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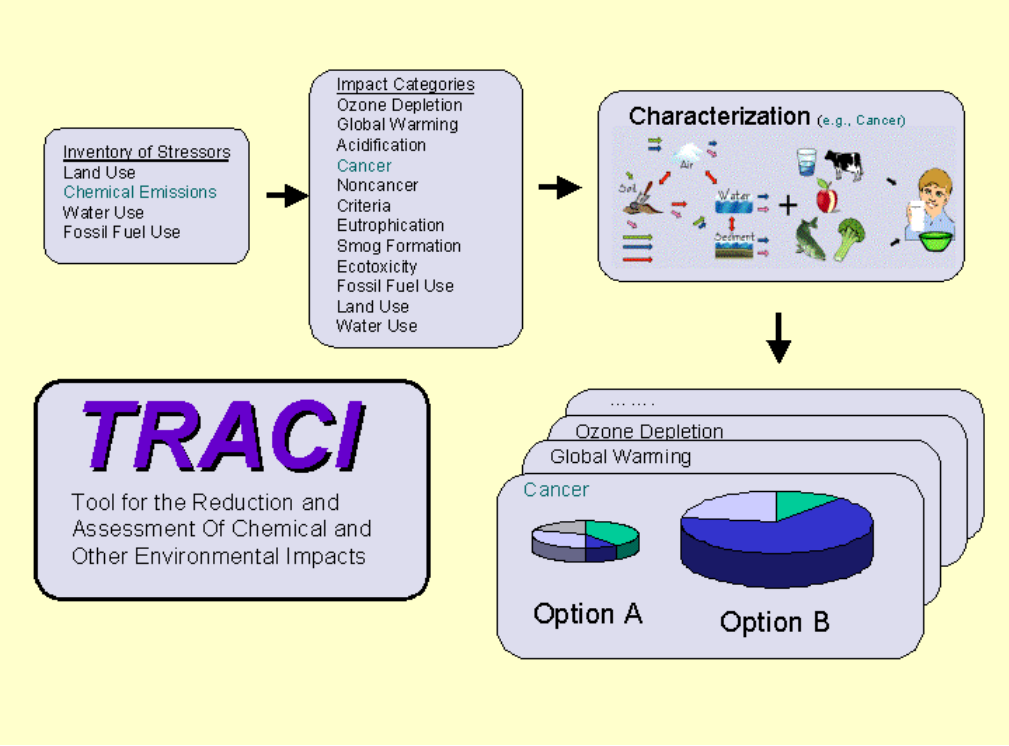
Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI): User's Guide and System Documentation



Acknowledgments

TRACI, the **T**ool for the **R**eduction and **A**ssessment of **C**hemical and other environmental **I**mpacts, was developed by the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory under the leadership of Jane Bare. In-house support for TRACI's development was provided by the following EPA researchers: Teresa Hoagland, Patrick Hofstetter, and David Pennington.

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Disclaimer

Use of TRACI (the Tool for the Reduction and Assessment of Chemical and other environmental Impacts), including but not limited to the impact assessment modeling, does not confer legal rights or impose legal obligations upon any member of the public. Furthermore, it does not release users from any potential liability, either administrative or judicial for any damage to human health or the environment.

Neither EPA nor anyone involved in the development of TRACI makes any warranty, expressed or implied, as to any matter whatsoever, including the accuracy of the database, the appropriateness of actions taken by third parties as a result of using the model, or the merchantability or fitness of the model for a particular purpose. EPA does not endorse any products or services.

Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

TRACI allows the examination of the potential for impacts associated with the raw material usage and chemical releases resulting from the processes involved in producing a product. TRACI allows the user to examine the potential for impacts for a single life cycle stage, or the whole life cycle, and to compare the results between products or processes.

The purpose of TRACI is to allow a determination of priorities or a preliminary comparison of two or more options on the basis of the following environmental impact categories: ozone depletion, global warming, acidification, eutrophication, photochemical smog, human health cancer, human health noncancer, human health criteria, ecotoxicity, fossil fuel use, land use, and water use. TRACI is an impact assessment tool that will support consistency in environmental decision making. It is recognized that additional tools may be useful to assess, prioritize and reduce potential environmental impacts. This user's guide presents information to assist in the use of, limitations and uncertainties associated with, and information concerning, the methodologies within TRACI.

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Acronyms

CAS	Chemical Abstract Service
EPA	Environmental Protection Agency
g	Gram
gal	Gallon
ISO	International Organization for Standardization
kg	Kilogram
L	Liter
lb	Pound
LC	Life Cycle
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCA	Life Cycle Assessment
M^3	Cubic Meter
mg	Milligram
MJ	Mega Joule
Qty	Quantity
scf	Standard Cubic Foot
SETAC	Society of Environmental Toxicology and Chemistry
sq.ft	Square Foot
sq.km	Square Kilometer
sq.mi	Square Mile
T&E	Threatened and Endangered Species
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
UOM	Unit of Measurement

Chapter 1. Introduction to TRACI

1.1 Overview

As environmental awareness increases, industries and businesses have started to assess how their activities affect the environment. Society has become increasingly concerned about the issues of natural resource depletion, environmental degradation and human health. Many businesses have responded to this public awareness and concern by providing "greener" products and using "greener" processes by moving *beyond* compliance using pollution prevention tools and environmental management strategies to improve their environmental performance.

Components of an LCA
- Goal definition and scoping
- Inventory analysis
- Impact assessment
- Interpretation

Life Cycle Assessment (LCA) is a technique for assessing the environmental aspects and potential impacts associated with a product. A complete LCA evaluates all stages of a product's life, from raw materials acquisition to product disposal (or recycling). There are four components to an LCA: goal definition and scoping, inventory analysis, impact assessment, and interpretation. For further information on these components, see Chapter 3 of this document.

The Life Cycle Impact Assessment (LCIA) phase of an LCA is the evaluation of potential human health, environmental, and resource depletion impacts identified during the inventory analysis. A life cycle impact assessment attempts to establish a linkage between the product or process and its potential environmental impacts. For example, what are the impacts of 9,000 tons of carbon dioxide or 5,000 tons of methane emissions released into the atmosphere? What are their potential impacts on smog? On global warming?

A **stressor** is a set of conditions that may lead to an environmental impact.

The key concept in this component is that of stressors. A stressor is a set of conditions that may lead to an impact. For example, if a product or process is emitting greenhouse gases, the increase of greenhouse gases in the atmosphere may contribute to global warming. Processes that result in the discharge of excess nutrients into bodies of water may lead to eutrophication. An LCIA provides a systematic procedure for classifying and characterizing the environmental impact of stressors.

The Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) is a tool that can be used to facilitate the environmental comparison of product and process alternatives for the purpose of internal environmental decision making.

1.2 TRACI

TRACI is intended to assist companies, federal facilities, industrial organizations, and public interest groups in performing broad-based impact assessments of a product's human health, environmental, and resource depletion impacts.

Impact Categories in TRACI

- Ozone depletion
- Global warming
- Acidification
- Eutrophication
- Photochemical smog
- Human health cancer
- Human health noncancer
- Human health criteria
- Ecotoxicity
- Fossil fuel use
- Land use
- Water use

After entering life cycle inventory data (such as resources and chemical emissions), users can run TRACI to perform a life cycle impact assessment. TRACI can be used to compare the environmental and human health preferability of two or more products or processes. TRACI facilitates the characterization of stressors that may have potential effects on the following impact categories: ozone depletion, global warming, acidification, eutrophication, photochemical smog, human health cancer, human health noncancer, human health criteria (also known as cancer, noncancer, and criteria, respectively), ecotoxicity, fossil fuel use, land use (also known as habitat -- threatened and endangered species), and water use. Other categories that could be included, but are not currently represented in TRACI are biodiversity, odor, noise and radiation. For TRACI, one impact assessment methodology was selected or developed to reflect the current state-of-the-art for each impact category, with a particular emphasis on methodologies that are relevant for the U.S. It is recognized that each of the selected methodologies in TRACI represents just one of many methodologies which may be appropriate for each impact category. The applicability of the methodologies to a specific situation is the responsibility of the study practitioner.

1.3 Life Cycle Impact Assessment (LCIA)

In an ideal world, an LCIA would use the highest quality data, incorporate all impact categories, all stressors, and all processes within life cycle stages at the highest level of simulation sophistication. Impact categories would be represented at a high level of disaggregation with a high level of simulation sophistication while accounting for all of the life cycle stages or off-site effects. One scenario would completely dominate the other scenario in all impact categories, and decisions could be made based on the environmental assessment with a high level of certainty. Unfortunately, in the real world, completing comprehensive assessments for all potential effects at a high level of simulation sophistication for an entire product life-cycle would require impossibly large amounts of time, data, and resources. Since, in reality, every study is limited in resources, it follows that every study must also be limited in some aspects of sophistication and/or comprehensiveness (Bare 1999).

Limitations in comprehensiveness lead to a more narrow focus on issues. An example of a study which is limited in comprehensiveness, but relatively sophisticated in simulation would be the traditional risk assessment. For years, very focused assessments of single impact categories (e.g., human carcinogenicity) have been conducted with relatively sophisticated simulations, many times only considering a single pollutant. These studies produce a relatively high degree of certainty in relation to a question with a relatively narrow focus. In some cases, when these sophisticated, but narrowly focused studies have been used to set new standards, opponents have conducted more comprehensive assessments which pointed out that such a narrow focus might have caused negative impacts elsewhere. A more comprehensive impact assessment would have allowed decision makers to incorporate a wider range of impact categories and life cycle stages.

When practitioners wish to answer broader questions about the overall impacts of a decision in relation to many life cycle stages and impact categories, it is obvious that conducting these studies, or LCIAs, at a high level of sophistication would be so time- and resource-consumptive as to be prohibitive. Conducting the appropriate level of sophistication and comprehensiveness for each impact assessment is key to effective environmental decision making. If too complex a methodology is selected with very

broad boundaries, limited resources will typically prohibit completion of the study. On the other hand, if a narrow and/or too simplistic framework is defined, the assessment can lead to incorrect decisions, either by relying on gross, inaccurate modeling and data assumptions (lack of sophistication), or by failing to address important factors relating impact to stressors (lack of comprehensiveness).

In contrast, a typical LCA often is conducted without the high level of knowledge available in conducting a traditional risk assessment. Within an LCA, the temporal and spatial characteristics of the stressor are often not available. Study initiators can make a special attempt to capture this data if the scope of the study allows for this level of detail. Tools such as TRACI provide insight into the relative importance of various stressors and life cycle stages with a screening level of sophistication. Specific impact categories may or may not allow differentiation on spatial matters.

Researchers have noted that the selection of an LCIA methodology should be scientifically valid, as well as consistent with the goal and scope of a study (Bare 2000). Studies should be presented as transparently as possible to acknowledge the modeling assumptions, data gaps, uncertainty, and other limitations of the study. It is left to the user to determine if the goal and scope of the study are consistent with the LCIA methodologies and to ensure that the models are clearly communicated to users of each study.

1.4 Limitations of TRACI

There are several limitations associated with TRACI.

- TRACI's impact categories are not comprehensive, but have been selected to represent many of the recognized environmental issues of our time. There are twelve impact categories that are currently modeled.
- TRACI does not provide estimates of actual risk. TRACI is simply a screening tool to allow consideration and quantification of the potential for impacts.
- TRACI is not intended for studies of accidental situations (e.g., accidental oil spills). TRACI focuses on normal industrial operations.
- An uncertainty and variability analysis is not available in this version of TRACI, but users are directed to the literature to review certain impact assessment methods used within TRACI which have conducted uncertainty and variability analysis (Hertwich 1999).

1.5 Conclusions

TRACI facilitates the characterization of stressors that may have potential effects, including ozone depletion, global warming, acidification, eutrophication, photochemical smog formation, ecotoxicity, human health criteria-related effects, human health cancer effects, human health non-cancer effects, fossil fuel depletion, land use and water use effects. To develop TRACI, impact categories were selected, available methodologies were reviewed, and categories were prioritized for further research. Impact categories were characterized at the midpoint level, for various reasons, including a higher level of societal consensus concerning the certainties of modeling at this point in the cause-effect chain. Research in the following impact categories – acidification, photochemical smog, eutrophication, land use, human cancer, human noncancer, and human criteria effects – was conducted to construct

methodologies for representing potential effects in the United States. The methodologies underlying TRACI are described in a paper which is cited on the TRACI web site.

1.6 Document Organization

A functional overview of the software is presented in Chapter Two. The user is guided through a screen-by-screen overview of TRACI. Details of how the user enters data, manipulates data and obtains and prints results are explained. An introduction to life cycle assessment and life cycle inventory is presented in Chapter Three. This information is intended to help users who are not familiar with these topics. Chapter Four explains how to collect life cycle inventory data for input into TRACI. The Appendices provide a glossary and other supporting information. The user is encouraged to read the publication within the *Journal of Industrial Ecology* entitled "TRACI - The Tool for the Reduction and Assessment of Chemical and other environmental Impacts" for more details on the impact assessment methodologies (Bare 2002).

Chapter 2. How to Use TRACI

2.1 Overview of TRACI's Functions

The main steps involved in using TRACI for a life cycle impact assessment include: completing a project description form, creating a list of products to be analyzed, entering the life cycle inventory data for each product, and generating the calculations. If you already have life cycle inventory data in an electronic format, you can import it using TRACI's import feature. After data are collected and entered into TRACI, TRACI will perform several calculations.

In the classification step, the resources/releases are assigned to the various impact categories: ozone depletion, global warming, acidification, eutrophication, photochemical smog, human health cancer, human health noncancer, human health criteria, ecotoxicity, fossil fuel use, land use, and water use.

Next, the resources/releases will be characterized. Characterization factors are based on the impact category and media of release. For chemical emissions, the characterization factor will be multiplied by the quantity of chemical release. Within each impact category, the characterization results will be added to form a characterization score for each impact category.

The purpose of this chapter is to describe how to use TRACI and perform these functions. The data structure used in TRACI is described herein.

2.2 Data Structure

Data in TRACI are organized on the basis of user-defined projects. For example, a typical project might compare the environmental impacts between two or more products derived via different manufacturing routes. You might define a high-level project to analyze several large products or processes or create specific projects that analyze one or two processes in greater detail. The user has the flexibility to define the level of analyses for a particular project.

Note: In order to compare two or more products on an equal basis, the same life cycle stages must be assessed for each product.

Data in TRACI are organized hierarchically, with the highest level being the project, followed by the product, life cycle stage, process, and resources/releases. Figure 2-1 illustrates the data structure. Life Cycle Inventory (LCI) data must be entered based on this structure. Each of these levels is described in greater detail within this section.

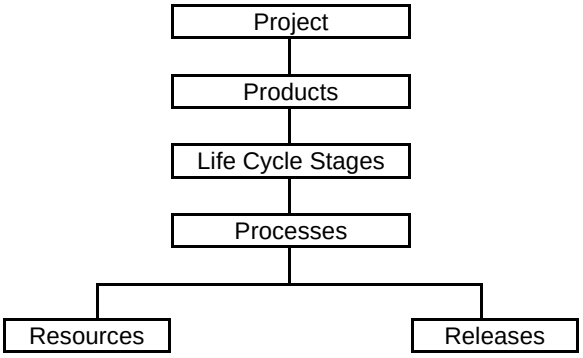

Figure 2-1. Levels of LCI Data

Project – name of the overall project under which you are conducting this life cycle impact assessment.

Products – names of the products or services that will be analyzed within the project.

Life Cycle Stages – each of the stages involved in the life cycle of a product or process. TRACI pre-defines these stages as: raw materials acquisition, materials manufacture, product fabrication, filling/packaging/distribution, use/reuse/ maintenance, and recycle/waste management. This list of stages cannot be modified.

Processes – each life cycle stage consists of one or more processes. These are not pre-defined, so the process names can be customized by the user.

Resources (Inputs) & Chemical Releases (Outputs) – the life cycle inventory data (resources and releases) associated with each process. Resources include: fossil fuel use, water use, and land use. With respect to the chemical releases, TRACI contains a list of many chemicals ranging from those which are commonly used in industry to relatively rare substances. TRACI also contains synonyms for many of the chemicals in order to avoid exclusion of a chemical due to differences in nomenclature. In order to maintain the integrity of the software, TRACI does not allow users to add new chemicals that are not on TRACI's list or to revise the characterization factors stored within TRACI.

2.3 Installation and Uninstallation

2.3.1 Installation

TRACI is designed to run as a stand-alone (executable) application on personal computers within the United States with Windows 95, Windows 98, or Windows NT. TRACI uses a run-time version of Microsoft (MS) Access 97, therefore it will work regardless of the version of MS Access that is already on your computer. It will also work on computers that do not have Microsoft Office installed.

Note: Before installing TRACI, exit all other programs on your computer.

First, download the TRACI.exe file from the TRACI web site and save it to your hard drive. Then, exit all open programs on your computer. Go to *Windows Explorer*, locate the TRACI.exe file on your hard drive, and double click on the file. Press **Next** to start the installation.

As a default, the TRACI software will be saved at the following location: C:\TRACI. It is recommended that you do not change this folder location. Note that modifications to the default location or names may affect the ability of the program to function correctly. Click **Next** twice. The installation will begin.

Click **Finish** to complete the installation. In some cases, your computer may need to be rebooted in order to complete the installation process. Afterwards, the TRACI icon will appear on your desktop. Double click the icon to start the program. You can also access TRACI by clicking the **Start** button, clicking on **Programs**, and then locating the TRACI icon.

2.3.2 Uninstallation

To uninstall TRACI, click on the *Start Menu* and go to *Settings - Control Panel*. Double click **Add/Remove Programs**. A window will display all programs that are currently on your machine. Click on **TRACI** and then the **Add/Remove button or Uninstall** button. This will remove TRACI appropriately. If a system message asks if you would like to remove shared files, click on **No to All**. This will ensure that you do not remove a file needed by another program. The application will complete the uninstallation.

Note: It is recommended that you close other programs, such as Lotus Notes and MS Access, while using TRACI in order to maximize the speed of the operation and minimize any potential conflicts in the software.

2.4 Introduction Screens

Double click on the TRACI icon to start the program and the splash screen (*see Figure 2-2*) will appear. The splash screen can be viewed for 30 seconds and will be followed by an introductory screen, which gives a brief explanation of the software. Click on the splash screen at any time to move forward.

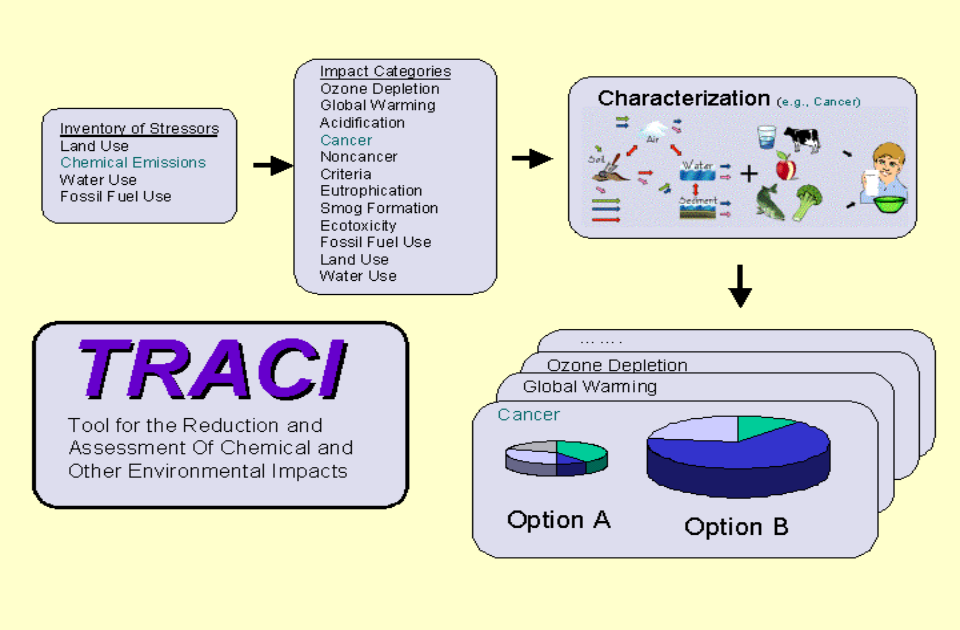

Figure 2-2. Splash Screen

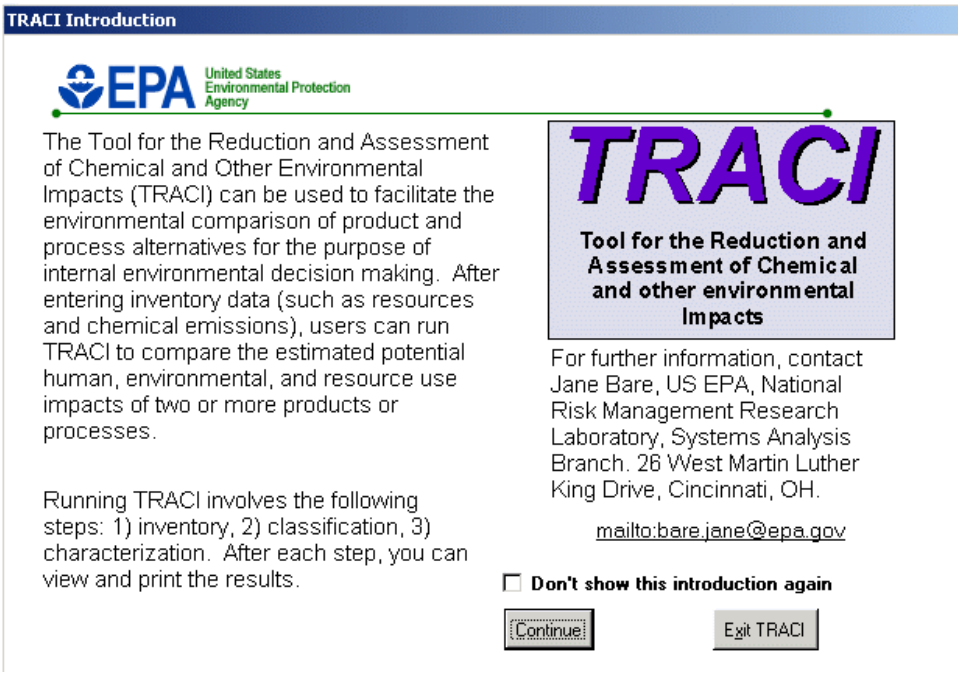

Figure 2-3. Introduction Screen

1. Click the box next to **Don't show this introduction again** to bypass the introduction screen (*see Figure 2-3*) the next time you use TRACI.

2. Next, click **Continue** and the U.S. EPA's disclaimer (*see Figure 2-4*) will appear. This screen can also be bypassed the next time you use TRACI by clicking the box next to **Don't show this introduction again**.

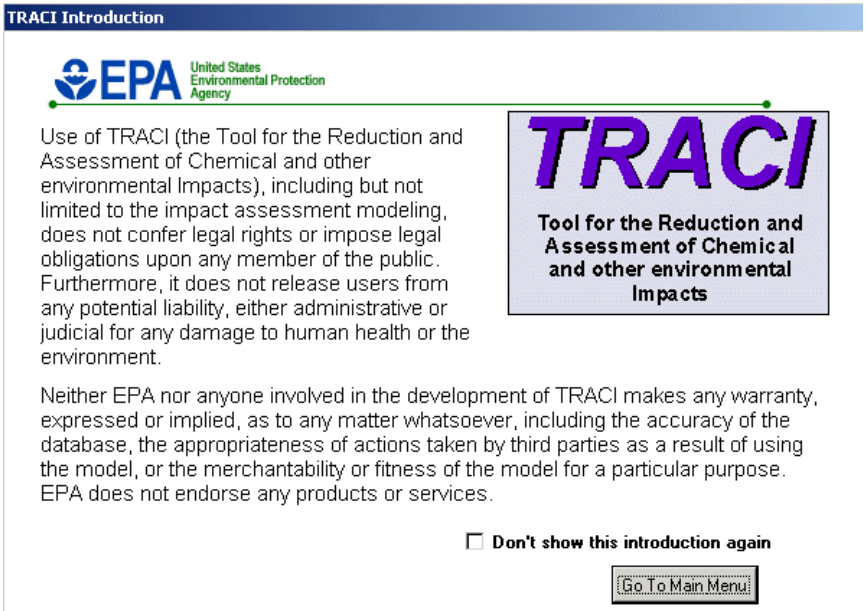

Figure 2-4. EPA Disclaimer

3. Click **Go to Main Menu**.

2.5 Main Menu

The following screen (*see Figure 2-5*) is the *Main Menu* of TRACI. This screen allows you to select one of five different options.

$ Click **Program Overview** to access TRACI's Program Overview (part of TRACI's help files). This feature presents an overall introduction on how TRACI works (*see Section 2.6*).

$ Click **Enter/Edit LCI Data** to enter data for a new project or access data from an existing project. Next, the *Projects in TRACI* screen will appear (*see Section 2.7*).

$ Click **Perform Calculations** to complete the calculations and to view and print results. TRACI's calculations include classification and characterization (*see Section 2.8*).

$ Click **Transfer Data** to export existing life cycle inventory data (*see Section 2.9*). To import data, see Section 2.7.12.

$ Click **Exit TRACI** to exit the program.

The remainder of this chapter is organized to discuss the different features under each of the main functions (buttons): Program Overview, Enter/Edit LCI Data, Perform Calculations, and Transfer Data.

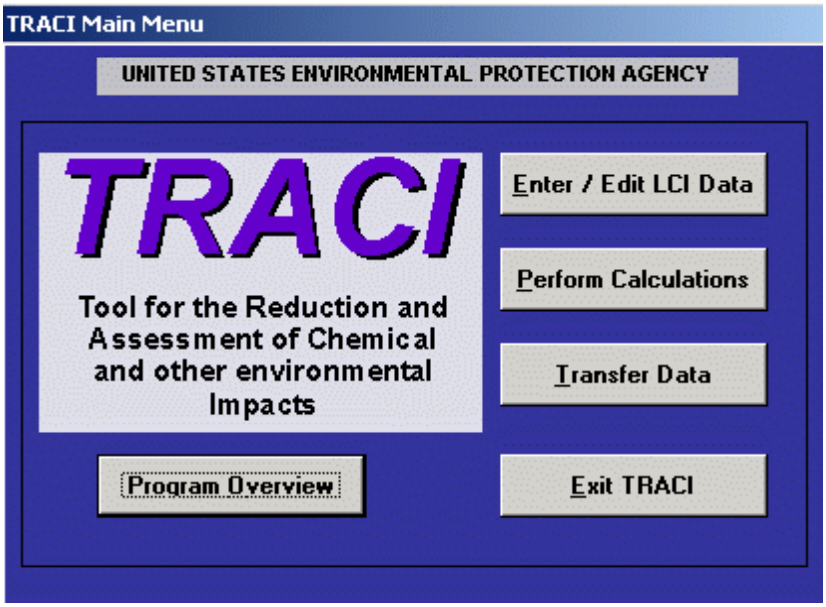

Figure 2-5. Main Menu

2.6 Program Overview

Hint: Click the F1 button on your keyboard at any time to access the Help Feature.

The Program Overview presents a high-level introduction to TRACI. This overview is part of TRACI's help feature. The Help Feature explains terms used in TRACI, explains how to use the software, and gives step-by-step instructions for each screen in TRACI. You are encouraged to use the Help Feature along with the User's Guide in order to learn how to use the program.

Help buttons are found on numerous screens; however the Help Feature can be accessed at any time by clicking the F1 button on your keyboard. When a help button is clicked, the Help Feature will appear. Click the **Contents** button to access the *Table of Contents*.

The Help Feature consists of a *Table of Contents* and an *Index*. There is also a *Find* feature that can perform a word search and provide the search results. Select a term from the list and then a list of topics related to that term will appear. Then, select a topic from the list. To print a help topic, click **Options** while in the *Help Topic* window. Then, click **Print Topic**.

After the Program Overview has been viewed, close the Help window and return to the *Main Menu*. To begin entering project data, see the following section.

2.7 Enter/Edit LCI Data

2.7.1 Projects in TRACI

From the *Main Menu*, click **Enter/Edit LCI Data** to enter or edit project information. The *Projects in TRACI* screen contains the project name, version number and the point of contact. TRACI includes one example project, called Lithography vs. Web Letterpress Printing, with fictitious data for illustration purposes only. The inventory data contained within this project were randomly selected and are not in any way related to the actual resources/releases associated with lithography or web letterpress printing.

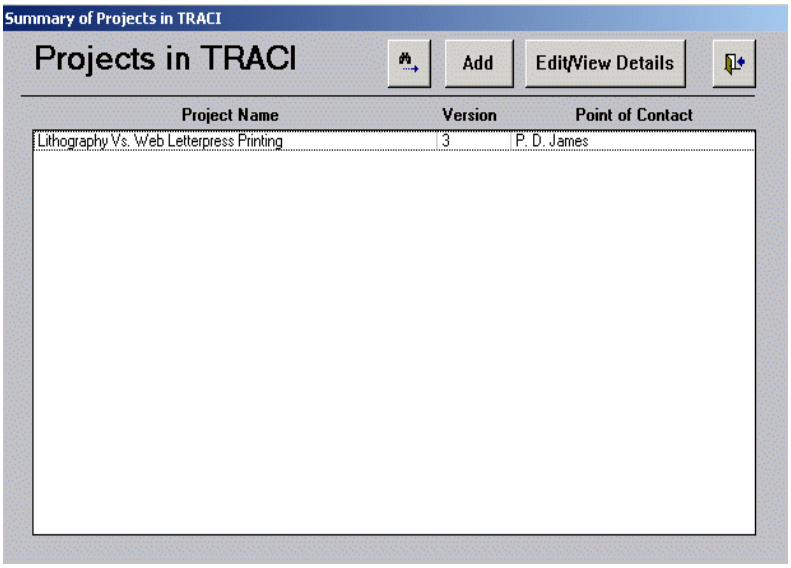

Figure 2-6. Projects in TRACI

The following sections describe the features of this screen.

2.7.2 Add New Project Description

To add a new project, click **Enter/Edit LCI Data** on the *Main Menu*. Then, click **Add** on the *Projects in TRACI* screen and a blank form will appear where the appropriate data can be entered (*see below*). Follow the steps outlined below to complete the form.

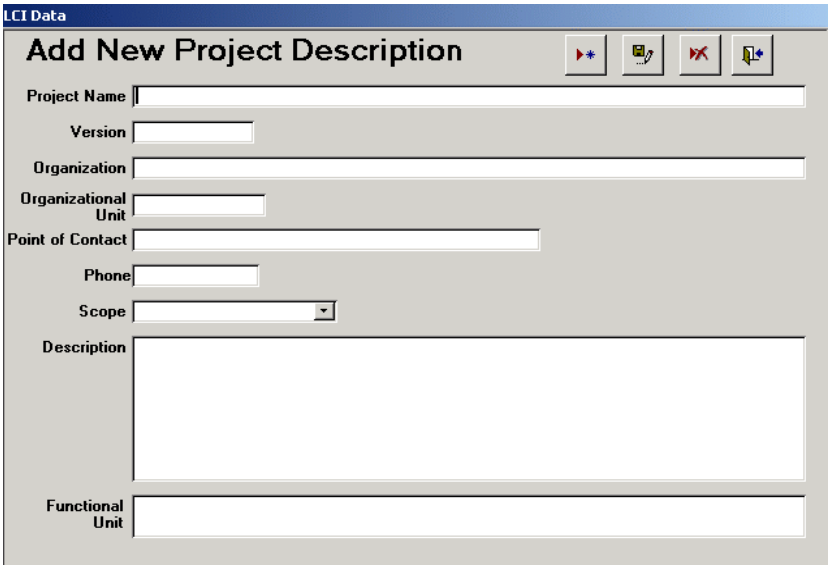

Figure 2-7. Add New Project Description

1. Enter the project name. It is recommended that project names are kept short so they can be easily identified when viewing the results.

2. Enter the version number. You may have multiple versions of a project if you make updates or changes.

3. Enter the organization name (name of the organization or company performing the LCA) and the organizational unit (i.e., environmental, accounting, etc.).

4. Enter the point of contact and his/her phone number so that he/she may be reached if there are questions regarding the project.

5. Select the scope of the project from the drop down list: cradle to grave, cradle to entry gate, entry gate to exit gate, or exit gate to grave.

    - **Cradle to grave** includes all product stages from raw materials acquisition to waste disposal.
    - **Cradle to entry gate** assesses just the upstream suppliers and transportation before the product reaches your company.
    - **Entry gate to exit gate** assesses the product only during the time it is at your facility.
    - **Exit gate to grave** analyzes the product from the time it leaves your facility to the time at which it is disposed.

6. Enter the description of the project. The description should include any assumptions used when conducting the project and the goal of the project.

7. Enter the functional unit of the project. The functional unit is defined as the basis for defining the data in the project. For example, you could collect inventory data for the production of 5,000 glass bowls, or 10,000 books. Or, you might define functional unit in terms of the dollar value of production. Regardless of how you define "functional unit," you should be consistent.

8. Click  to save the entered information.

When you have completed entering the project description, you can:

$ Add another new project by clicking  . Then, repeat Steps 1 through 8.

$ Delete a project by clicking  . **Caution:** Deleting a project will include the deletion of any products, life cycle stages, processes, and resources/releases within the project.

Note: After adding a new project, the next step is to add a new product (*see Section 2.7.6*).

$ Add a new product. First, close the form by clicking  and then turn to Section 2.7.6 for step-by-step instructions on how to enter a product.

$ Return to the *Projects in TRACI* screen by clicking  .

$ Return to the *Main Menu* by clicking  twice.

2.7.3 Edit/View an Existing Project Description

To edit or view an existing project description, click **Enter/Edit LCI Data** on the *Main Menu*. On the *Projects in TRACI* screen (*see Figure 2-6*), select a project name and click **Edit/View Details**. The project description will appear.

As an example, click on the Lithography vs. Web Letterpress Printing project name and then click on **Edit/View Details**. The project description includes the project name, the version number, the company/organization name, the organizational unit, the point of contact and his/her phone number, the scope, the description which includes the purpose and assumptions made, and the functional unit. For further details on each field, see Section 2.7.2.

Caution: The delete function will delete the entire project and all of its corresponding products, life cycle stages, processes, and inventory data. Deleted data cannot be recovered.

$ Edit the project description and then click  to save any changes.

$ Delete a project by clicking  . See cautionary note to the left.

$ Close the form and return to the *Projects in TRACI* screen by clicking  or return to the *Main Menu* by clicking  twice.

2.7.4 Find a Project

To conduct a search for a particular project in TRACI, click **Enter/Edit LCI Data** on the *Main Menu*. Then click  on the *Projects in TRACI* screen. This feature will be most useful once you have many projects contained within TRACI.

Figure 2-8. Find Project

1. Type in the project name or use the pull down menu to select the project you would like to view.

2. Click **Find** and TRACI will highlight the project on the *Projects in TRACI* screen.

3. Click **Edit/View Details** to see the project description (*see Section 2.7.3*).

2.7.5 View Product List and Related Projects

To view the product list and list of related projects, click **Enter/Edit LCI Data** on the *Main Menu*. Then, select a Project Name on the *Projects in TRACI* screen and its list of products and related projects will automatically appear (*see Figure 2-9*).

As an example, highlight the Lithography vs. Web Letterpress Printing project. The Product List will show the following products: Lithographic printed magazine and Web letterpress printed magazine.

$ To add a new product, see Section 2.7.6.

$ To view or edit an existing product, see Section 2.7.7.

$ To add or edit related projects, see Section 2.7.17.

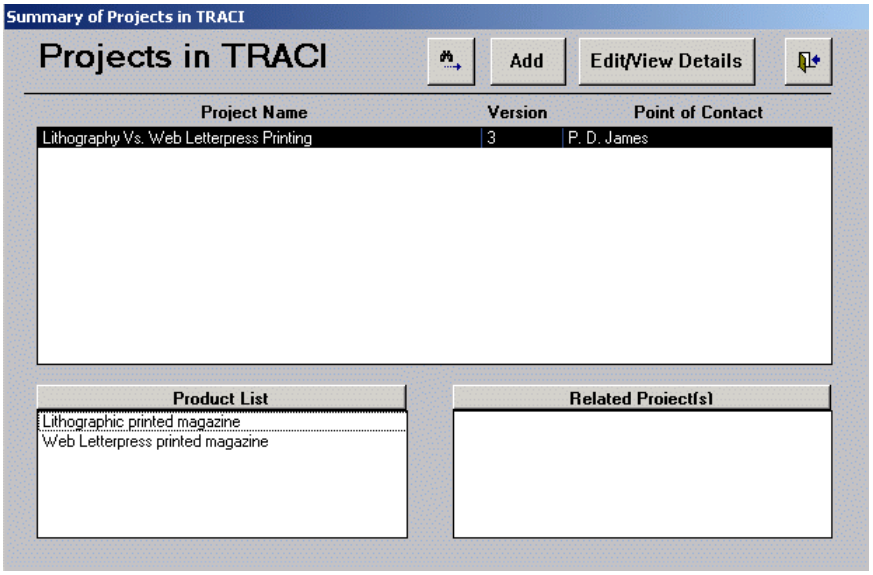

Figure 2-9. Projects in TRACI with Details

2.7.6 Add a New Product

To add the first new product to TRACI, click **Enter/Edit LCI Data** on the *Main Menu*. Select the project name under which the product will be added. Then, click the **Product List** button.

To add a new product to a project under which there is already an existing product, double click on the existing product name. Then, click  and the following screen will appear.

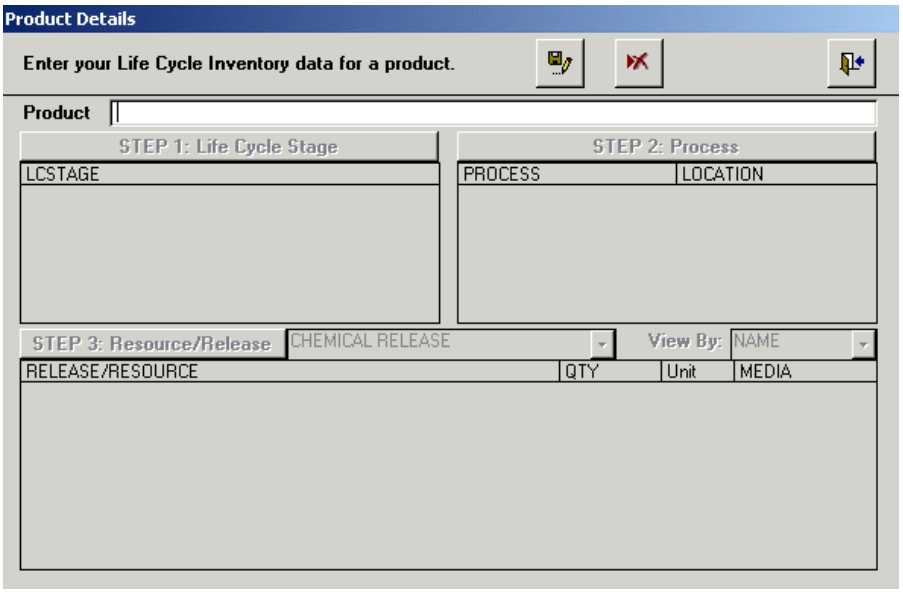

Figure 2-10. Add a New Product

Enter the name of the product and click . The Steps 1 through 3 will become enabled. There are three main steps involved in entering product data:

1. Step 1 is to add life cycle stages (*see Section 2.7.8*).
2. Step 2 is to add processes (*see Section 2.7.9*).
3. Step 3 is to add resources/releases (*see Section 2.7.11*).

2.7.7 Edit/View an Existing Product

To edit or view an existing product in TRACI, click **Enter/Edit LCI Data** on the *Main Menu*. On the *Projects in TRACI* screen, select the project name under which the product is listed. Then, double click on the product name under the Product List.

As an example, select the Lithography vs. Web Letterpress Printing project from the *Projects in TRACI* screen. Then, double click on Lithographic printed magazine. The following screen will appear.

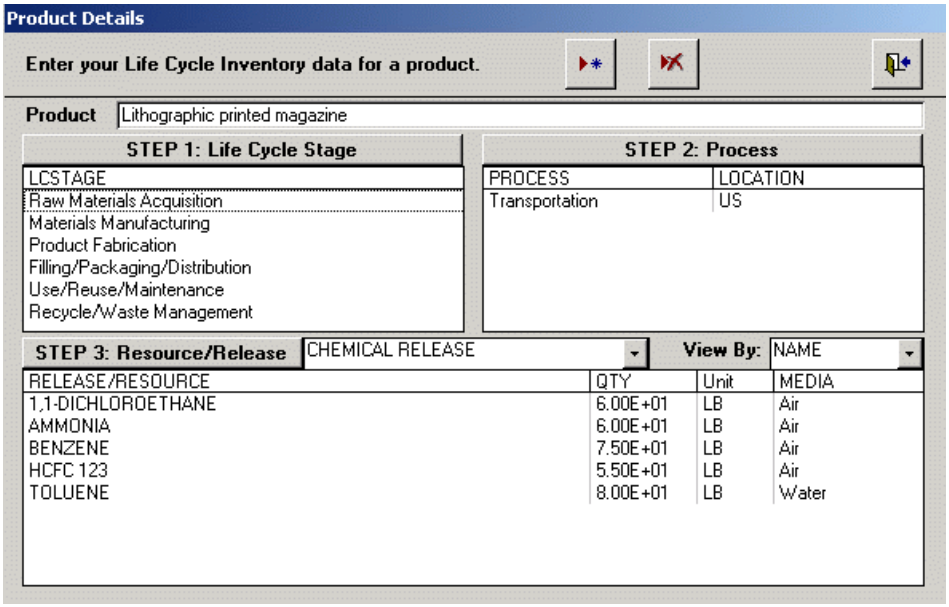

Figure 2-11. Edit an Existing Product

From this screen, there are three main functions:

$ Edit/view the list of life cycle stages (*see Section 2.7.8*).

$ Edit/view the list of processes (*see Section 2.7.10*).

$ Edit/view the list of resources/releases (*see Section 2.7.13*).

Caution: The delete function will delete the entire product and all of its corresponding life cycle stages, processes, and inventory data. If you delete the name of the product and hit save, you have deleted the product. You cannot save a product without a name.

This screen also enables you to:

$ Add a new product by clicking  (*see Section 2.7.6*).

$ Delete a product by clicking  . See cautionary note to the left.

$ Close the form and return to the *Projects in TRACI* screen by clicking  or return to the *Main Menu* by clicking  twice.

2.7.8 Add/Edit Life Cycle Stages

To add or edit life cycle stages for an existing product, click **Enter/Edit LCI Data** on the *Main Menu*. Select an existing project on the *Projects in TRACI* screen. Double click the product name on the Product List. Then, click the **Step 1: Life Cycle Stage** button. The following screen will appear.

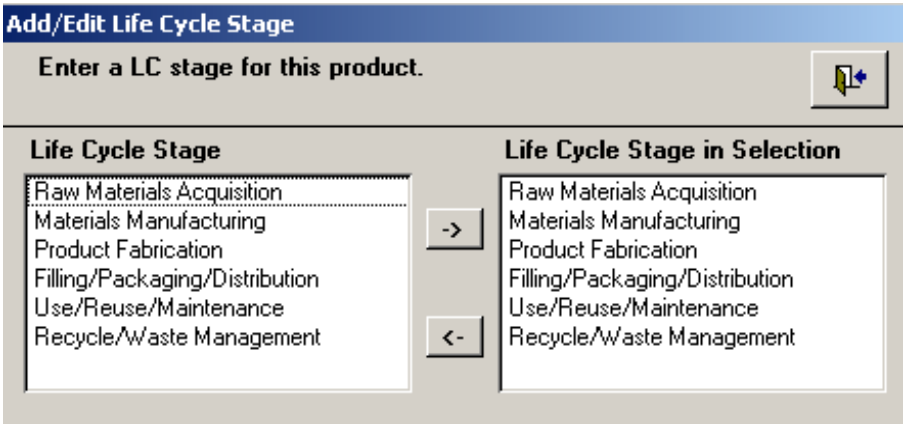

Figure 2-12. Add/Edit Life Cycle Stages

TRACI contains six different life cycle stages: Raw Materials Acquisition, Materials Manufacturing, Product Fabrication, Filling / Packaging / Distribution, Use / Reuse / Maintenance, and Recycle / Waste Management. This selection list cannot be altered.

From this screen, you can:

$ Add a life cycle stage by selecting an item from the box on the left and clicking the º button. Complete this step for each life cycle stage that is included within your project. To select more than one life cycle stage at once, hold down the control key while selecting items. Then, click the º button.

Caution: When you remove a life cycle stage, all processes and resource/release records associated with that life cycle stage will be deleted.

$ Remove a life cycle stage by selecting an item from the box on the right and clicking the » button. See cautionary note to the left.

$ Close the form and return to the *Projects in TRACI* screen by clicking  or return to the *Main Menu* by clicking  three times.

2.7.9 Add a New Process

To add a new process for an existing product, click **Enter/Edit LCI Data** on the *Main Menu*. Select an existing project on the *Projects in TRACI* screen. Double click the product name on the Product List. Select the life cycle stage under which the process occurs. [*Note: If you have not already entered the life cycle stages for this product, see Section 2.7.8.*] Then, click the **Step 2: Process** button. The following screen will appear.

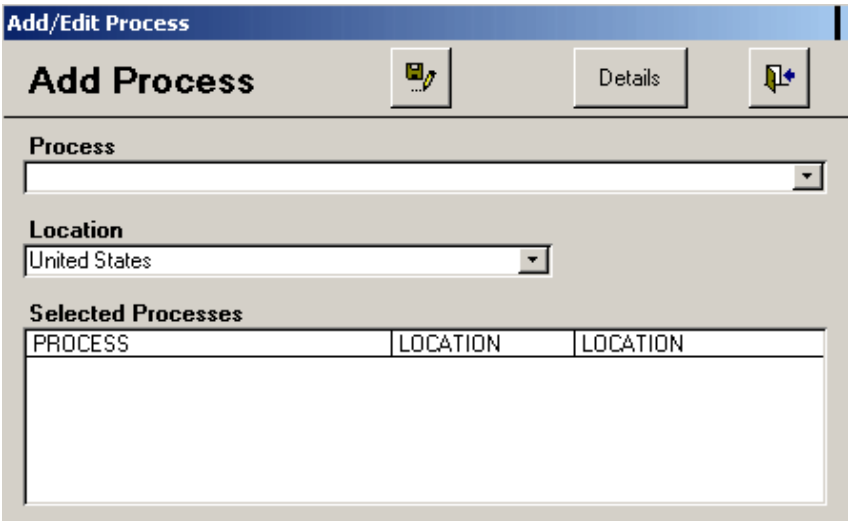

Figure 2-13. Add Process

1. Type in the process name or select one from the drop down list. The drop down list will consist of processes that you have added previously. Process names are user-defined and are permanently added to the process drop down list. Process names cannot be deleted from the drop down list.

2. Select the geographic location at which the resource usage and releases occur by using the drop down list under *Location*. The drop down list contains all fifty states, the four Census regions, Eastern U.S., Western U.S., and the U.S. as a whole. The list also contains all counties in the U.S.

   TRACI enables you to assign a different geographic level for each process. Once you select a process location, all resource usage and chemical releases for that process are assumed to occur in the selected location.

   Although several of TRACI's impact categories only contain U.S. characterization factors, several of the impact indicator models are regionalized (i.e., acidification, photochemical smog, eutrophication, human health criteria and land use). If there is no factor for a particular resource/release for the location specified, TRACI finds the closest available geographic factor for your resources/releases by impact category. For instance, if your process is located in Fairfax County, Virginia, TRACI will determine if there is a county-level characterization factor for each impact category. If there is not, it will check for the following geographic levels for each impact category: state, region, East/West and U.S. For methodologies that do not contain region-specific factors, the U.S. value will be used.

Note: The current version of TRACI does not contain characterization factors for non-U.S. locations. Therefore, if you are analyzing a non-U.S. location, (1) select U.S. since it is the broadest geographic location listed and (2) enter the country name in the process data quality screens. Locations outside of the U.S. may not be suited for the conditions used to develop the TRACI characterization factors.

3. Click  to save the new process.

4. Click the **Details** button to enter data quality information (*see Section 2.7.16*).

5. Click  to close the form and return to the *Product Details* screen (*see Figure 2-11*) or click  three times to return to the *Main Menu*.

2.7.10 Edit/View an Existing Process

To edit or view an existing process for a product, click **Enter/Edit LCI Data** on the *Main Menu*. Select a project on the *Projects in TRACI* screen. Double click the product name on the Product List. Select the life cycle stage under which the process occurs. Then, double click the process name for the process that you want to edit/view.

Note: Don't forget to select the life cycle stage first in order to view its list of processes.

As an example, select the Lithography vs. Web Letterpress Printing project from the *Projects in TRACI* screen. Then, double click on Lithographic printed magazine. Select the Use/Reuse/Maintenance life cycle stage. Double click on the Paper Use process. The following screen will appear.

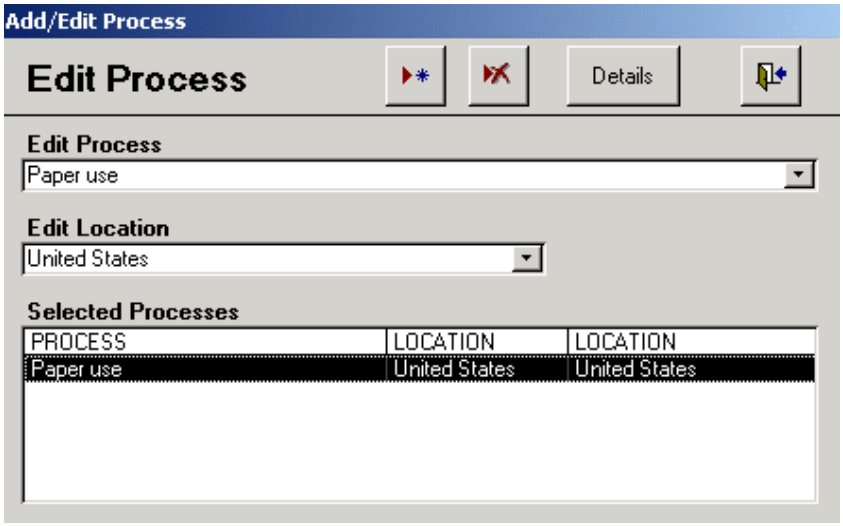

Figure 2-14. Edit Process

From this screen, you can:

- Edit a process name by clicking on the name of the process you would like to edit in the box at the bottom of the screen. Then, that process name will appear automatically under *Edit Process*. You can edit the name or select a different process name from the drop down list.

Caution: This button will delete the entire process and all of its related resource/release inventory data.

- Edit a process location by clicking on the name of the process you would like to edit in the box at the bottom of the screen. Then, change the location of the process by using the drop down list under *Edit Location*.
- Add a new process by clicking  (*see Section 2.7.9*).
- Delete a process by clicking on the name of the process you would like to delete in the box at the bottom of the screen. Then, click  .
- Add or edit information on data quality by clicking **Details** (*see Section 2.7.16*).
- Return to the *Product Details* screen by clicking  .

2.7.11 Add a New Resource/Release

To add inventory data (resources and releases) to an existing product, click **Enter/Edit LCI Data** on the *Main Menu*. Select the project on the *Projects in TRACI* screen. Double click the product name on the Product List. Select the life cycle stage and the process under which the resource usage and releases occur. Then, click the **Step 3: Resource/Release** button.

If there are no resources/releases already entered for this process, the following screen will appear.

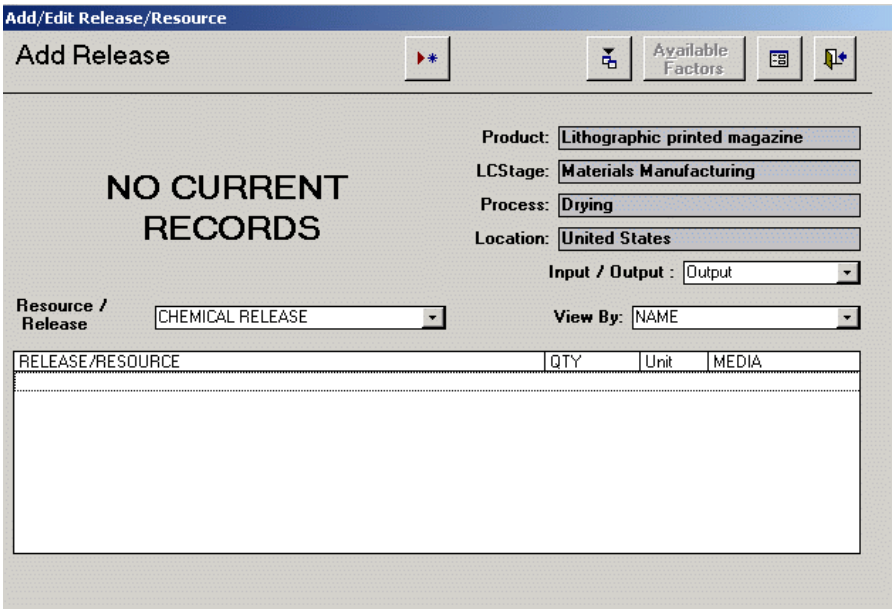

Figure 2-15. Add Release

However, if you have previously entered resources/releases for this process, the *View Release* screen will appear (*see Figure 2-16*). To add a resource/release from the *View Release* screen, click  .

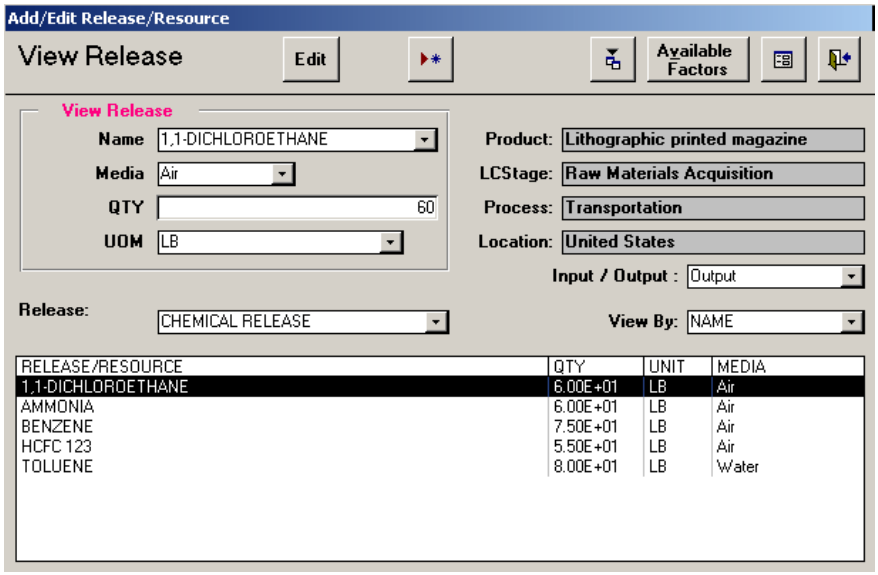

Figure 2-16. View Release

The name of the product, life cycle stage, process, and location which you selected on the previous screen are shown.

Select whether you would like to add an Input (Resource) or Output (Release).

- If you select **Output**, chemical releases can be viewed by name or Chemical Abstract Service (CAS) number by using the *View By* drop down list.

- If you select **Input**, you must select the type of resource you would like to add (land use, fossil fuel, or water use) from the *Resource/Release* drop down list.

The following sections provide detailed data entry instructions for resources and releases.

Add a New Chemical Release (Output)

Chemical releases can be viewed by name or Chemical Abstract Service (CAS) number. Many chemicals have several synonyms, therefore it may be easier to locate a chemical on the list by searching for its CAS number.

1. On the *Add Release* screen, click .

2. In the *Name* field, select a chemical from the drop down list or begin typing the name (or CAS number) of the chemical and the one that most closely matches by name (or CAS number) will automatically appear.

The list only contains chemicals that contribute to the impact categories used in TRACI. You cannot add chemicals that are not on TRACI's list because they will *not* be factored into the impact assessment.

Note that if you are unable to find a chemical on TRACI's list this means that the chemical's characterization factor is currently unknown or it is not included within TRACI's methodologies. Chemicals not within TRACI's list should *not* be assumed to have no environmental impact.

3. In the *Media* field, select the media to which the chemical was released: air or water. It is important that you choose the correct media for each chemical. If the incorrect media is chosen, then either no characterization value or an incorrect characterization value will be used. It is recommended that you check to make sure that all chemical releases have characterization values in TRACI (*see Section 2.7.14*).

4. In the *QTY* field, enter the numerical quantity of the chemical release.

5. In the *UOM* field, select the unit of measurement from the drop down list: gram (g), kilogram (kg), pound (lb), or milligram (mg). TRACI will automatically convert all units for chemical releases into pounds.

6. Click  to save the information.

Add Land Use Data

1. On the *Add Release* screen, select **Input** from the *Input/Output* drop down list.

2. Select **Land Use** from the *Resource/Release* drop down list.

3. Click  to add land use data.

4. In the *Name* field, select **Area of Land Impacted by Human Activity**. The area of land impacted by human activity represents the amount of land converted from natural function to human activity.

5. In the *Media* field, select **No Media**.

6. In the *QTY* field, enter the numerical quantity of land converted.

7. In the *UOM* field, select the unit of measurement from the drop down list: square miles (sq.mi), acres, square feet (sq.ft), or square kilometers (sq.km). For land use, TRACI will automatically convert all units into square miles.

8. Click  to save the information.

Add Fossil Fuel Use Data

1. On the *Add Release* screen, select **Input** from the *Input/Output* drop down list.

2. Select **Fossil Fuel** from the *Resource* drop down list.

3. Click  to add fossil fuel use data.

4. In the *Name* field, select the type of fossil fuel from the drop down list: natural gas, oil, or hard coal, open pit mining.

5. In the *Media* field, select **No Media**.

6. In the *QTY* field, enter the numerical quantity of fossil fuel used during the process.

7. In the *UOM* field, select the unit of measurement from the drop down list. For natural gas, the options are mega joules (MJ), standard cubic foot (scf), and cubic meter (M^3). For oil, the unit of measurement is mega joules (MJ). For hard coal, open pit mining, the options are pounds (lb), short ton, kilograms (kg), or mega joules (MJ). For natural gas, oil and hard coal, units will be automatically converted to mega joules (MJ).

Add Water Use Data

1. On the *Add Release* screen, select **Input** from the *Input/Output* drop down list.

2. Select **Water Use** from the *Resource* drop down list.

3. Click  to add water use data.

4. In the *Name* field, select **Water Use**.

5. In the *Media* field, select **No Media**.

6. In the *QTY* field, enter the numerical quantity of water used during the process.

7. In the *UOM* field, select the unit of measurement from the drop down list: liters (L) or gallons (gal). TRACI will automatically convert all units to gallons.

2.7.12 Importing Releases

Chemical releases can be imported into TRACI as a comma delimited text file (.csv). First, you must arrange your data file to match the layout of data within TRACI so that it will import correctly. This step is very important. If the instructions are not followed carefully, data may not be imported properly.

In the table you are importing, the columns should appear in the following order: chemical, CAS number, media, quantity, and unit of measurement. Do NOT skip any columns. The column structure must remain the same. Be sure to create a header row with the exact column headings shown in Table 2-1.

Chemical	CASNumber	Media	QTY	UOM
Carbon Dioxide	124-38-9	Air	4.00E+02	lb

Table 2-1. Preparing Import Table

Resources such as fossil fuels, land use, or water use cannot be imported. Resources must be entered manually.

The import feature is designed to compare each CAS number in your import spreadsheet with the list of CAS numbers in TRACI. If a match is found, the chemical will be imported. If no match is found or if there is no CAS number for the chemical, the import feature will then compare the chemical name against the list of chemicals in TRACI. If no match is found, the chemical will not be imported.

Column 1 (Chemical) should contain the chemical name. TRACI will automatically convert the chemical names in your import file to capital letters in order to match them with TRACI's list of chemicals. You must list a chemical name for each entry.

Note: Inclusion of CAS numbers within your import file will increase the likelihood of TRACI finding a match on its list of flows.

Column 2 (CASNumber) should contain the CAS number. You can easily obtain the CAS number for a chemical by visiting http://www.chemfinder.com. This field may be left blank if the chemical does not have a CAS number of if you are unable to determine a CAS number. Inclusion of CAS numbers in your spreadsheet will increase the likelihood of TRACI finding a match on its list of flows.

Column 3 (Media) should contain the media to which the chemical was released. The media must be either "air" or "water."

Column 4 (Qty) should contain the quantity of chemical released. The quantity must be in numerical form.

Column 5 (UOM) should contain the unit of measurement. Enter the abbreviation for the appropriate unit of measurement. For chemical releases, TRACI can import the following units: pound (lb), kilogram (kg), milligram (mg), and gram (g). All units for chemical releases will be converted into pounds (lb) prior to the characterization calculations.

Once you have finished preparing your table, save the file as a comma delimited file with the extension .csv. If you are using a MS Excel file, click **Save As** from the File menu. Change the file type to .csv (comma delimited text file).

1. From the *Main Menu*, click on **Enter/Edit LCI Data**. Select the product for which you are importing the data. Then, select the Life Cycle Stage and the Process to which this data relates. Click the **Step 3: Resource/Release**

button on the *Product Details* screen. The *Add Release* or *View Release* screen will appear (*see Figures 2-15 and 2-16*).

2. Click  to import your data file. The *Data Import Wizard* screen will appear.

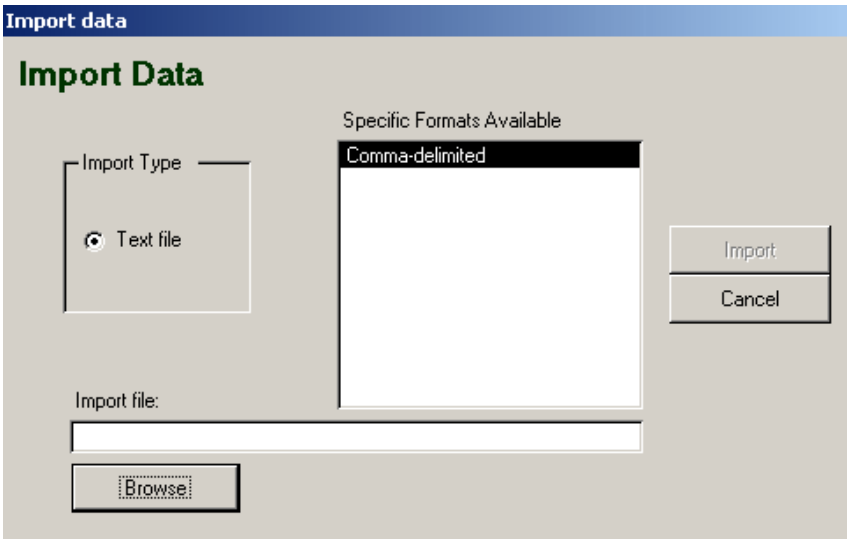

Figure 2-17. Import Data

3. To select the Import Type, click on the **Text File** option.

4. In the Specific Formats Available box, click on **Comma-delimited**.

5. The browse button will become active. Click on **Browse** and locate the file you would like to import. You may need to change the *Files of type* box to "text files."

6. Once you have located your file, click on **Save**. Your file's location will be displayed on the *Import Wizard* screen.

7. Click on **Import**.

8. A system message will appear stating "Import Complete." Click **OK**. The chemicals should now appear in the list of releases. These will be saved automatically.

2.7.13 Edit/View Resources and Releases

To edit or view inventory data (resources and releases) for an existing product, click **Enter/Edit LCI Data** on the *Main Menu*. Select the project on the *Projects in TRACI* screen. Double click the product name on the Product List. Select the life cycle stage and the process under which the resource usage and releases occur. At the bottom of the *Product Details* screen, you can view the resources and releases for the selected process. Then, click the **Step 3: Resource/Release** button.

As an example, select the Lithography vs. Web Letterpress Printing project from the *Projects in TRACI* screen. Then, double click on Lithographic printed magazine. Select the Raw Material Acquisition life cycle stage and the Transportation process. Click the **Step 3: Resource/Release** button and the following screen will appear.

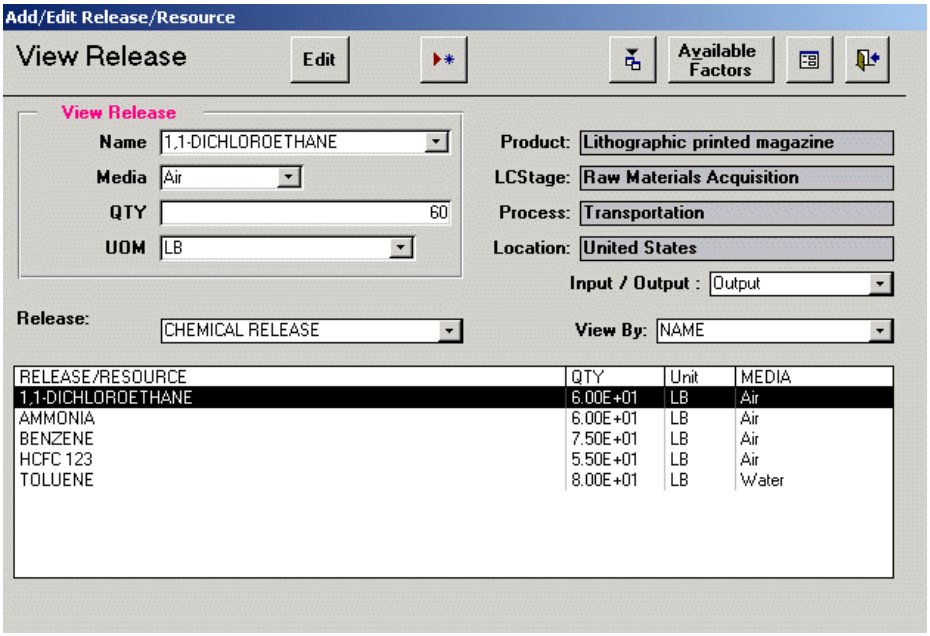

Figure 2-18. View Release

This screen shows the product name, life cycle stage, process, and location that you selected on the previous screen. Since these are pre-selected, they cannot be changed on this screen. To view resources/releases for a different process, return to the *Product Details* screen.

1. Select **Input** from the *Input/Output* drop down list to view resources. Select **Output** to view releases.

2. If you selected **Input**, select one of the following three resources (land use, fossil fuel use, or water use) from the *Resource* drop down list.

   If you selected **Output**, select whether you would like to view chemicals by name or CAS number from the *View By* drop down list.

TRACI will display the resource or release data based on your selections.

This screen contains several features:

$ Edit a chemical by selecting it in the box at the bottom of the screen and clicking **Edit**. The chemical name, media, quantity, or unit of measurement can be changed. Click  to save the changes. If you determine that no changes need to be made, click **View**.

$ Delete a resource/release by selecting it in the box at the bottom of the screen and clicking **Edit**. Click  to delete the chemical.

$ Add a new resource/release by clicking  (*see Section 2.7.11*).

$ Import a list of chemicals by clicking  (*see Section 2.7.12*).

$ View a list of available characterization factors for a selected resource/release by clicking **Available Factors** (*see Section 2.7.14*).

$ View TRACI's characterization factors by impact category by clicking  (*see Section 2.7.15*).

$ Close the form and return to the *Product Details* screen by clicking  .

2.7.14 View Available Factors

Note: TRACI's characterization factors quantify the magnitude of the potential impacts of each inventory flow.

To view available characterization factors for a particular resource/release, click **Enter/Edit LCI Data** on the *Main Menu*. Then, follow the instructions provided in Section 2.7.13 on how to Edit/View Resources and Releases. Once you have selected a particular resource or release, click the **Available Factors** button (*see Figure 2-16*).

As an example, select the Lithography vs. Web Letterpress Printing project from the *Projects in TRACI* screen. Then, double click on Lithographic printed magazine. Select the Raw Material Acquisition life cycle stage and the Transportation process. Click the **Step 3: Resource/Release** button. Select **1,1-Dichloroethane** in the box at the bottom of the screen and click the **Available Factors** button. The following screen will appear.

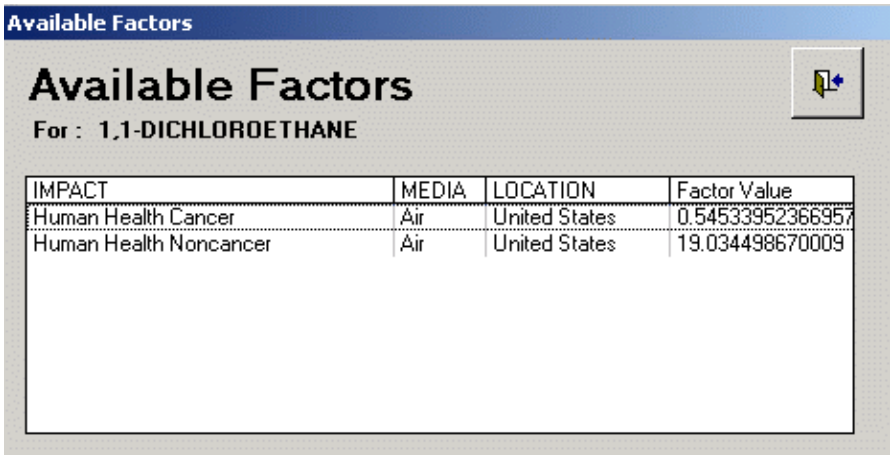

Figure 2-19. Available Factors

As discussed in Section 2.7.9, some of TRACI's impact categories contain location-specific characterization factors. For example, the land use impact category has characterization factors at the county, state, Census region, East/West of the Mississippi, and U.S. level, whereas the global warming impact category only has characterization factors at the U.S. level.

TRACI finds the geographically closest characterization factor for each resource and release by impact category. For instance, if your process is located in Fairfax County, Virginia, TRACI will determine if there is a county-level characterization factor for each impact category. If there is not, it will check for the following geographic levels: state, region, East/West and U.S. As a result, TRACI may use a county-level characterization factor for land use impacts and a U.S. characterization factor for global warming impacts.

The purpose of the *Available Factors* screen is to display which characterization factor(s) will be used for a particular resource/release. This screen shows the factor(s) that TRACI will use in the characterization calculations, based on the location and media previously selected. This screen should be used to ensure that all resources/releases you have inputted have a characterization factor in TRACI. For instance, if you specify a media for a resource/release that does not have a corresponding characterization factor, TRACI will not include the resource/release in the subsequent data processing steps. It is recommended that you check the list of available factors for each resource/release. A factor will be shown for each impact category to which the resource/release contributes. Therefore, if a chemical has the potential to impact both photochemical smog and human health cancer, two characterization factors will be shown.

Figure 2-19 shows that a release of 1,1-Dichloroethane to air has the potential to impact both the human health cancer and human health noncancer impact categories.

After you have viewed the available factors, click  to close the form and return to the *View Release* screen.

2.7.15 View TRACI's Characterization Factors

To view TRACI's list of characterization factors, click **Enter/Edit LCI Data** on the *Main Menu*. Then, follow the instructions provided in Section 2.7.13 on how to Edit/View Resources and Releases. On the *View Release* screen (*see Figure 2-16*), click  and the following screen will appear.

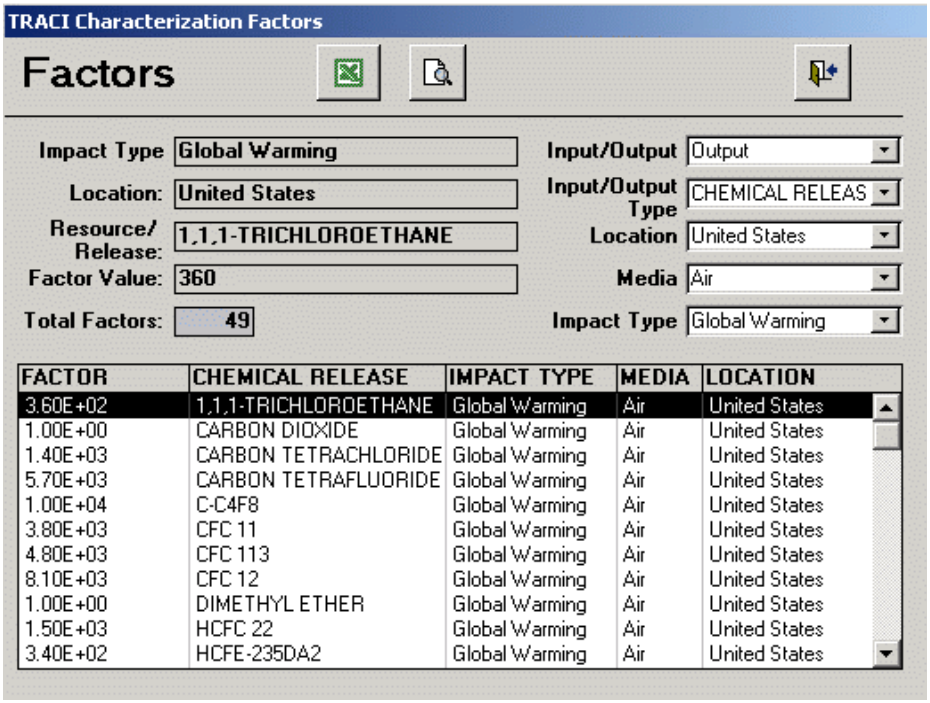

Figure 2-20. TRACI Characterization Factors

The *Factors* screen displays TRACI's characterization factors based on user selections. Use the drop down lists on the right side of the screen to make your selections.

1. In the *Input/Output* field, select **Input** to view resources or select **Output** to view chemical releases.

2. In the *Input/Output Type* field, if you selected **Input** in Step 1, select a resource usage impact category: Land Use, Fossil Fuel or Water Use. If you selected **Output** in Step 1, the default will be Chemical Release.

3. In the *Location* field, select a location from the drop down list. The default is the United States; however, the list contains regions, states, and counties. The location drop down list will be based on the select Impact Type.

4. In the *Media* field, select **Air** or **Water** for chemical releases. There is no media selection for Inputs (resources).

5. In the *Impact Type* field, select one of the impact categories: global warming, acidification, eutrophication, ozone depletion, ecotoxicity, human health cancer, photochemical smog, human health noncancer, human health criteria. There is no selection required when viewing Inputs (resources).

The fields on the upper lefthand side will be updated based on the user selections.

This screen contains several features:

- Click  to view or print a report of the selected characterization factors.

- Click  to export the selected characterization factors. The table will automatically be exported to a Microsoft Excel file on your hard drive (C:\TRACI folder). The export file name will be TRACI_Factors_1.xls. TRACI enables the user to export multiple groups of characterization factors. Each time factors are exported, the file name will increase incrementally by one.

- Click  to close the form and return to the *View Release* screen.

2.7.16 Enter Process Details

To enter process details for a particular process, click **Enter/Edit LCI Data** on the *Main Menu*. Select a project on the *Projects in TRACI* screen. Double click the product name on the Product List. Select the life cycle stage under which the process occurs. Then, double click the process name for the process that you want to edit/view. The *Add/Edit Process* screen will appear (*see Figure 2-14*). Click on **Details** to enter the process details.

The screen related to process details can be used to maintain process information and data quality information for inventory data that are entered into TRACI. However, this information is not used in any calculations and is therefore, not required.

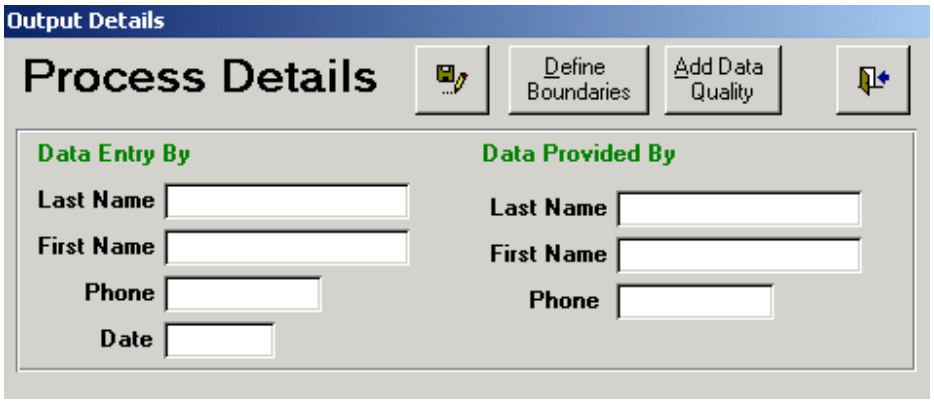

Figure 2-21. Process Details

1. Enter the name and phone number of the data entry person and the date on which the data were entered.

2. Enter the name and phone number of the person who provided the data (e.g., point of contact).

3. Click  to save your data.

4. Click **Define Boundaries** to add more information about the process.

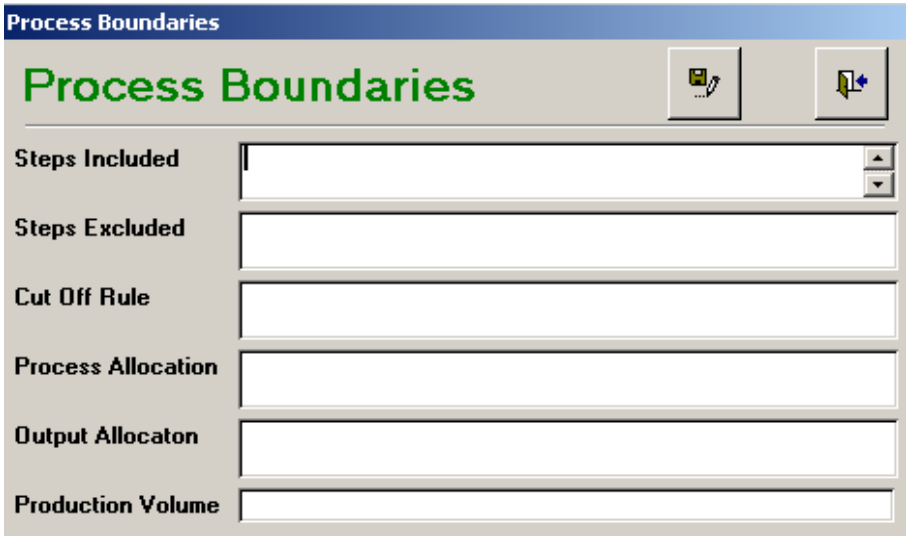

Figure 2-22. Process Boundaries

5. Enter the **Steps Included**. Which specific steps did you include in the process boundaries?

6. Enter the **Steps Excluded**. Which steps did you exclude?

7. Enter the **Cut Off Rule**. You only included releases that account for _____ percentage of raw material usage.

8. Enter the **Process Allocation**. How did you allocate materials/wastes from a process line that produces multiple products?

9. Enter the **Output Allocation**. How did you allocate a waste stream to the different media?

10. Enter the **Production Volume**. What percentage of the total production volume does this entry represent?

11. Click  to save your information.

12. Click  to close the form and return to the *Process Details* screen *(see Figure 2-21*).

13. Click **Add Data Quality** on the *Process Details* screen.

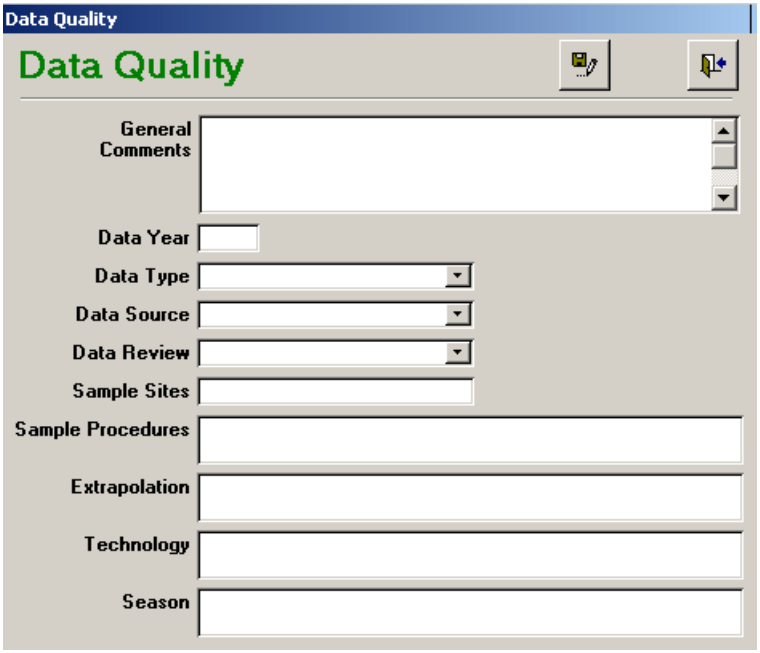

Figure 2-23. Data Quality

14. Enter **General Comments**. Include any general comments on data quality.

15. Enter the **Data Year**. What year were the data collected?

16. Enter the **Data Type**. Were the data primary data (collected on-site) or secondary data (collected off-site)? Select from the drop down list.

17. Enter the **Data Source**. What was the source of the data? Select from the drop down list: measured, calculated, estimated, mixed or unknown.

18. Enter the **Data Review**. Who reviewed the data? Select from the drop down list: third party, external, internal, none, or unknown.

19. Enter the **Sample Sites**. How many sites were sampled?

20. Enter the **Sampling Procedures**. Describe sampling procedures used to collect data (i.e., grab, continuous, etc.).

21. Enter the **Extrapolation**. Were data extrapolated from another data source?

22. Enter the **Technology**. Assess the type of technology used in the process.

23. Enter the **Season**. During what season were the data collected?

24. Click  to save the data quality information.

25. Click  to close the form and return to the *Process Details* screen.

2.7.17 Add/Edit Related Projects

To add or edit the list of related projects, click **Enter/Edit LCI Data** on the *Main Menu*. Then, select a Project Name on the *Projects in TRACI* screen and its list of related projects will automatically appear (*see Figure 2-9*). Click on the **Related Project(s)** button and the following screen will appear.

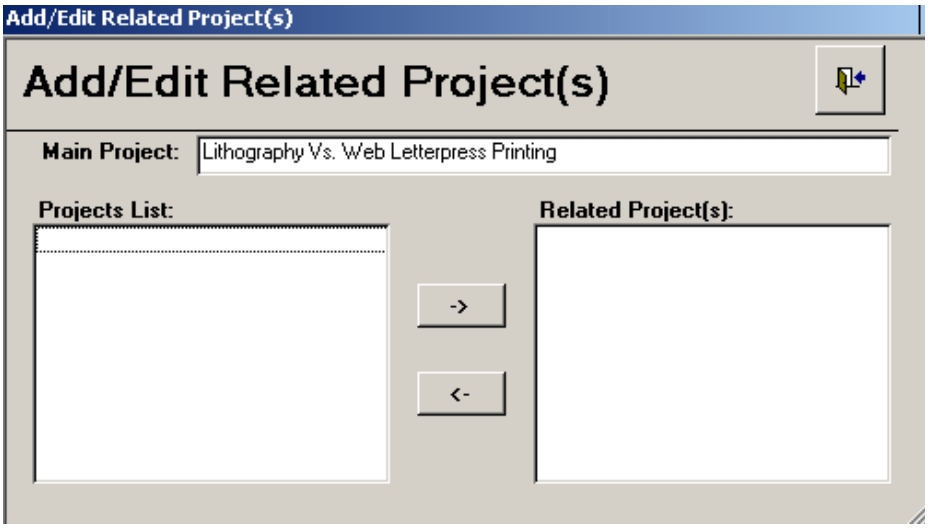

Figure 2-24. Add/Edit Related Project(s)

By using the *Related Projects* screen, you can link the names of existing projects that are associated with one another. For example, you might define a project for evaluating the impacts associated with the manufacture of a boat engine. You might define other projects to more fully evaluate the impacts for particular boat engine parts. TRACI enables you to list these two projects as related projects; however TRACI does not link the data between these projects.

Hint: To highlight more than one project at once, hold down the control key while selecting projects and then click the **o** arrow or select one project and hold down the left mouse button while moving down the list.

$ To add a related project, select a project from the *Projects List* and click the **o** arrow to add it to the *Related Project(s)* list.

$ To remove a project from the *Related Project(s)* list, select the project name and click the **»** arrow.

$ To close the form and return to the *Projects in TRACI* screen, click .

2.8 Perform Calculations

After you have entered your inventory data (manually or by import), you can run TRACI's calculations. Click **Perform Calculations** from the *Main Menu* and the following screen will appear.

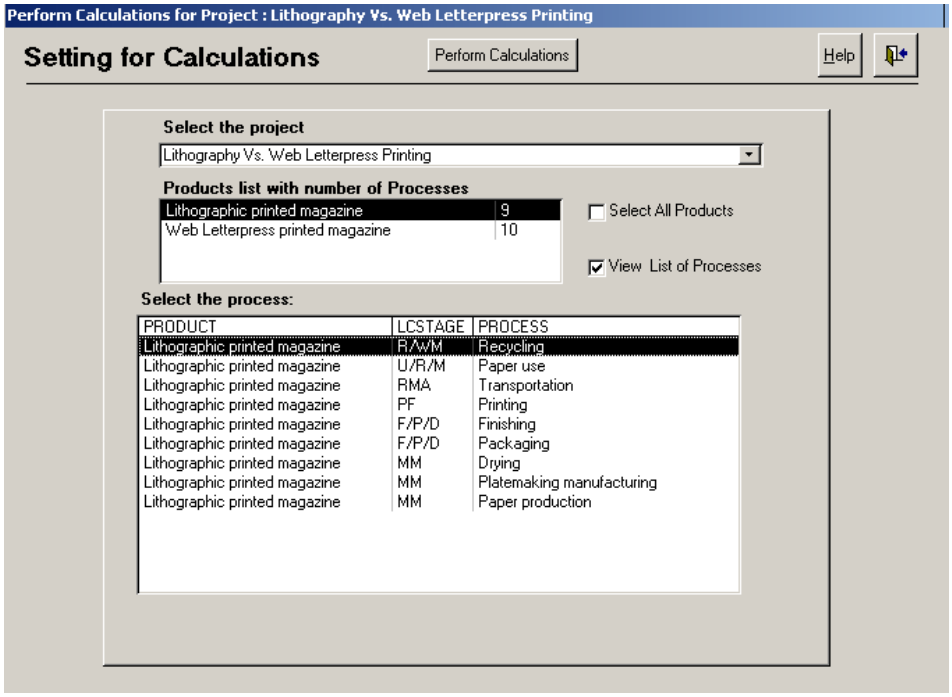

Figure 2-25. Setting for Calculations

2.8.1 Setting for Calculations

1. Select the project you want to analyze from the drop down list. Then, the list of products that correspond with that project will appear.

2. Select one or more products from the Products List by clicking on the product name.

   $ To select multiple products, hold down the control key on your keyboard while clicking on each product name.

   $ Click on the box next to **Select all Products** to select the entire list of products.

3. If you would like to analyze the LCI data at the process level, click the box next to **View List of Processes** to view the list of processes associated with each selected product.

4. If you would like to narrow your results you may select one or more processes. To run the calculations at the product level, de-select the box next to **View List of Processes**.

Note: If a process does not contain any LCI data, it will not be shown on the List of Processes. Calculations can only be performed on processes that contain LCI data.

5. Once you have completed your selections, click **Perform Calculations**.

TRACI will begin calculating the results and forming the tables and graphs. Depending on the number of resources/releases being analyzed, this could take several minutes. A status bar will be displayed to show the progression through the calculations. When the calculations are complete, the *Inventory Results* screen will appear (*see Figure 2-26*).

2.8.2 View the Results

After TRACI completes the calculations, the *Inventory Results* screen will appear. This screen displays the inventory, classification and characterization results based on user selections.

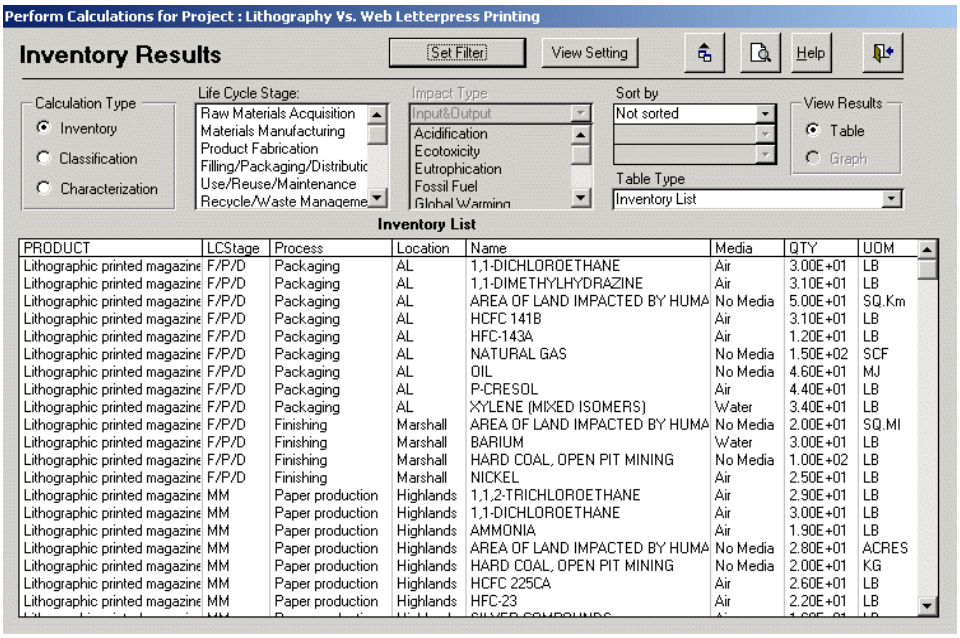

Figure 2-26. Inventory Results

Select a *Calculation Type* from the following list: Inventory, Classification and Characterization. The results table will change based on your selection. There are several different types of tables and graphs available.

Inventory Table

Select **Inventory** from the *Calculation Type* box to view the Inventory List (*see Figure 2-26*). The inventory results contain all of the data you entered or imported into TRACI based on the settings you selected on the *Setting for Calculations* screen. Please note that TRACI only imports chemicals for which it has characterization factors. Therefore, the Inventory Results can be used to compare the list of chemicals imported against your original spreadsheet of LCI data to determine if any chemicals were not imported.

To view results for certain life cycle stages, click on the names of one or more life cycle stages in the *Life Cycle Stage* box. Selecting none is the same as selecting all options. Re-click a life cycle stage to deselect it.

The results can also be sorted by up to three columns. To sort a column, select the column name from the *Sort By* drop down list. To sort by two or more columns, use the two remaining drop down lists to select other columns in the results table. For instance, the user may decide to sort the results by Process, Media, then Quantity.

The *Impact Type* box will be disabled when viewing the Inventory Results. The inventory data is not classified into various impact types until the classification step. To view impact type information, select Classification in the *Calculation Type* box.

To print the Inventory Results, click  to see the Print Preview. When in Print Preview mode, a Print menu will appear at the upper left hand side of the screen. Select **Print** to print the results. The printable report will contain all inventory results (not filtered or sorted).

To export the Inventory Results, click  . The results will automatically be exported to a Microsoft Excel file on your hard drive (C:\TRACI folder). The first export file will be named TRACI_Inventory_1.xls. TRACI allows multiple exports of inventory data. The number in the file name will increase by one each time the inventory results are exported. Note that data will not be sorted or filtered in the export file. However, data can be sorted using MS Excel. Graphs cannot be exported.

Classification Table

In classification, TRACI assigns and aggregates results from the resources/releases inventory into environmental impact categories. Each resource/release is assigned to one or more of the impact categories based on the methodologies in TRACI.

Select **Classification** from the *Calculation Type* box to view the classification table: Classification Results (*see Figure 2-27*).

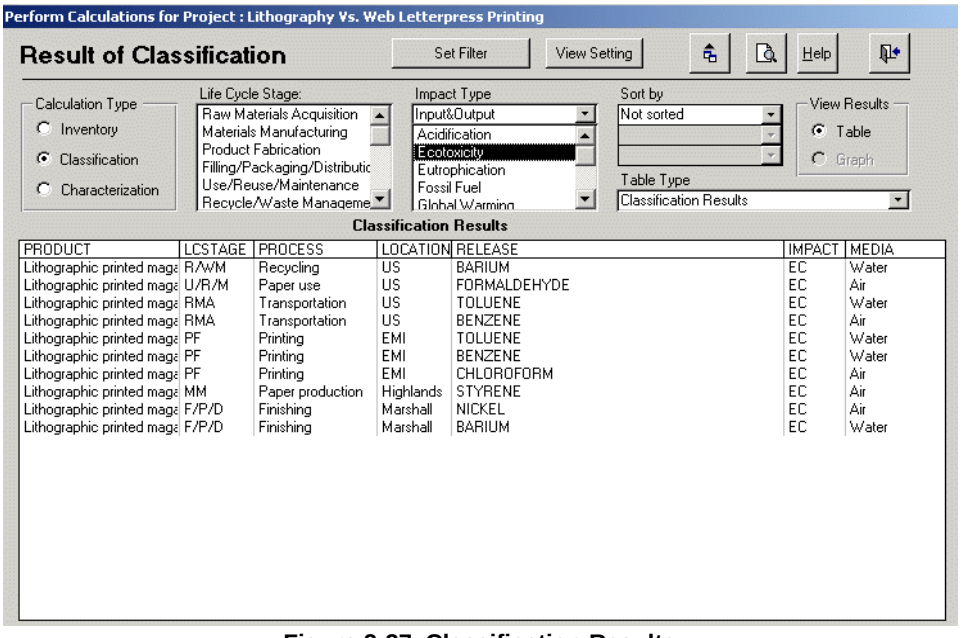

Figure 2-27. Classification Results

For each resource/release, the table shows the associated impact type(s). Note that TRACI will only classify the resource/release if it has a corresponding characterization factor.

To view the classification results for certain life cycle stages, click on the names of one or more life cycle stages in the *Life Cycle Stage* box. Selecting none is the same as selecting all options. Re-click a life cycle stage to deselect it.

To filter the results by impact type, first select one of the following from the *Impact Type* drop down list: Input, Output or Input & Output. Input refers to the resource usage categories: land use, fossil fuel use, and water use. Output refers to all other impact categories. Then, select an impact category in the *Impact Type* box to view results for a specific impact type. For example, if you would like to see only results for ecotoxicity (*see Figure 2-27*), select that category from the list.

The results can also be sorted by up to three columns. To sort a column, select the column name from the *Sort By* drop down list. To sort by two or more columns, use the two remaining drop down lists to select other columns in the results table. For instance, the user may decide to sort the results by Impact Type, Media, then Resource/Release.

To print the Inventory Results, click  to see the Print Preview. When in Print Preview mode, a Print menu will appear at the upper left hand side of the screen. Select **Print** to print the results.

To export the Classification Results, click  . The results will automatically be exported to a Microsoft Excel file on your hard drive (C:\TRACI folder). The first export file will be named TRACI_Classification_1.xls. TRACI allows multiple exports of classification data. The number in the file name will increase by one each time the classification results are exported. Note that data will not be sorted or filtered in the export file. However, data can be sorted using MS Excel. Graphs cannot be exported.

Characterization Tables

In characterization, TRACI multiplies the quantity of the resource/release by the equivalency factor for the corresponding impact categories. For example, carbon dioxide has a characterization value of one for global warming. If your inventory includes carbon dioxide, TRACI multiplies the inputted quantity by the characterization factor. Some chemical releases have characterization factors for more than one impact category. In this case, TRACI multiplies the full quantity by each of the relevant characterization factors.

For characterization, there are four tables: Characterization List, Characterization Crosstable (Resource/Release Level), Characterization Crosstable (Process Level) and Characterization Crosstable (Product Level).

- $ Characterization List - This table presents the product name, life cycle stage, process name, location, resource/release name, impact type, characterized result, unit of measurement, and the media.
- $ Characterization Crosstable (Resource/Release Level) - This table presents the product name, the resource/release names and their characterized results for one product. For this table, you are required to select one impact category from the *Impact Type* box.
- $ Characterization Crosstable (Process Level) - This table shows the characterized results for one or more products broken down to the process level. You must select an impact type from the *Impact Type* box.
- $ Characterization Crosstable (Product Level) - The table sums the characterized results for all the life cycle stages associated with the products. You must select an impact type from the *Impact Type* box.

Select Characterization in the *Calculation Type* box to view the Characterization List table (*see Figure 2-28*). To view one of the other characterization tables, select the table name from the *Table Type* drop down list.

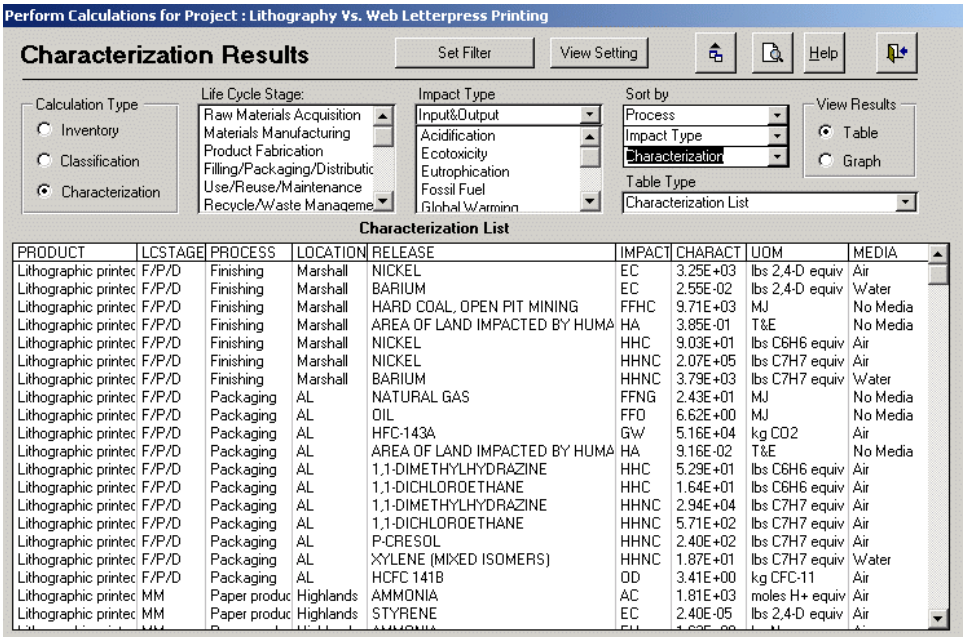

Figure 2-28. Characterization Results

To view the characterization results for certain life cycle stages, click on the names of one or more life cycle stages in the *Life Cycle Stage* box. Selecting none is the same as selecting all options. Re-click a life cycle stage to deselect it.

To filter the results by impact type, first select one of the following from the *Impact Type* drop down list: Input, Output or Input & Output. Input refers to the resource usage categories: land use, fossil fuel use, and water use. Output refers to all other impact categories. Then, select an impact category in the *Impact Type* box to view results for a specific impact type.

The results can also be sorted by up to three columns. To sort a column, select the column name from the *Sort By* drop down list. To sort by two or more columns, use the two remaining drop down lists to select other columns in the results table. For instance, the user may decide to sort the results by Process, Impact Type, and Characterization.

To print the Inventory Results, click  to see the Print Preview. When in Print Preview mode, a Print menu will appear at the upper left hand side of the screen. Select **Print** to print the results.

To export the Characterization Results, click  . The results will automatically be exported to a Microsoft Excel file on your hard drive (C:\TRACI folder). The first export file will be named TRACI_Characterization_1.xls. TRACI allows multiple exports of characterization data. The number in the file name will increase by one each time the characterization results are exported. Note that data will not be sorted or filtered in the export file. However, data can be sorted using MS Excel. Graphs cannot be exported.

Characterization Graphs

There are six characterization graphs: Resources/Releases for One Process, Multiple Products by Life Cycle Stage, Multiple Processes for One Product, Life Cycle Stages for One Product, Resources/Releases for Multiple Processes for One Product and Resources/Releases at the Product Level. These graphs are described in more detail on the next few pages.

1. Select **Characterization** in the *Calculation Type* box to view the characterization results.

2. Select **Graph** from the *View Results* box.

3. Select a graph name from the *Graph Type* drop down list. Note that the drop down list of graphs will change based on the number of products and processes selected on the *Setting for Calculations* screen. Certain graphs are only available when analyzing one product, while others may be available when analyzing two products.

4. Select an impact type from the *Impact Type* box.

5. For certain graphs, you can filter the results based on life cycle stage. Click on the names of one or more life cycle stages in the *Life Cycle Stage* box. Selecting none is the same as selecting all options. Re-click a life cycle stage to deselect it.

To print a graph, click  to see the Print Preview. When in Print Preview mode, a Print menu will appear at the upper left hand side of the screen. Select **Print** to print the results.

Graphs cannot be exported. Please view the characterization tables to export the characterized results.

Characterization of Resources/Releases for One Process

This pie chart shows the relative contribution of individual resources and/or releases at the process level for the selected impact type. The characterized results associated with the selected impact type are displayed for the process selected on the previous screen. You may only view the results for one impact type at a time. For example, if you choose "Human Health Noncancer" from the *Impact Type* list, the resulting graph shows the percentage contribution of each release in the process to the total Human Health Noncancer characterized result. The *Life Cycle Stage* box displays the life cycle stage associated with the process you selected. You cannot change the life cycle stage. This graph is only available when you have selected one process on the *Setting for Calculations* screen or if you selected a product that contains only one process.

Figure 2-29: This graph shows the relative contribution of individual resources and/or releases for an impact type at the process level.

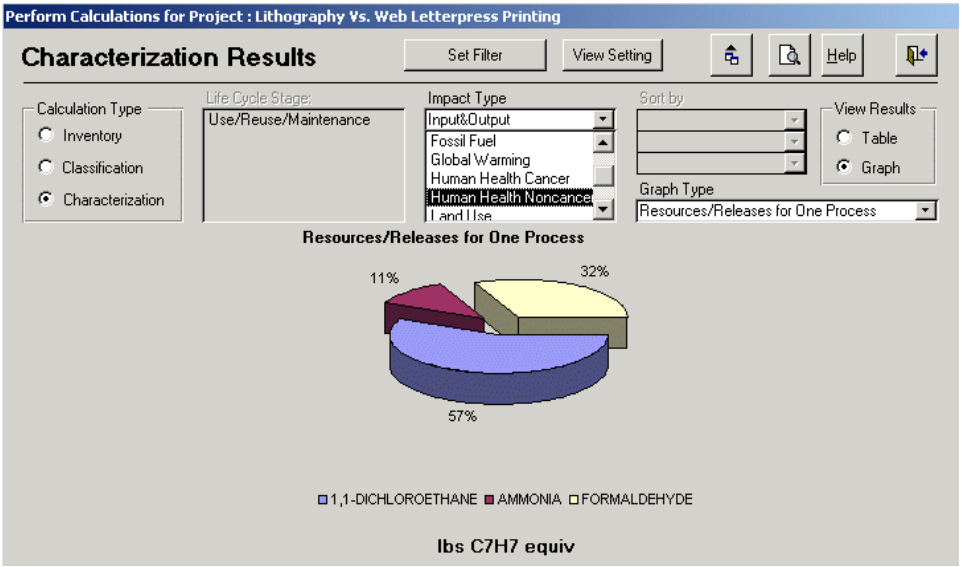

Figure 2-29. Resources/Releases for One Process

Limitations

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will appear.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

$ Since pie charts cannot graph negative numbers, negative LCI data are converted to zero for the purpose of displaying a pie chart. If all LCI data within the process are negative, no graph will appear.

Characterization of Multiple Products by Life Cycle Stage

For multiple products, this pie chart shows the relative potential impact by impact type for one or more life cycle stages. For example, if you choose Eutrophication from the *Impact Type* box and all life cycle stages from the *Life Cycle Stage* box, the graph sums the characterized results for these parameters and displays the resulting percentages. The graph calculates the sum of the characterized results for all of the processes (and associated resources/releases) within the selected life cycle stage(s) and filters the results based on the selected impact type. This graph is only available when two or more products have been selected on the *Setting for Calculations* screen.

Figure 2-30: This graph compares the relative contribution to an impact type for multiple products.

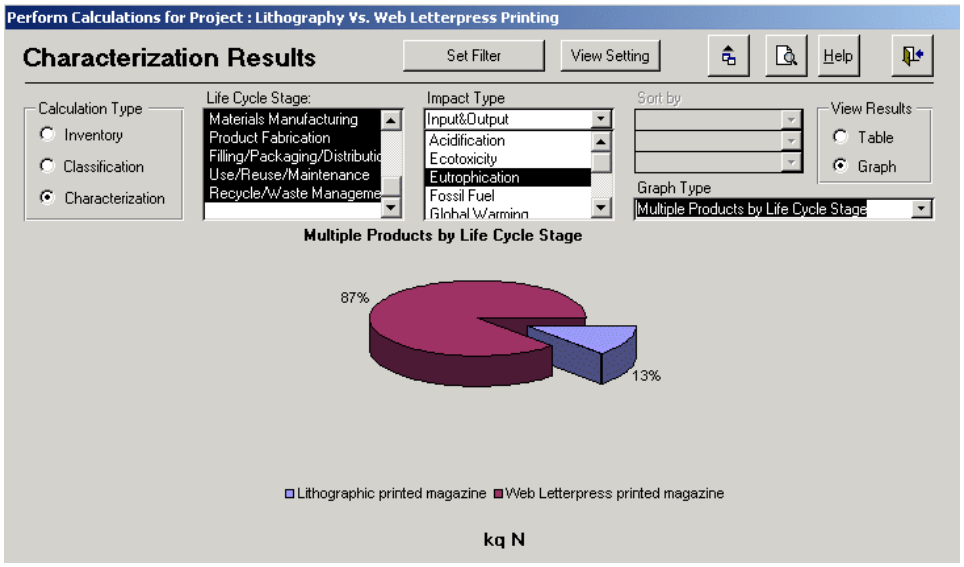

Figure 2-30. Multiple Products by Life Cycle Stage

Limitations

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will appear.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

$ Since pie charts cannot graph negative numbers, negative LCI data are converted to zero for the purpose of displaying a pie chart.

Characterization of Multiple Processes for One Product

This pie chart shows the relative contribution to an impact type for multiple processes associated with a single product. The graph totals the characterization results for the selected processes and filters the results based on the selected impact type. The life cycle stage(s) cannot be changed. They are based on the selected product and processes. This graph is only available when one product and multiple processes have been selected on the *Setting for Calculations* screen.

Figure 2-31: This graph shows the relative contribution to an impact type for multiple processes for one product.

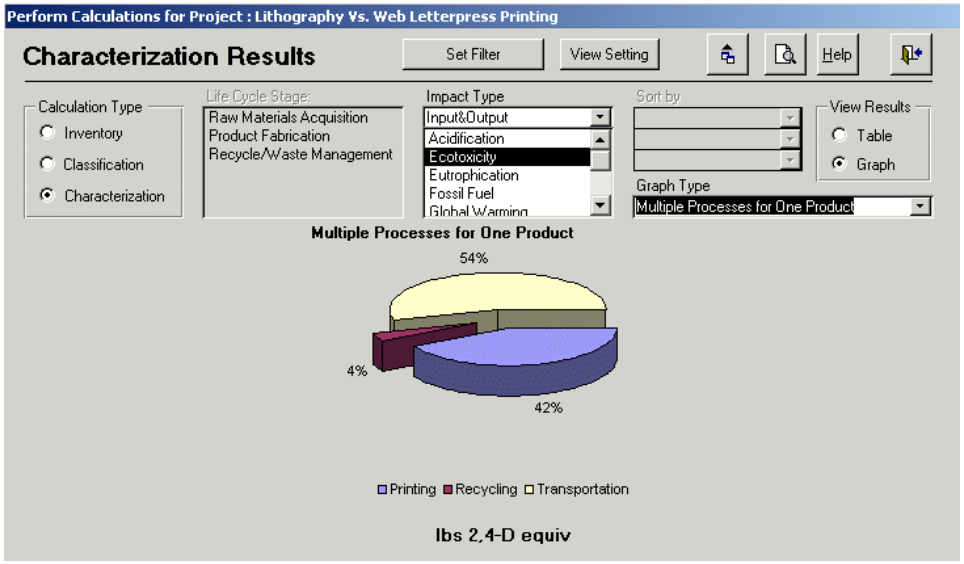

Figure 2-31. Multiple Processes for One Product

Limitations

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will be displayed.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

$ Since pie charts cannot graph negative numbers, negative LCI data are converted to zero for the purpose of displaying a pie chart.

Characterization of Life Cycle Stages for One Product

This pie chart shows the characterization results by impact type for all life cycle stages associated with the product. For example, you could use this graph to compare the Human Health Cancer results to the Human Health Noncancer results for Product A. Or, you could compare the Human Health Cancer results for Product A to the results for Product B by setting the filter for Product A, viewing/printing the results and then following the same steps for Product B. This graph is only available when one product with multiple processes has been selected on the *Setting for Calculations* screen.

Figure 2-32: This graph shows the relative contribution for one product by each life cycle stage for one impact type.

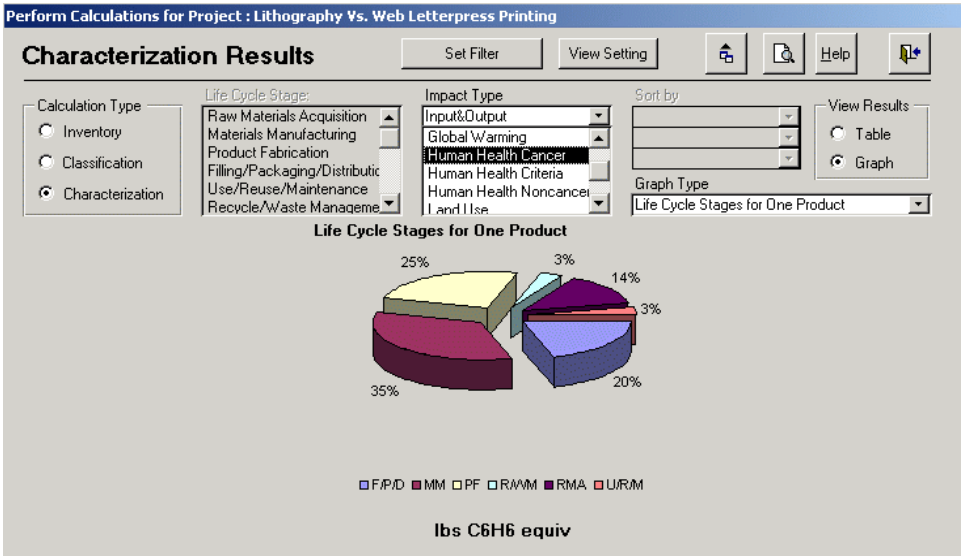

Figure 2-32. Life Cycle Stages for One Product

Limitations

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will be displayed.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

$ Since pie charts cannot graph negative numbers, negative LCI data are converted to zero for the purpose of displaying a pie chart.

Characterization of Resources/Releases for Multiple Processes for One Product

Use this graph to compare the relative contribution of individual resources/releases at the process level for the selected impact type. The characterized results associated with the impact type are displayed for the selected processes. Each bar represents a single process. Results can only be viewed for one impact type at a time. For example, if you choose Acidification from the *Impact Type* list, the resulting graph shows the characterized result for each release in the process. This graph is only available when one product with multiple processes was selected on the *Setting for Calculations* screen.

Figure 2-33: This graph shows the relative contribution of individual resources/releases to processes for the selected impact type.

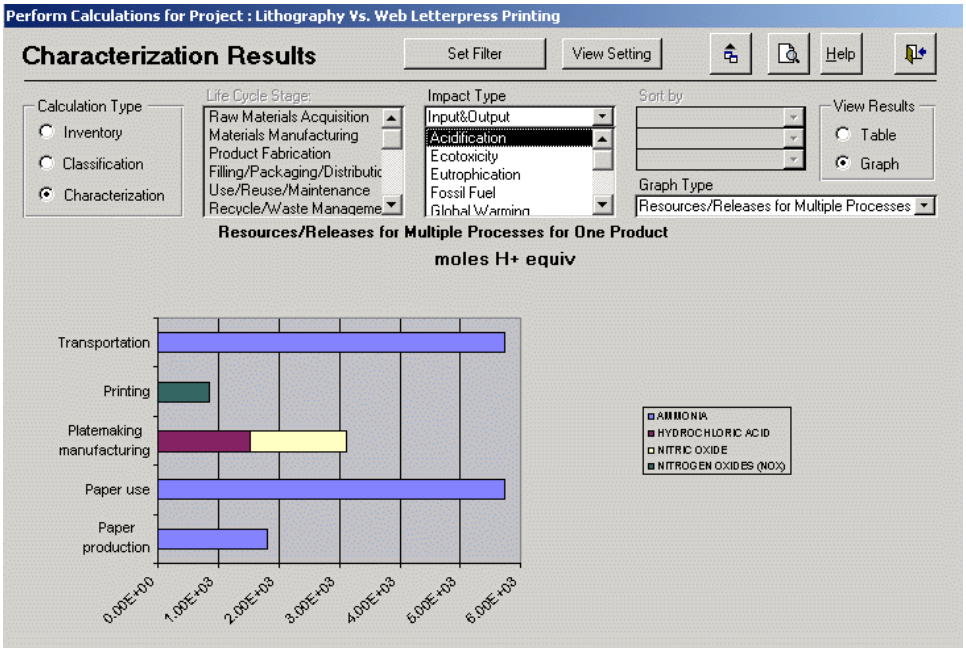

Figure 2-33. Resources/Releases for Multiple Processes for One Product

Limitations

$ This graph displays all the resources/releases for the selected processes. Because of the screen size limitations, TRACI may not display all the results.

$ If the values for several resources/releases are much greater than the values for the rest, the smaller resources/releases will appear in the legend but may not be visible in the graph.

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will be displayed.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

Characterization of Resources/Releases at the Product Level

This stacked bar graph shows the value of individual resources/releases at the product level for a particular impact type. The characterization results associated with an impact type are displayed for the product which you selected. Each bar represents a single product. You may only view the results for one impact type at a time. This graph is available when one or more products were selected on the *Setting for Calculations* screen.

Figure 2-34: This graph shows the overall contribution of resources/releases to a product based on the selected impact type.

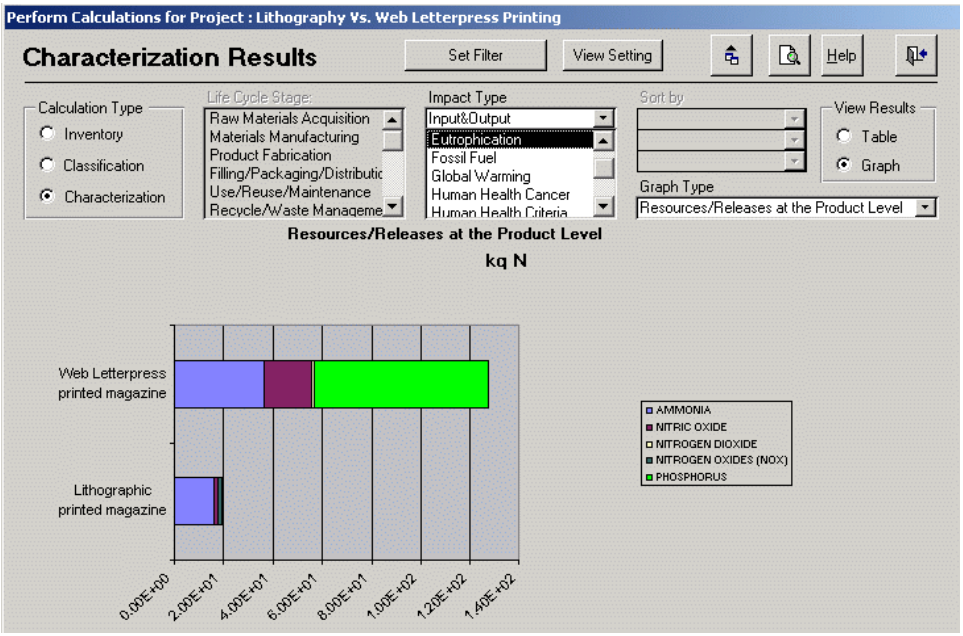

Figure 2-34. Resources/Releases at the Product Level

Limitations

$ This graph displays all resources/releases for the selected products. Because of the screen size limitations, TRACI may not display all the results.

$ If the values for several resources/releases are much greater than the values for the rest, the smaller resources/releases will appear in the legend but may not be visible in the graph.

$ If there are no results for the parameters you specified, you will receive a system message or a blank screen. No graph will be displayed.

$ Long names (i.e., for chemical releases, products, processes, etc.) will be truncated because of the size constraints of the screen. The information displayed in the legend may also be cut off. Click  to see the full graph and legend.

Abbreviations in Tables and Graphs

In order to improve the appearance of both the tables and the graphs, abbreviations are used for the impact types, life cycle stages, and locations. See the following tables for the location, impact type and life cycle stage abbreviations.

Location	Abbreviation
Northeastern Region	NE(R)
Midwestern Region	MW(R)
Southern Region	S(R)
Western Region	W(R)
East of the Mississippi River	EMI
West of the Mississippi River	WMI

Table 2-2. Location Abbreviations

Impact Type	Abbreviation
Ozone Depletion	OD
Global Warming	GW
Acidification	AC
Eutrophication	EU
Photochemical Smog	PS
Human Health Cancer	HHC
Human Health Noncancer	HHNC
Human Health Criteria	HHCR
Ecotoxicity	EC
Fossil Fuel - Oil	FFO
Fossil Fuel - Natural Gas	FFNG
Fossil Fuel - Hard Coal, Open Pit Mining	FFC
Land Use	LU
Water Use	WU

Table 2-3. Impact Type Abbreviations

Life Cycle Stage	Abbreviation
Raw Materials Acquisition	RMA
Materials Manufacturing	MM
Product Fabrication	PF
Filling/Packaging/Distribution	F/P/D
Use/Reuse/Maintenance	U/R/M
Recycle/Waste Management	R/WM

Table 2-4. Life Cycle Stage Abbreviations

Other Features for Graphs and Tables

The Results screen has several other features:

Note: Graphs, labels, and legends are limited due to screen size. Some items may not appear on the graph screen. For a detailed view of the graph and all labels, select Print Preview.

$ Select  for a detailed view of the graphs and labels. Graphs, labels, and legends are limited due to screen size. Some items may not appear on the graph screen. Then, select **Print** from the menu at the very top left to print the graph or table.

$ Select **View Setting** to view the project and products that were selected on the previous screen. Then, select **View Result** to return to the results screen.

$ Click **Set Filter** to return to the previous screen so that you can reset your project and product selections. Re-setting the selections will require TRACI to recalculate the results. Re-setting the selections numerous times without returning to the *Main Menu* could potentially cause an error message to appear. If you receive an error message, return to the *Main Menu* and re-start your calculations.

$ Click  to close the form and return to the *Main Menu*.

2.9 Transfer Data

Inventory data can be exported from TRACI to three different formats: spreadsheet, database, or text. To export data, click **Transfer Data** on the *Main Menu* and the following screen will appear.

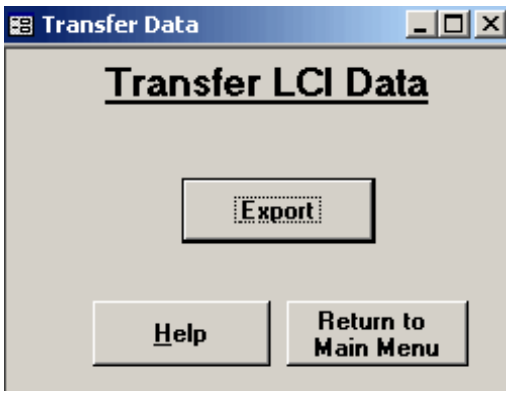

Figure 2-35. Transfer LCI Data

1. Click **Export** to transfer life cycle inventory data from within TRACI to a spreadsheet, database, or text file. The following screen will appear.

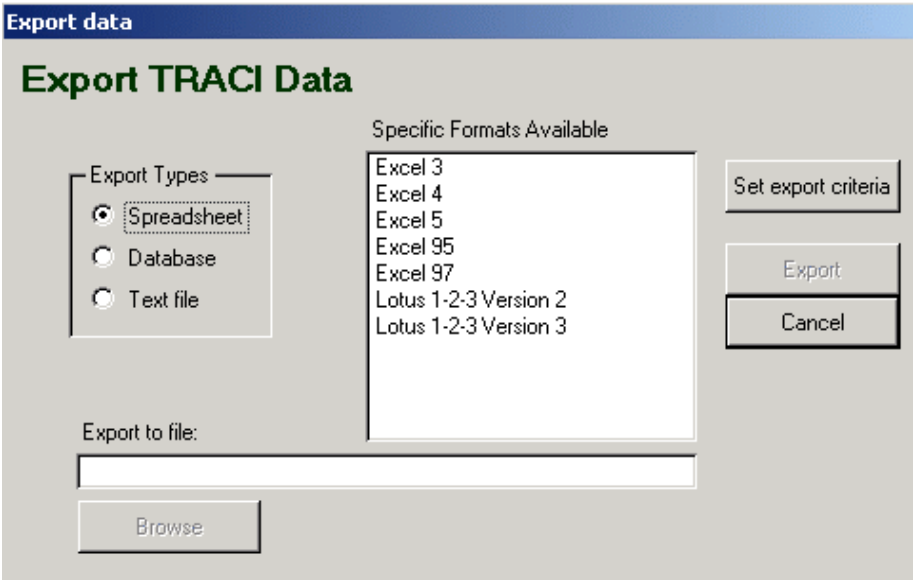

Figure 2-36. Export TRACI Data

2. You must create or identify the spreadsheet, database or text file to which the data will be exported. This file must be created before you begin TRACI's export procedure.

3. Select the *Export Type*: spreadsheet, database, or text file. Once the *Export Type* is selected, the list of specific formats available will appear.

4. Highlight the format of your choice.

   Database - MS Access, dBase 5.0, dBase IV, dBase III, Fox Pro 3.0, Fox Pro 2.6, Fox Pro 2.5, Fox Pro 2.0, Paradox 5.x, Paradox 4.x, and Paradox 3.x

   Spreadsheet - Excel 3, Excel 4, Excel 5, Excel 95, Excel 97, Lotus 1-2-3 Version 2, and Lotus 1-2-3 Version 3

   Text File - Comma-delimited, HTML, and Merge

5. Click **Set Export Criteria** to specify exactly what will be exported. The following screen will appear.

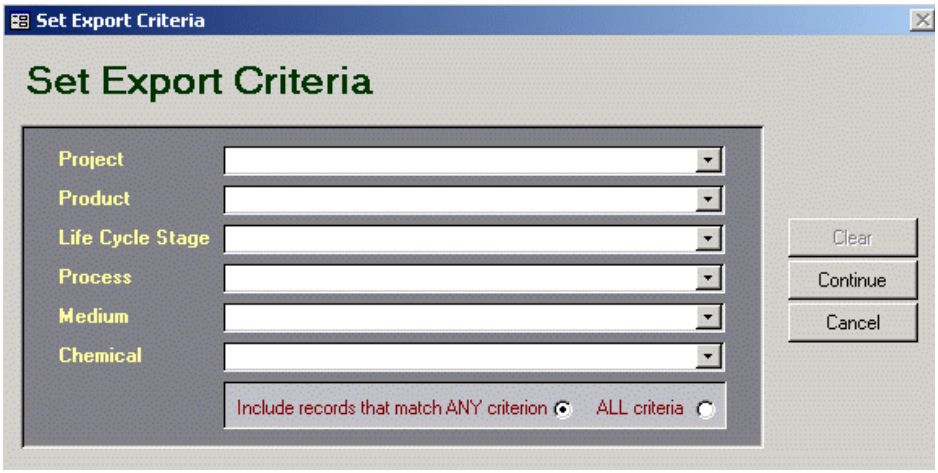

Figure 2-37. Set Export Criteria

6. Determine what information you want to export out of TRACI. Select the appropriate information. TRACI provides the following options: Project, Product, Life cycle stage, Process, Medium, and Chemical.

7. Select whether the export should include records that match ANY criteria or if records should match ALL criteria.

8. Click **Continue**.

9. Click **Browse** and identify the file to which the data will be exported.

10. Click **Save**.

11. The path that the file will be exported to will appear at the bottom of the *Export TRACI Data* screen.

12. Click **Export**.

13. The message "Export Complete" will appear. Click **OK**. The inventory data is automatically added to the selected file.

Chapter 3. Introduction to Life Cycle Assessment

3.1 Life Cycle Assessment (LCA)

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product or process. An LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. A complete "cradle-to-grave" life cycle assessment begins with the extraction of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth (i.e. via disposal). This approach provides a comprehensive view of the environmental aspects of the product or process.

The International Organization for Standardization (ISO), a worldwide federation of national standards bodies from approximately 100 countries, has developed standards and guidelines regarding life cycle assessment. According to one of the ISO guidance documents, ISO 14040, ecological consequences, human health, and resource use are environmental impact categories that should be considered.

> LCA is a technique for assessing the environmental aspects and potential impacts associated with a product by:
>
> - compiling an inventory of relevant inputs and outputs of a product system;
> - evaluating the potential environmental impacts associated with those inputs and outputs;
> - interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.
>
> *ISO 14040*

The Society of Environmental Toxicology and Chemistry (SETAC), an independent, nonprofit professional society that provides a forum for individuals and institutions engaged in the study of environmental issues, has driven the technical developments in the field of life cycle assessment. A SETAC workshop held in 1990 provided the basis for the technical framework and methodology that is used today. In response to the increase in the number of groups conducting life cycle assessments, the U.S. Environmental Protection Agency (EPA) has been developing consensus-based guidelines to promote consistency in the LCA methodology (USEPA 1993b).

3.2 Components of LCA

LCA allows the organization of data related to the various environmental stressors to the environment. It is a systematic, phased approach and consists of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation (*see Figure 3-1*). An organization can choose to only perform the goal

definition and scoping and the inventory analysis components of the LCA. Unfortunately, listing and quantifying the stressors without greater analysis can lead a decision maker to data overload. Organization beyond inventory allows the decision maker the freedom to consider a more reasonable number of factors within the decision.

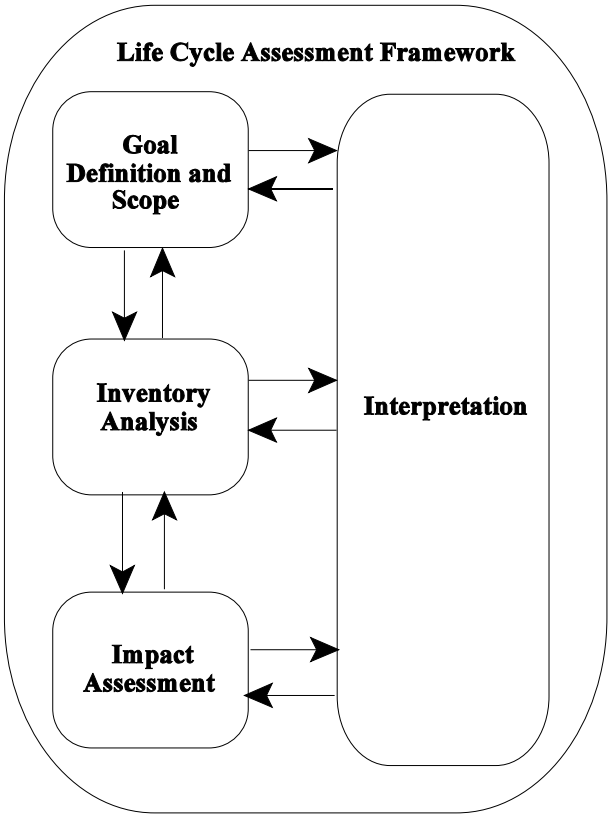

Figure 3-1. Life Cycle Assessment Framework
(ISO 1998)

3.2.1 Goal Definition and Scoping

Goal definition and scoping identifies the extent of the study based on the goal of the LCA.

Goal definition and scoping is the first of four steps involved in conducting an LCA. Originally, this component was not part of the LCA methodology; however, currently many practitioners consider this step to be important, consequently, the early steps of goal definition and scoping should not be taken lightly. The scoping analysis identifies the extent of the study based on the goal of the LCA. "All subsequent activity in the assessment, including defining the boundaries, collecting data, and presenting results, must be consistent with the intended purpose." (Curran 1996)

This step defines the boundaries (breadth and depth) of the LCA study. In addition, the time frame in which the data will be collected should be established. It is usually best to use the most recent and highest quality data available. When comparing two or more products or processes, the user must determine the basis for comparison, which is known as the functional unit. The functional unit is the unit of comparison that assures that the products being compared are true substitutes for each other.

According to the U.S. EPA (1993b), many organizations have one or more of the following objectives when performing an LCA:

- To establish a baseline of information on a system's overall resource use, energy consumption, and environmental loadings
- To identify stages within the life cycle of a product or process where a reduction in resource use and emissions might be achieved
- To compare the system inputs and outputs associated with alternative products, processes, or activities
- To help guide the development of new products, processes, or activities toward a net reduction of resource requirements and emissions
- To help identify areas to be addressed during life cycle impact analysis.

3.2.2 Inventory Analysis

The inventory analysis component is a technical, data-based process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes and other releases for the entire life cycle of a product, package, process, material, or activity (USEPA 1993b).

A life cycle inventory is the identification and quantification of energy and raw material requirements and environmental releases to air, water, and land. The inventory takes into account all inputs to and outputs from a system (*see Figure 3-2*). All parts of a system within the scope of the inventory must be assessed.

To begin a life cycle inventory, the user must consider the system or part of a system that will be assessed. U.S. EPA defines a system as "a collection of operations that together perform some well-defined function." It is helpful to create a system flow diagram to determine the inputs and outputs of a system. Calculations can be used to determine resource requirements and environmental emissions for a product. Once the system diagram is complete, the user can decide if it is appropriate to view the system as a whole or as a series of subsystems. A subsystem is defined by the U.S. EPA as an "individual step or process that is part of the defined production system. Some steps in the system may need to be grouped into a subsystem due to lack of specific data for the individual steps. For each subsystem, the inventory analysis should describe materials and energy sources used and the types of environmental releases." (USEPA 1993b)

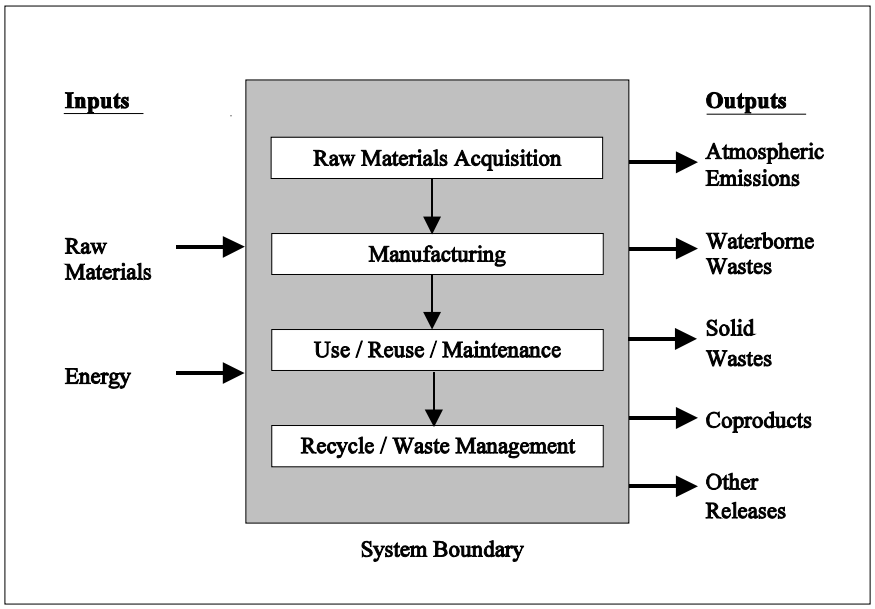

Figure 3-2. Inputs and Outputs (USEPA 1993b)

3.2.3 Life Cycle Impact Assessment

Impact assessment is the technical, qualitative and quantitative characterization and assessment of the consequences of products or processes on the environment.

LCIA is the third of the four steps and is used to determine the most important stressors and guide the assessment of overall impact (Fava 1993). The impact assessment component is a process that characterizes and assesses the environmental effects of the product or process, based on its inventory. Impact assessment should address ecological and human health effects. It is important to keep in mind that a life cycle impact assessment attempts to establish a linkage between the product or process and its *potential* environmental impacts. It does not quantify any specific *actual* impacts (USEPA 1993b). The key concept in this component is that of stressors. A stressor is a set of conditions (e.g., emissions or resource uses) that may lead to an impact. For example, if a product or process is emitting greenhouse gases, the increase of greenhouse gases in the atmosphere *may* contribute to global warming. Processes that result in the discharge of excess nutrients into bodies of water *may* lead to eutrophication.

Classification is the first step of an impact assessment. It is the process of assigning inventory outputs into specific environmental impact categories. Stressors are classified into a relatively homogeneous group based on the type of impact they cause. For example, greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, are classified into a category of substances that contribute to global warming.

The second step of the impact assessment is characterization. This step characterizes the magnitude of the potential impacts of each inventory flow. TRACI's impact indicator methodologies convert the quantities of each pollutant into the unit of potential impact. For each impact category, there is a list of substances and their relative contributions to the environmental impact.

In characterization, TRACI multiplies the quantity of the resource/release from the inventory data by the associated characterization factors to obtain the characterized

results. Since the impact categories have different equivalency potential indicators, it is inaccurate to compare the characterization results between categories. You can, however, examine the characterization results by impact category for a particular product to identify which processes or chemicals are making the greatest contribution.

TRACI classifies and characterizes inventory data into the following twelve impact categories: ozone depletion, global warming, acidification, eutrophication, photochemical smog, human health cancer, human health noncancer, human health criteria, ecotoxicity, fossil fuel use, land use and water use. Information on these impact categories and the impact assessment methodologies can be found in the publication entitled "TRACI - The Tool for the Reduction and Assessment of Chemical and other environmental Impacts" within the *Journal of Industrial Ecology* (Bare 2002).

3.2.4 Interpretation

Interpretation is the evaluation of the results of the inventory analysis and impact assessment to select the preferred product, process, or activity.

Life cycle interpretation involves interpreting and communicating the results of the assessment. There should be a clear understanding of the uncertainty and the assumptions used to generate the results. According to the ISO's draft standard entitled "Environmental Management - Life Cycle Assessment - Life Cycle Interpretation," the interpretation step involves identifying significant issues, evaluating the completeness, sensitivity, and consistency of the data, and drawing conclusions and recommendations.

ISO has defined the following two objectives of life cycle interpretation: (1) analyze results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases of the LCA and to report the results of the life cycle interpretation in a transparent manner and, (2) provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study (ISO 1998).

3.3 Product Stages

Life cycle assessment is a holistic approach that analyzes the entire life cycle of a product, beginning with resource consumption and ending as residuals eventually return to the earth (Curran 1996). The life cycle of a product encompasses the following stages: Raw Materials Acquisition, Manufacturing (Materials Manufacture, Product Fabrication, Filling/Packaging/Distribution), Use/Reuse/Maintenance, and Recycle/Waste Management. The user must have a clear understanding of where each stage of a life cycle begins and ends in order to collect data properly.

3.3.1 Raw Materials Acquisition

The life cycle of a product begins with the removal of raw materials and energy sources from the earth. For instance, the harvesting of trees or the mining of nonrenewable materials would be considered raw materials acquisition. Transportation of these materials from the point of acquisition to the point of processing is also included in this stage (USEPA 1993b).

3.3.2 Manufacturing

During the manufacturing stage, raw materials are transformed into a product or package. The product or package is then delivered to the consumer. The manufacturing stage consists of three steps: materials manufacture, product fabrication, and filling/packaging/distribution (USEPA 1993b).

Materials Manufacture

The materials manufacture step involves the activities that convert raw materials into a form that can be used to fabricate a finished product (USEPA 1993b).

Product Fabrication

The product fabrication step takes the manufactured material and processes it into a product that is ready to be filled or packaged (USEPA 1993b).

Filling/Packaging/Distribution

This step finalizes the products and prepares them for shipment. It includes all of the manufacturing and transportation activities that are necessary to fill, package, and distribute a finished product (USEPA 1993b). Products are transported either to retail outlets or directly to the consumer. This stage accounts for the environmental effects caused by the mode of transportation, such as trucking and shipping.

3.3.3 Use/Reuse/Maintenance

This stage involves the consumer's actual use, reuse, and maintenance of the product. Once the product is distributed to the consumer, all activities associated with the useful life of the product are included in this stage. This includes energy demands and environmental wastes from both product storage and consumption. The product or material may need to be reconditioned, repaired or serviced so that it will maintain its performance (USEPA 1993b). When the consumer no longer needs the product, the product will be recycled or disposed.

3.3.4 Recycle/Waste Management

The recycle/waste management stage includes the energy requirements and environmental wastes associated with disposition of the product or material (USEPA 1993b). Post-consumer waste management options such as recycling, composting, and incineration are also included. These options can recover material and energy. Residuals of products and processes should also be considered. Although some generated residuals are released directly into the environment, others may undergo treatment processes that are designed to reduce the volume and toxicity of the waste (Curran 1996).

3.4 Calculating the Results

Within each stage, energy and other inputs must be considered, along with the emissions and releases. The values for each stage must be consistently converted to the same unit of measurement. Then, the values may be summed for each life cycle stage individually and then the results from each stage are combined to calculate the total results for the product. When comparing products, it could be misleading to conduct an inventory analysis and impact assessment on only one stage of the life cycle. A product may be environmentally friendly in one stage, but harmful to the environment in another. Without looking at the whole picture, it is difficult to

make an accurate decision. Therefore, it is better to assess all life cycle stages of a product, if possible.

3.5 Data Sources

Quality data are needed to produce credible results. When interpreting the results of an LCA, the user must consider the boundary conditions, quality of data, and assumptions used.

First, the user should look at the various sources from which data can be collected. Data can be facility-specific or more general industry data. Considering the purpose and specificity of the study should help in determining what type of data sources to use. There are two main categories of data: site-specific and non-site-specific. Site-specific data refers to data on the specific product or process being analyzed. Non-site-specific data refers to data that are not specific to the product, such as industry average data. Facility-specific data or company-specific data should be used if a company intends to compare its product to the product of a competitor. Figure 3-3 lists some of the various categories of data, as noted in the U.S. EPA's *Life Cycle Assessment: Inventory Guidelines and Principles* (USEPA 1993b).

Examples include:

- Individual process- and facility-specific: data from a particular operation within a given facility that are not combined in any way.
- Composite: data from the same operation or activity combined across locations.
- Aggregated: data combining more than one process operation.
- Industry-average: data derived from a representative sample of locations and believed to statistically describe the typical operation across technologies.
- Generic: data whose representativeness may be unknown but are qualitatively descriptive of a process or technology.

When collecting data and using it in the LCA, the user must consider the issue of confidentiality. If a company is using its own facility data to conduct an LCA for internal purposes, then keeping data confidential from outsiders is not usually an issue. It is a different story when LCAs are conducted for external use and the results are made public. The company may have proprietary data or confidential business information that cannot be made accessible to the public. This is also an issue when data are gathered from external or upstream suppliers. A company must determine whether it can risk the disclosure of previously confidential information in order to provide a detailed life cycle assessment for external review (USEPA 1993b). Most companies that choose to make their life cycle documents publicly available present industry averages, while many internal industrial studies use plant-specific data (USEPA 1993b).

Sources of Data
(*EPA Life Cycle Assessment: Inventory Guidelines and Principles*)

Private industry data sources	-Independent or internal reports -Periodic measurements -Accounting or engineering reports -Specific measurements -Machine specifications
Publicly available data sources	-Government documents and databases -Technical books, reports and articles -Conference papers
Other resources	-Market research firms (usage and customer preference data)

Figure 3-3. Sources of Data

Chapter 4. Providing LCI Data

Before using TRACI, you must perform a life cycle inventory (LCI). TRACI's LCI must be completed for each life cycle stage that is going to be evaluated. When using TRACI, the user can identify resources and releases and place them under the appropriate life cycle stage: raw materials acquisition, manufacturing, use/reuse/maintenance, or recycle/waste management.

Resources (Inputs)
- Land Use
- Water Use
- Fossil Fuel Use

Releases (Outputs)
- Chemical Emissions

TRACI's LCI takes into consideration the following resources (inputs): land use, water use, and fossil fuel use. In terms of releases (outputs), TRACI assesses *chemical* emissions to the environment. Each of TRACI's impact categories has a corresponding list of resources/releases that are associated with that particular impact. If a resource/release entered into TRACI is not associated with any of the impact categories, then it will NOT be factored into the impact assessment. It is recommended that the user inventory all resources/releases and try to perform a qualitative impact assessment on the ones not accounted for in TRACI.

Since TRACI uses the LCI data that are entered by the user, the software is limited by the data that it is given. The quality of the analysis is only as good as the data entered, hence the importance of data quality. LCI data should be properly identified and collected.

Data quality characteristics include data uncertainty (based on data source), completeness, comparability and variability. Completeness of a data set is evaluated by identifying data gaps.

Data quality can significantly affect the results of the analysis. Data of equal quality and caliber should be used, particularly when comparing two or more products or processes based on environmental preferability. For more information on sources of data and data quality, see Section 3.5.

When collecting inventory data, it is important to remain consistent with the functional unit decided upon in the goal and scoping stage (e.g., production of one thousand eight-ounce glass cups). This is especially important when using this software to compare two or more products or processes.

To ensure that the appropriate inventory data are collected for use in TRACI, it is recommended that you use the Inventory Worksheets provided here. By having various production lines complete these worksheets, data collection will be more consistent and data entry into TRACI will be much easier. The following worksheets lay out all of the information needed for input into TRACI. The first worksheet is the *Project Description Worksheet* on which you can compile all of general project information and a list of all products assessed in the project. On the *Inventory of Resources and Releases Worksheet*, you will provide all of the resource/release information for each process. The *Inventory Worksheet* should always be filled out at the process level.

Project Description Worksheet

Project Name: _____

Company Name: _____

Organizational Unit: _____

Point of Contact: _____ **Phone Number:** _____

Description: Describe key assumptions and life cycle stages that will be assessed.

_____

_____

_____

_____

Scope of the Project: (select one)

- ² Cradle to grave
- ² Cradle to entry gate
- ² Entry gate to exit gate
- ² Exit gate to grave

Functional Unit:

State the basis for comparison between products: (Example: 1000 units, 1000 uses) _____

_____

If products or processes are not normally used on a one-to-one basis, state how equivalent function was established.

_____

_____

Products: List the products analyzed in this inventory.

_____

_____

_____

Inventory of Resources and Releases

Project Name: _____

Product Name: _____

Life Cycle Stage: (select one)

² Raw Materials Acquisition
² Materials Manufacture
² Product Fabrication
² Filling/Packaging/Distribution
² Use/Reuse/Maintenance
² Recycle/Waste Management

Process/Activity: State the process/activity being analyzed. _____

Location of Release: County: _____ State: _____ Region: _____

Process Details:

Data Provided By: _____ Phone Number: _____

Process Boundaries:

Steps Included: Which specific steps are included in the process boundaries? _____

Steps Excluded: Which steps were excluded? _____

Cut-off Rule: _____

Process Allocation: How did you allocate chemical releases from a process line that produces multiple products? _____

Output Allocation: How did you allocate chemical releases to the different media? _____

Production Volume: What percentage of the total production volume was represented by these releases? _____

Data Quality:

Date of data collection: _____

Data Type: Is the data primary (collected on-site) or secondary (collected off-site)? _____

Data Source: (select one) ² Measured ² Calculated ² Estimated ² Mixed ² Unknown

Data Review: (select one) ² Third party ² External ² Internal ² None ² Unknown

Sample Sites: How many sites were sampled? _____

Sampling Procedures: Describe the sampling procedures. _____

Extrapolation: Were data extrapolated from another data source? _____

Technology: What type of technology was used in the process? _____

Season: _____

Other Comments: _____

Inventory of Resources and Releases (cont.)

Resource	Quantity	Units
Land Use		
Fossil Fuel - Oil		
Fossil Fuel - Natural Gas		
Fossil Fuel - Hard Coal		
Water Use		

Chemical Release	CAS No.	Quantity	Units	Media Released To
Example: Nitrogen	**7727-37-9**	**100**	**pounds**	**T Air** ² Water
				² Air ² Water
				² Air ² Water
				² Air ² Water
				² Air ² Water
				² Air ² Water
				² Air ² Water
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				² Air ² Water

Appendix A. Glossary

Aggregated data	Data combining more than one process operation.
Atmospheric emissions	Residual discharges of emissions to the air following emission control devices (USEPA 1993b).
CAS number	A number assigned by the Chemical Abstract Service to identify a chemical. Each chemical substance has its own unique CAS Number, which can be obtained from www.chemfinder.com.
Characterization	Characterization is the second step of an impact assessment and quantifies the magnitude of the potential impacts of each inventory flow to its corresponding environmental impact.
Classification	Classification is the first step of an impact assessment and is the process of assigning inventory outputs into specific environmental impact categories.
Composite data	Data from multiple facilities performing the same operation that have been combined or averaged in some manner (USEPA 1993b).
Composting	A waste management option involving the controlled biological decomposition of organic materials into a relatively stable humus-like product that can be handled, stored, and/or applied to the land without adversely affecting the environment (USEPA 1993b).
Environmental aspects	Elements of a business' products, actions, or activities that may interact with the environment.
Environmental loadings	Releases of pollutants to the environment, such as atmospheric and waterborne emissions and solid wastes.
Equivalency potential factors	Factors that indicate the potential of each chemical to impact the given environmental impact category in comparison to the reference chemical used.
Facility-specific data	Data from a particular operation within a given facility, as opposed to industry-wide or average data.
Functional unit	The unit of comparison that assures that the products being compared provide an equivalent level of function or service.
Generic data	Data whose representativeness may be unknown but are qualitatively descriptive of a process or technology.
Global warming	The theory that elevated concentrations of certain atmospheric constituents are causing an increase in the earth's average temperature (USEPA 1993b).

Greenhouse gas	An atmospheric constituent, such as carbon dioxide, that is thought to contribute to global warming (USEPA 1993b).
Impact analysis	The assessment of the environmental consequences of energy and natural resource consumption and waste releases associated with an actual or proposed action (USEPA 1993b).
Impact categories	Classifications of human health and environmental effects caused by a product throughout its life cycle.
Impact indicators	Impact indicators measure the potential for an impact to occur rather than directly quantifying the actual impact.
Industrial system	A collection of operations that together perform some defined function.
Industry-average data	Data derived from a representative sample of locations and believed to statistically describe the typical operation across technologies.
Inventory analysis	Inventory analysis is the identification and quantification of energy and raw material requirements and environmental releases to the air, water, and land.
Life cycle assessment	A cradle-to-grave approach for assessing industrial systems that evaluates all stages of a product's life. It provides a comprehensive view of the environmental aspects of the product or process.
Life cycle impact assessment	A tool used to evaluate detrimental effects on human health and the environment caused by a particular product or process.
Life cycle inventory	The identification and quantification of energy, resource usage, and environmental emissions for a particular product, process, or activity (USEPA 1993b).
Non-site-specific data	Data not specific to one facility (e.g., industry average data, national average data, surrogate data, estimated data).
Pollution prevention	Any practice that reduces the amount of any pollutant released into the environment prior to recycling, treatment, or disposal.
Product life cycle	The life cycle of a product system begins with the acquisition of raw materials and includes bulk material processing, engineered materials production, manufacture and assembly, use, retirement, and disposal of residuals produced in each stage (USEPA 1993a).
Resource requirements	The amounts of raw materials or natural inputs and energy used in a system (USEPA 1993b).
Site-specific data	Data applicable to the product in question (e.g., process data, facility data, and regulatory reporting data).

Stressors	A set of conditions that may lead to an environmental impact. For example, an increase in greenhouse gases may lead to global warming.
Subsystem	An individual step or process that is part of the defined production system.
System flow diagram	A depiction of the inputs and outputs of a system and how they are connected.

Appendix B. Location Specific Data

TRACI contains location-specific data for several of its models: eutrophication, acidification, photochemical smog, human health criteria and land use. Therefore, TRACI allows you to specify the location where your resource depletion/releases occur in order to more accurately and precisely assess these impact types. The location is specified at the process level. The selections include all fifty states, all U.S. counties, four Census regions, Eastern U.S., Western U.S. and the U.S. as a whole.

Table B-1 summarizes the geographic level for each of the methodologies. For example, for smog, TRACI contains over 500 chemicals and for each it has a U.S. value, one value for states East of the Mississippi, one value for states West of the Mississippi, one value for each of the four Census Regions, and one for each of the 48 contiguous States (i.e., not for Hawaii and Alaska). Regions were determined using the four major Census regions: West [*W(R)*], Midwest [*MW(R)*], Northeast [*NE(R)*], and South [*S(R)*] (*see Figure B-1*).

Impact Category	U.S.	East or West of the Mississippi River	U.S. Census Region	State	County
Ozone Depletion	U				
Global Warming	U				
Acidification	U	U	U	U	
Eutrophication	U	U	U	U	
Photochemical Smog	U	U	U	U	
Human Health Cancer	U				
Human Health Noncancer	U				
Human Health Criteria	U			U	
Ecotoxicity	U				
Fossil Fuel Use	U				
Land Use	U	U	U	U	U
Water Use	U				

Table B-1. Geographic Levels for Impacts

CENSUS REGIONS

Northeast - NE(R)
Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

South - S(R)
Alabama, Arkansas, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia

Midwest - MW(R)
Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin

West - W(R)
Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

Figure B-1. Census Regions

The Eastern U.S. [*EMI*] is comprised of states that are located east of the Mississippi River (*see Table B-2*). The Western U.S. [*WMI*] is comprised of states that are located west of the Mississippi River. The Mississippi River passes through two states: Minnesota and Louisiana. In order to declare for each of these states whether they should be listed East or West of the Mississippi River, their environmental releases were assessed. Both states were placed to the West of the Mississippi River based on the fact that the portion of the states West of the river had greater amounts of environmental releases than the eastern portions (*see Table B-2*).

Location	Abbreviation	East/West	Region
Alabama	AL	East	South
Alaska	AK	West	-
Arizona	AZ	West	West
Arkansas	AR	West	South
California	CA	West	West
Colorado	CO	West	West
Connecticut	CT	East	Northeast
Delaware	DE	East	Northeast
District of Columbia	DC	East	South
Florida	FL	East	South
Georgia	GA	East	South
Hawaii	HA	West	-
Idaho	ID	West	West
Illinois	IL	East	Midwest
Indiana	IN	East	Midwest
Iowa	IA	West	Midwest
Kansas	KS	West	Midwest
Kentucky	KY	East	South
Louisiana	LA	West	South
Maine	ME	East	Northeast
Maryland	MD	East	South
Massachusetts	MA	East	Northeast
Michigan	MI	East	Midwest

Location	Abbreviation	East/West	Region
Minnesota	MN	West	Midwest
Mississippi	MS	East	South
Missouri	MO	West	Midwest
Montana	MT	West	West
Nebraska	NE	West	Midwest
Nevada	NV	West	West
New Hampshire	NH	East	Northeast
New Jersey	NJ	East	Northeast
New Mexico	NM	West	West
New York	NY	East	Northeast
North Carolina	NC	East	South
North Dakota	ND	West	Midwest
Ohio	OH	East	Midwest
Oklahoma	OK	West	South
Oregon	OR	West	West
Pennsylvania	PA	East	Northeast
Rhode Island	RI	East	Northeast
South Carolina	SC	East	South
South Dakota	SD	West	Midwest
Tennessee	TN	East	South
Texas	TX	West	South
Utah	UT	West	West
Vermont	VT	East	Northeast
Virginia	VA	East	South
Washington	WA	West	West
West Virginia	WV	East	South
Wisconsin	WI	East	Midwest
Wyoming	WY	West	West
Northeastern Region	NE(R)	-	Northeast
Midwestern Region	MW(R)	-	Midwest
Southern Region	S(R)	-	South
Western Region	W(R)	-	West
East of the Mississippi	EMI	East	-
West of the Mississippi	WMI	West	-

Table B-2. Geographical Location Abbreviations and Designated Regions

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