "Chemical pollution", whereas conventional one uses pesticides and fertilizer. On the other hand, organic avocado had a little more impact in "Water" than conventional one. This was because we assumed yield of organic avocado is 80% of conventional one and water use per acre is the same, then water use per product was more than conventional.

As for Apple, organic one had much less "Ecotoxicity" impact than conventional one. This was because a conventional apple uses a certain number of pesticides while organic one does not use any pesticide. The impact in transportation should be much higher in an organic apple than conventional one because it is very small impact in conventional one shipped from Ypsilanti to Ann Arbor. However, "Global Warming" or "Acid Rain", which mainly come from the transportation phase, had almost no differences, because when "1 pound" is used as a functional unit, the impact becomes very small, even if the impact per shipment is different. Organic apple had a little more impact in "Water" because its yield per acre is less than conventional one.

As for Grape, we conducted LCA only on conventional one because PFC did not sell organic one. However, in the test period, the store did not have any grapes for sale, therefore consequently this environmental declaration was not used in this test.

We counted estimated working time to conduct LCA. These vegetable cases are the simplest case because the production process is very simple and the data can be easily collected. The most time consuming work in LCA is collecting LCI data. This estimation can be considered as the minimum work case.

- Place the environmental declaration on shelf sign

The radar graph pictures in the LCA results were printed on the environmental declaration cards, whose size was 13 x 18 cm (5 x 7 in), and the cards were placed near the products from 2/22 to 3/26. The format was the same as Figure B.1. Presentation formats of the environmental declaration cards were created based on the research in Chapter 4 and "Customer survey (Appendix A)". Then, the environmental declaration cards were placed in front of the vegetables; organic and conventional apples; organic and conventional avocados. In the test period, grapes were not sold in the store.

Organic and conventional apples were placed in buckets next to each other in the same place, and therefore it allowed customers to compare the environmental impact on the label easily. On the other hand, organic and conventional avocado were placed 2 meter apart from each other. The placement difference could change the condition of customers' recognition on the cards. It could be assumed that closer cards were easier for customers to compare the information than farther cards.

We tried to make PFC's customers aware the meaning of the environmental declaration and the program as much as possible. Before the test period, we advertised the program and explained summary of ten indicators in the newsletter of PFC in September 2005 and January 2006, so that customers could recognize the label. In the test period, we placed the poster to explain the program and the environmental indicators near the environmental declaration cards, and attached business cards which explained summary of them and URL of the program website to allow customers to pick up. The business cards are also attached to two of four environmental declaration cards. We assumed the customers who were interested in the program picked up the business cards and they would connect to the website in order to learn detailed environmental information.

Finally, we were provided the sales data in the test period by the store and the data in two weeks before the test period and the total sales data from the beginning of the year to 4/9. Sales in the test period were compared to the sales of two weeks before the test period and the average sales from 1/1 to the beginning of the test period (2/19)[37]. If the sales organic vegetables which had less environmental impact increased, it could be the evidence that the environmental declaration could change consumers' behavior to choose the products that have less environmental impacts.


**Figure B.3.** On-shelf sign near avocados in PFC

- Present the detailed LCA results in the program website

We created the website (envdata.org) with a web creation software and publicized it to provide detailed LCA information, and explanation of the program and environmental indicators in the test period (See the website "http://www.envdata.org" ). The URL was shown on the environmental declaration cards in front of the products in the store, and the poster and business cards near them. Presentation formats were created based on the information of Chapter 4.

[37] Actual start of the test period was 2/22, but since the store collected data from Monday to Sunday, the first week's data of the test period was assumed as 2/20.

The website allowed customers to learn the meanings of the ten environmental indicators and the program. In addition, customers could know more detailed LCA results, which showed the environmental impacts in each life cycle stages (production, transportation, use, disposal stages).

Finally we checked how many people visited the website from FTP server.

The website contained these pages:

(a) Picture of the label (*Top page*)

This was the same information as the shelf signs in the store. The top page allowed audiences to select the product. Audiences could find the large picture of the label in the website. Labels in stores cannot help being small because the space of product packages or the space of shelves to place the environmental declaration cards are generally limited. On the other hand, the website does not have such limitations and can easily manage the size of the picture for most monitor sizes. The product information should be so easy to search that any audience do not have trouble to find the product information which they need.

This part was the most important part of the website, and therefore we placed this information at the top page. Then, audiences could select the product information which they wanted, choosing Product Group => Product Category => Product name. In the future when a number of products are registered and one product has several different types, the product information should also be identified with Product ID number, which is written in the label.

(b) LCA data sheet

This presented the ten indicators of products' LCA results separately for life cycle stages (production, transportation, use, disposal stages). The information of each product was linked from the top page's radar graph as PDF files. The advantage of a website is that it can contain any detail information, regardless of space. The detail information about the LCA results of products can be publicized in the website. In fact, the main part of existing Type III programs is the LCA datasheet in their website.

This detail LCA data sheet included detail information of the environmental impact separated to each life cycle phase: production, transportation, use, and disposal stages. This had bar graphs of the environmental impacts whose colors were changed for life cycle stages. In addition, each environmental impact had more detailed information which is used before combining one indicator. For example, "Ecotoxicity" consists of "Contaminated Water Volume", "Contaminated Soil Volume", and "Contaminated WWTP". The table showed the numerical impact before combination of percentage. Moreover, the LCA datasheet contained numeric information about the environmental impacts, although the environmental declaration cards in the store could have only percentage compared to the American average.

(c) Explanation of the environmental indicators

This page explained the meanings and units of the ten environmental indicators attaching the illustrations in the graph which represented each indicator. Because the label on a product could not have detailed explanation of the environmental indicators, the website explained their meaning and the units of each indicator.

(d) Explanation of the program

This page explained the objective of this program and that the program was a research project of individual at the University of Michigan, School of Natural Resources and Environment. In addition, we explained general meaning of a Type III environmental declaration.

(e) Entrance to a Personal page

A form of an entrance to a personal page was shown in the pages but it could not actually be linked to the personal pages.

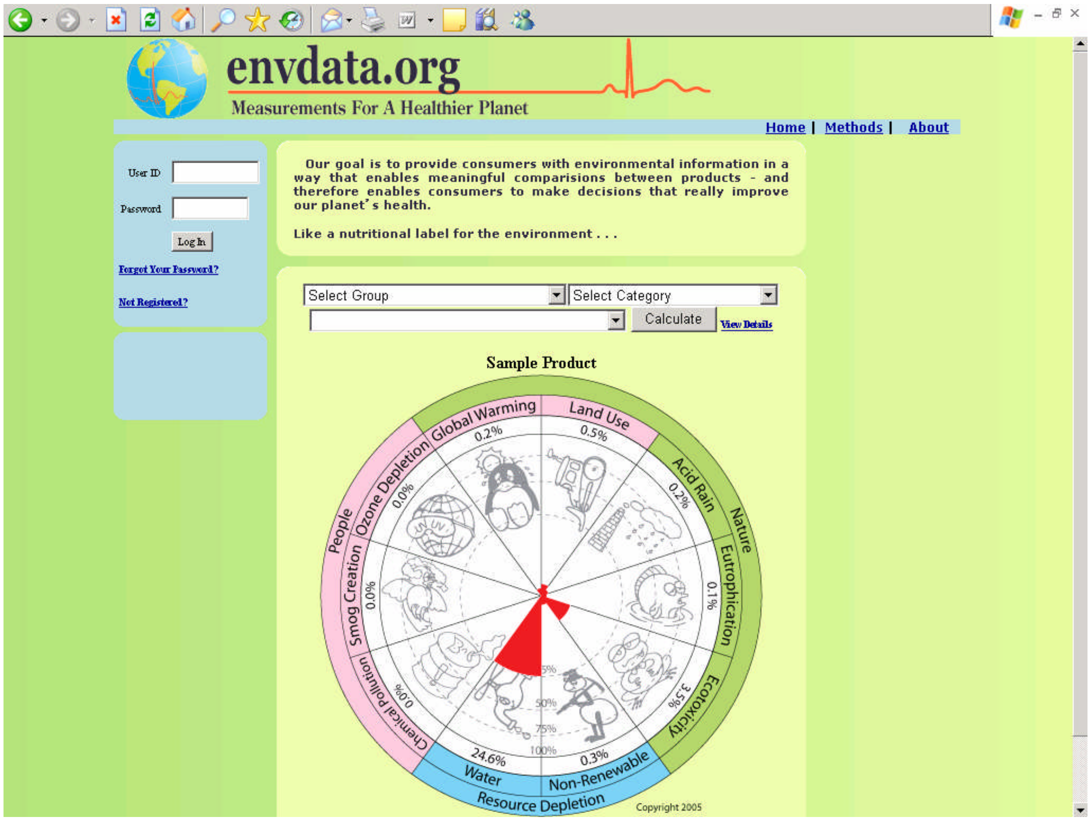



**Figure B.4.** Top page of the website "envdata.org"

## B.3 Results

- LCA working time

LCA process included:

(i) Data collection of LCI

We did not take any time because LCI data was already provided by UC Davis studies.

(ii) Making generic data for the data which is not contained in the database

In actual Type III environmental declaration program, the administrator shall provide generic data for general component parts (such as packaging and fuels in this case), and materials (such as minerals or chemicals). In testing process, we collected those generic data and input the database software. Especially for chemical inputs, we created another database to calculate Chemical Pollution (Human Toxicity) and Ecotoxicity (*volTOX*). Inputting chemical data from EPI suite [100] (U.S. Environmental Protect Agency's software) and TOXNET (U.S. National Library of Medicine's chemical database website [101]), California State Department of Pesticide Regulation's chemical database [102], takes 20-30 minutes for each chemical.

We conducted LCA for each component parts (Cardboard, Gasoline, Diesel), collecting data from SimaPro. The LCA for those component parts and the impact of transportation took 1-2 hours each.

In addition, the administrator shall collect Land Use data using GIS data source. Collecting Land Use data took 30 minutes.

(iii) LCA calculation with database.

Once LCI data are collected and any generic materials/component parts data exist in the database, an applicant input all LCI data into LCA database software and run the software. Inputting LCI data and calculating it takes 2-3 hours each vegetable.

Overall, LCA calculations for those vegetables calculated in this practice took minimum 2-3 hours if all generic data exist in the database, and approximately 12 hours if most generic data do not exist in the database (the first time). This practice does not include LCI data collection process. Generally, LCA process takes much more time depending on complexity of a product and difficulty of collecting LCI data and site specific data.

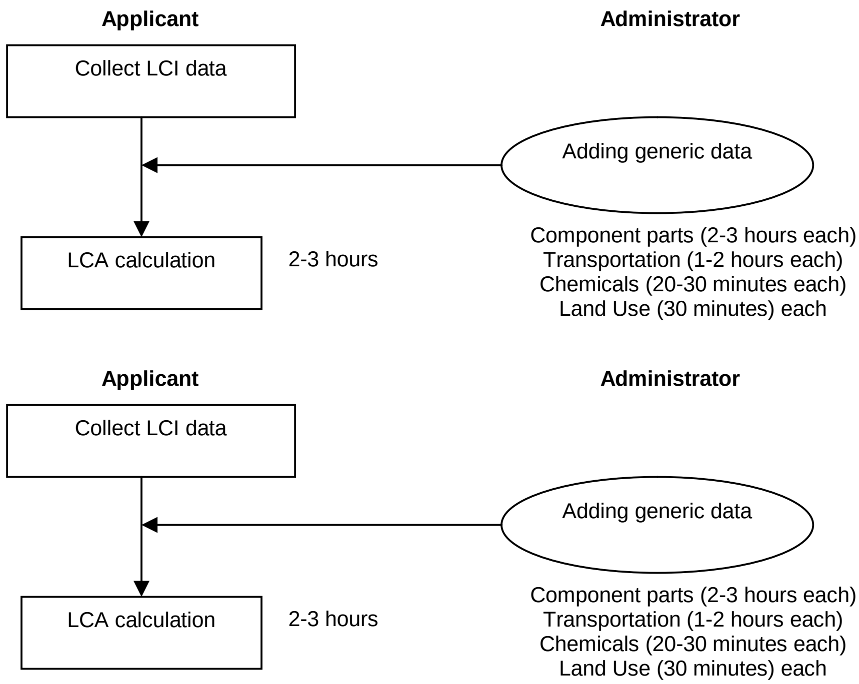



**Figure B.5.** Procedure and estimated time for LCA

- Influence on sales

The result of the sales of conventional/organic apples and avocados is shown in Table B.2. The average sales before the test period (1/1-2/19) are highlighted by green. The average sales in the test period (2/20-3/26) are highlighted by orange. Upper boxes are actual sales as pound per week. Lower boxes are percentage of the sales of organic/conventional ones to the total sales.

The average percentage of organic apples to the total (organic and conventional) apple sales before the test period was 88.5%, and the average percentage in the test period was 92.5%. The average percentage of organic avocados to the total avocado sales before the test period was 55.5%, and the average percentage in the test period was 58.8%. This result shows that in the test period, the sales of organic ones slightly increased for both apples and avocados. Even the data of test period are compared to previous individual two weeks (2/6-2/12, 2/13-2/19), sales of both organic apple and organic avocado increased. The sales of organic apples in 2/6-2/12 was 89.9% and 2/13-2/19 was 90.4%. The sales of conventional avocado in 2/6-2/12 was 42.2% and 2/13-2/19 was 42.6%.

This result shows that the environmental declaration sign may have influenced customers' decision to choose organic vegetables that show the quantitatively less environmental impacts. However, because the data of test period and before test period given the store was limited and quality is not high, the reliability of the result is not high. In addition, it is difficult to know how many customers actually read the sign when they purchased those vegetables. In order to prove the influence of the environmental declaration, more kinds of products and longer test period will be needed.

| | Units Sold (pound per week) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Average Before Test Wkly Avg | | | | | | Test Period Wkly Average |
| *Start Date* | 2006/02/06 | 2006/02/13 | 2006/01/01 | 2006/02/20 | 2006/02/27 | 2006/03/06 | 2006/03/13 | 2006/03/20 | 2006/02/20 |
| *End Date* | 2006/02/12 | 2006/02/19 | 2006/02/19 | 2006/02/26 | 2006/03/05 | 2006/03/12 | 2006/03/19 | 2006/03/26 | 2006/03/26 |
| **LOCAL APPLES (CONVENTIONAL)** | 68.39 | 66.48 | 67.435 | 55.79 | 53.98 | 50.11 | 60.94 | 58.13 | 55.79 |
| **APPLES MISCELLANEOUS (ORGANIC)** | 497.13 | 534.71 | 419.999 | 548.415 | 453.43 | 611.96 | 586.12 | 542.15 | 548.415 |
| **APPLES PINK LADY (ORGANIC)** | 112.83 | 92.73 | 100.352 | 135.783 | 97.42 | 114.99 | 164.15 | 166.57 | 135.783 |
| **AVOCADOES (CONVENTIONAL)** | 172 | 182 | 182.315 | 147.25 | 125 | 167 | 128 | 169 | 147.25 |
| **AVOCADOES (ORGANIC)** | 236 | 245 | 227.71 | 210.5 | 202 | 227 | 233 | 180 | 210.5 |
| ***Percentage*** | | | | | | | | | |
| **APPLE ORG/TOTAL** | 89.9% | 90.4% | 88.5% | 92.5% | 91.1% | 93.6% | 92.5% | 92.4% | 92.5% |
| **APPLE CONV/TOTAL** | 10.1% | 9.6% | 11.5% | 7.5% | 8.9% | 6.4% | 7.5% | 7.6% | 7.5% |
| **AVOCADO ORG/TOTAL** | 57.8% | 57.4% | 55.5% | 58.8% | 61.8% | 57.6% | 64.5% | 51.6% | 58.8% |
| **AVOCADO CONV/TOTAL** | 42.2% | 42.6% | 44.5% | 41.2% | 38.2% | 42.4% | 35.5% | 48.4% | 41.2% |

**Table B.2.** The sales of conventional/organic apples and avocados in PFC
Yellow boxes are the sales in the test period where the environmental declaration sighs are placed. Blue boxes are the period where before the sign were not placed. The sales data 2/20-2/26 (red texts) is lacked, therefore the sales are assumed as the average of other weeks' data in the test period. Green boxes are the average sales before the test period. Orange boxes are the average sales in the test period.

- The number of visitors to the website

The number of visitors in the test period was 20 people. When we searched the webpage, typing "envdata", the web search engines, "Google" and "Yahoo" could not hit the page. Therefore, it seemed rare that people accidentally visit the website. Then, the number probably shows the number of visitors who tried to see the page, though some of them may have visited accidentally via some other path.

This number is much fewer than we expected. One of the possible reasons of this is that customers could not notice the environmental declaration signs, although we advertised that in the news letters and on the board in the store. Even if they were interested in the environmental declaration in the store, they may not have been willing to pick up the business card or memorize the URL. Another reason may be that people thought connecting internet and typing URL was troublesome.

The result shows that the disadvantage of the current technology. All existing Type III environmental declaration program use the webpage as primary tools to publicize the environmental declaration. However, even in the Ecoleaf, the number of visitors to the website is not very many. Therefore, home PC internet based publicity seems to have limitation to attract many people. This is why on-shelf signs or on-product labels are more preferable to just a logo that certifies the product is available in the administrator's website (as existing Type III programs do). In addition, this shows new technologies such as handheld device internet or 2D code is expected in order to make the environmental program more useful.

## APPENDIX C. LCA CASE STUDY – CONVENTIONAL GRAPES

We conducted life cycle assessment (LCA) on conventional/organic avocado, conventional/organic apple, and conventional grape. This appendix explains LCA of conventional grape as a case study of LCA of those products.

### C.1 Scope

(a) Functional Unit

The functional unit is pound.

(b) System Boundaries

The system studied includes Grape production and Transportation stages, but not include Use and Disposal/Recycle stages, because in Use stage, grapes are just consumed as foods and the rate of disposal is uncertain. Grape production stage includes farming, harvesting, and packaging. Transportation includes the distance from production sites to retailers.

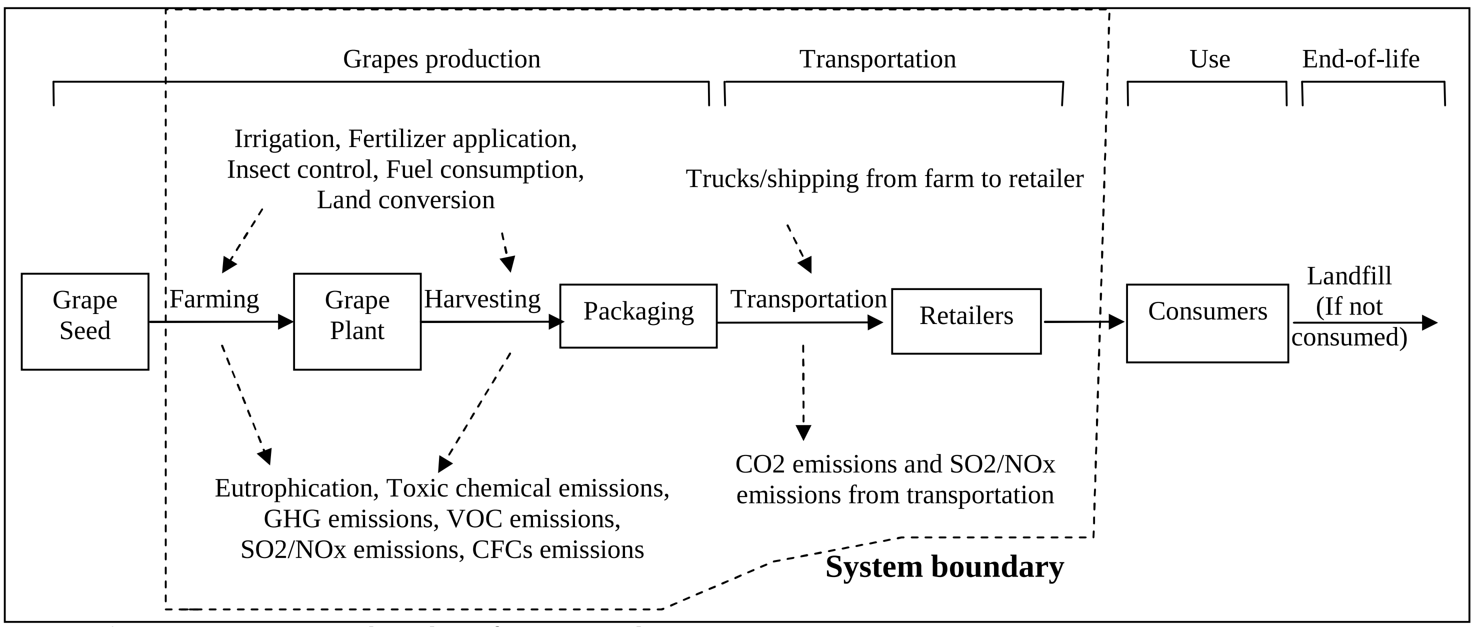



**Figure C.1.** System boundary of conventional grapes

### C.2 Data Collection

The life cycle inventory (LCI data) in production stage referred to the life cycle analysis of the University of California, Davis, Department of Agricultural and Resource Economics Outreach [95], about "Sample costs to establish and produce table grapes (Crimson Seedless) [99]." LCI data for cardboards (packaging), gasoline and diesel were collected from SimaPro (LCA software). Average distance in shipment from the production site to undetermined destination in the continental U.S was estimated from "Bureau of Transportation Statistics[103]." For productivity of the land, the GIS data from the Biodiversity Support Program (BSP) [72] and the Food and Agriculture Organization (FAO) of the United Nations [74] were used. Land Use input was calculated as "global hectare" considering the productivity of the land.

## C.3 Life cycle inventory (LCI)

Table C.1 shows the summary inventory for the grape production. The unit of the inputs is per acre. Yield of grapes is 19000 pound per acre.

| Item Name | Input Type | Value/acre | Units | Comment |
|---|---|---|---|---|
| Surflan 4 AS | To Soil | 2.4 | pint, liquid | Includes only toxicity impacts |
| Roundup Ultra Max | To Soil | 1.1 | pint, liquid | Includes only toxicity impacts |
| Abound (Strobilurin) | To Soil | 12 | fluid ounce | Includes only toxicity impacts |
| Mirothiol Special (micronized wettable sulfur) | To Soil | 11 | pound | Includes only toxicity impacts |
| Dusting Sulfur | To Soil | 30 | pound | Includes only toxicity impacts |
| Rally 40W (Sterol Inhibitor) | To Soil | 16 | fluid ounce | Includes only toxicity impacts |
| Vangard WG | To Soil | 10 | fluid ounce | Includes only toxicity impacts |
| Lorsban 4E | To Soil | 4 | pint, liquid | Includes only toxicity impacts. Assume Lorsban 4E-HF |
| Kryocide | To Soil | 6 | pound | Ignored |
| Provado 1.6 Solupak | To Soil | 1 | fluid ounce | Includes only toxicity impacts |
| Neutral Zinc 50% (foliar) | To Soil | 5 | pound | Ignored |
| UN 32 Applied | To Water | 50 | pound | Total applied fertilizer(lb N) |
| Nitrogen Removed when Harvesting | To Water | -2.1 | pound | (lb N) |
| Water | Water Input | 36 | acre inch | Pumped |
| Gibberelic Acid (ProGibb) | To Soil | 9 | gram | Includes only toxicity impacts. Progibb T&O PGR. 1g = 1oz |
| Ethrel | To Soil | 1 | pint, liquid | Includes only toxicity impacts |
| Cardboard Box | Sub Component Input | 90 | kilogram | 1 box = 0.09kg (1 box for 9 bags, or 19 pounds of grapes, 1000 boxes per acre) |
| Plastic Bags | Sub Component Input | 9000 | bags | Ignored, 9 per box |
| Gasoline | Sub Component Input | 44.7 | liter | 11.81 gal/acre Includes production of fuel only (not combustion) |
| Diesel | Sub Component Input | 107.2 | liter | 28.32 gal/acre Includes production of fuel only (not combustion) |
| Land | Land Input | 1 | acre | Average of all San Joaquin Valley (taken visually from map) |

**Table C.1.** Life cycle inventory of Grape Production per acre

## C.4 Shipment condition

Grapes are shipped by truck (HDDV 8a). Average distance in shipment from San Joaquin Valley, CA to undetermined destination in the continental U.S is 790 mile.

## C.5 Indicator Result

LCI data is input to our original database software (exLCA and volTOX). Then, the ten environmental indicators are calculated. Table C.2 shows the indicator result for grapes. The functional unit of this analysis is pound of grapes.

| | Production | Transportation | Use | Disposal | Total | Unit |
|---|---|---|---|---|---|---|
| **Global Warming** | 7.535444316 | 24.59492164 | N/A | N/A | 32.13037 | gram CO2 equiv |
| **Acid Rain** | 0.061591198 | 0.102903848 | N/A | N/A | 0.164495 | gram SO2 equiv |
| **Eutrophication** | 5.074612363 | 0.039898994 | N/A | N/A | 5.114511 | gram NO3- equiv |
| **Photochemical Smog Creation** | 0.000728621 | 0.001737222 | N/A | N/A | 0.002466 | gram C2H4 equiv |
| **Ozone Depletion** | 2.24502E-05 | 2.08499E-05 | N/A | N/A | 4.33E-05 | gram CFC11 equiv |
| **Human Toxicity** | | | | | | |
| Finally To Air Compartment | 40564.68882 | 37.90235084 | N/A | N/A | 40602.59 | cubic meter Air*day |
| Finally To Water Compartment | 4.27588E-05 | 4.36878E-08 | N/A | N/A | 4.28E-05 | cubic meter Water*day |
| Finally To Soil Compartment | 1.392675999 | 8.87837E-07 | N/A | N/A | 1.392677 | cubic meter Soil*day |
| **Ecotoxicity** | | | | | | |
| Contaminated Water Volume | 8.776362988 | 4.163030695 | N/A | N/A | 12.93939 | cubic meter Water*day |
| Contaminated Soil Volume | 543.6005953 | 6.827543622 | N/A | N/A | 550.4281 | cubic meter Soil*day |
| Contaminated WWTP | 0 | 0 | N/A | N/A | 0 | N/A |
| **Land Use** | | | | | | |
| Agricultural Productivity | 3.62467E-05 | 0 | N/A | N/A | 3.62E-05 | global Agricultural hectare |
| Biological Diversity | 2.4031E-05 | 0 | N/A | N/A | 2.4E-05 | global Biodiversity hectare |
| **Water Depletion** | 0.194761088 | 0 | N/A | N/A | 0.194761 | cubic meter Water depleted |
| **Non-Renewable Resource Depletion** | | | | | | |
| Mineral Resource Depletion | 0 | 0 | N/A | N/A | 0 | megajoule equivalent |
| Energy Resource Depletion | 0.441542238 | 0.375062995 | N/A | N/A | 0.816605 | megajoule equivalent |

**Table C.2.** Indicator result for grape's life cycle

## C.6 The U.S average individual's Total Daily Consumption Impact (TDCI)

TDCI is the average values which the U.S. consumers daily contribute to the environmental impacts. This value is used for proportional values in data presentation of the environmental declaration, as is shown in Table C.3. (see Chapter 3)

| **Item** | **Sub item** | **Value** | **Unit** |
|---|---|---|---|
| Global Warming | | 67691.4718 | gram CO2 equiv |
| Acid Rain | | 284.0800404 | gram SO2 equiv |
| Eutrophication | | 164.3001534 | gram NO3- equiv |
| Photochemical Smog Creation | | 61.86577147 | gram C2H4 equiv |
| Ozone Depletion | | 0.620804356 | gram CFC11 equiv |
| Human Toxicity From All Emissions | Finally To Air Compartment | 29231401.87 | cubic meter Air*day |
| | Finally To Water Compartment | 8.863102861 | cubic meter Water*day |
| | Finally To Soil Compartment | 457.1904569 | cubic meter Soil*day |
| Ecotoxicity From All Emissions | Contaminated Water Volume | 401.5261938 | cubic meter Water*day |
| | Contaminated Soil Volume | 1062.124158 | cubic meter Soil*day |
| | Contaminated WWTP | | |
| Land Use | Agricultural Productivity | 0.006077741 | global Agricultural hectare |
| | Biological Diversity | 0.006077741 | global Biodiversity hectare |
| Water Depletion | | 1.120470059 | cubic meter Water depleted |
| Non-Renewable Resource Depletion | Mineral Resource Depletion | | megajoule equivalent |
| | Energy Resource Depletion | 872.6483077 | megajoule equivalent |

**Table C.3.** Total Daily Consumption Impact

## C.7 Percentage of indicators to TDCI

Finally, the indicator is compared to TDCI as percentages. Table C.4 shows the percentage of the indicators to TDCI.

| | Production | Transportation | Use | Disposal | Total |
|---|---|---|---|---|---|
| **Global Warming** | 0.01% | 0.04% | N/A | N/A | 0.05% |
| **Acid Rain** | 0.02% | 0.04% | N/A | N/A | 0.06% |
| **Eutrophication** | 3.09% | 0.02% | N/A | N/A | 3.11% |
| **Photochemical Smog Creation** | 0.00% | 0.00% | N/A | N/A | 0.00% |
| **Ozone Depletion** | 0.00% | 0.00% | N/A | N/A | 0.01% |
| **Human Toxicity** | 0.15% | 0.00% | N/A | N/A | 0.15% |
| Finally To Air Compartment | 0.14% | 0.00% | N/A | N/A | 0.14% |
| Finally To Water Compartment | 0.00% | 0.00% | N/A | N/A | 0.00% |
| Finally To Soil Compartment | 0.30% | 0.00% | N/A | N/A | 0.30% |
| **Ecotoxicity** | 17.79% | 0.56% | N/A | N/A | 18.35% |
| Contaminated Water Volume | 2.19% | 1.04% | N/A | N/A | 3.22% |
| Contaminated Soil Volume | 51.18% | 0.64% | N/A | N/A | 51.82% |
| Contaminated WWTP | N/A | N/A | N/A | N/A | N/A |
| **Land Use** | 0.33% | 0.00% | N/A | N/A | 0.33% |
| Agricultural Productivity | 0.60% | 0.00% | N/A | N/A | 0.60% |
| Biological Diversity | 0.40% | 0.00% | N/A | N/A | 0.40% |
| **Water Depletion** | 17.38% | 0.00% | N/A | N/A | 17.38% |
| **Non-Renewable Resource Depletion** | 0.05% | 0.04% | N/A | N/A | 0.09% |
| Mineral Resource Depletion | N/A | N/A | N/A | N/A | N/A |
| Energy Resource Depletion | 0.05% | 0.04% | N/A | N/A | 0.09% |

**Table C.4.** Percentage of indicators to TDCI

## APPENDIX D. LIST OF ADDITIONAL RESOURCES

### D.1 Demonstration LCA Software – exLCA

exLCA version 0.1c
exLCA version 0.1 Normalization Sheets

### D.2 Demonstration Toxicity Calculation Software – volTOX

volTOX version 0.1c

### D.3 U.S. 2000 Total Agricultural Chemical Use and Ecotoxicity Data

USDA 2000 Agricultural Chemical Use and USGS Ecotoxicity Data

### D.4 HTP Calculations for U.S. 2000 Toxic Release Inventory Data

EPA TRI 2000 Release Data and HTP Equivalents

### D.5 LCA Data File for Case Study of Grapes

exLCA 0.1b 150040001AAAAA Conventional Grapes San Joaquin CA

### D.6 Full Scale Images of On-shelf Labels Using Radar Area Format

On-shelf labels

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