Chapter 2

PREPARING FOR A CTSA

Project partners in a CTSA perform a number of preliminary steps prior to embarking on the detailed analyses of a CTSA. These include recruiting partners, preparing scoping documents, selecting a use cluster for evaluation, and setting the boundaries of the evaluation. These preliminary steps not only ensure the selection of a productive project focus, they also help build relationships among the potential team members and lay the foundation for the culture of collaboration essential to project success.

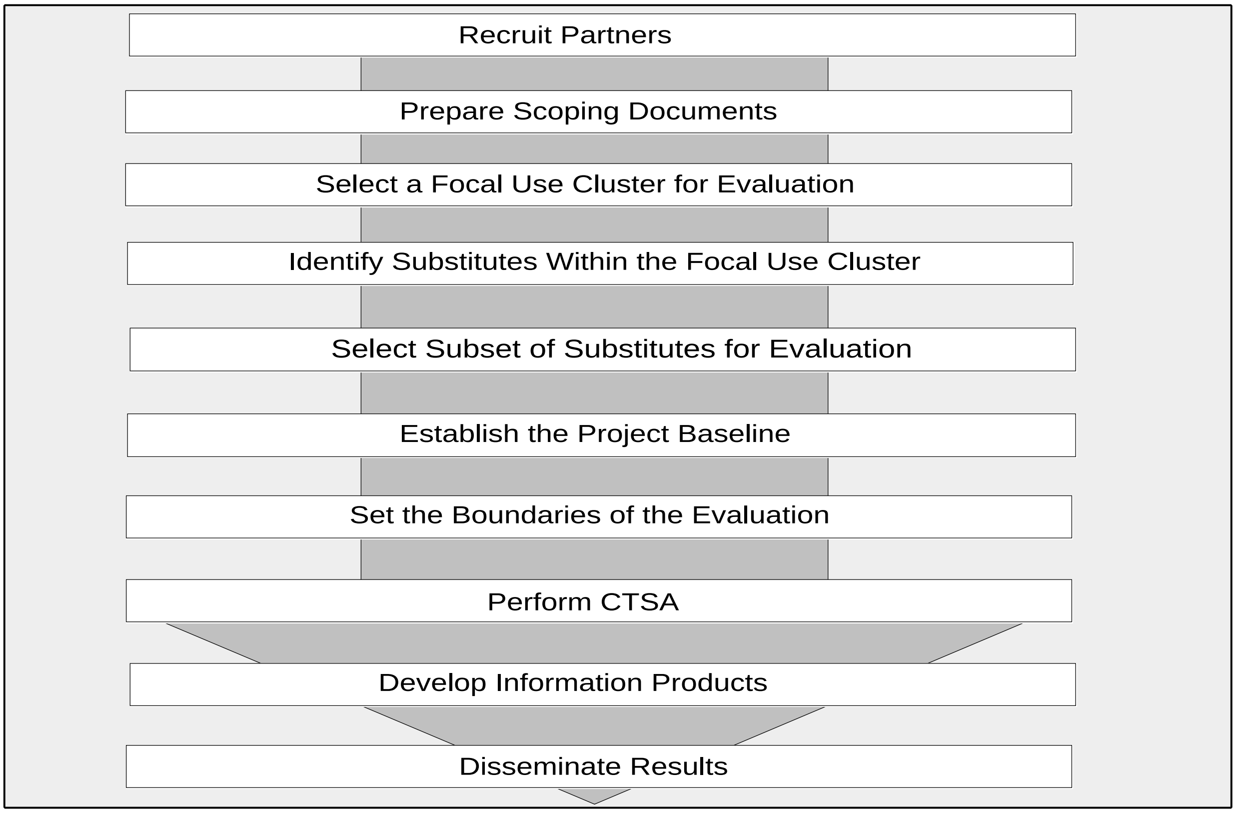
This chapter summarizes the basic steps leading up to a CTSA and the scoping documents which help a DfE project team select a use cluster. It then gives a more detailed overview of each of the preparatory analytical steps. Design for the Environment: Building Partnerships for Environmental Improvement *(EPA, 1995a) addresses each of these steps and describes in more detail how to involve multiple stakeholders in the DfE process and how to disseminate results.*

Figure 2-1 illustrates the basic steps leading up to and following a CTSA. First, DfE project organizers recruit partners from various stakeholder communities to create a project team. Team members then develop an Industry and Use Cluster Profile document and a Regulatory Profile document to help define the project focus. An Industry and Use Cluster Profile gives market data for the industry, describes technological trends, and presents a summary of key industry processes, individual steps within processes, chemicals typically used in each step, and a preliminary list of substitutes for each step. These sets of substitutes make up the use clusters for the industry. A Regulatory Profile identifies the principal federal environmental regulations that may affect the industry under study and the factors that determine which regulations apply to any particular operation. The project team typically selects the use cluster with the greatest opportunities for environmental improvement for the detailed analysis of a CTSA.

Once the use cluster is selected, team members identify substitutes within the use cluster, select a subset of these substitutes for evaluation in a CTSA, and establish the project baseline. The project baseline is typically the industry standard practice, to which other substitutes can be effectively compared. The next step is to set the boundaries of the evaluation by identifying the life cycle stages and types of environmental impacts (e.g., human health and environmental risk to workers, energy impacts, etc.) of greatest concern.

Each of these steps sets the stage for the detailed substitutes assessments that are performed in a CTSA. Following completion of a CTSA, DfE project partners develop a variety of outreach tools to communicate the results of the CTSA. These may include fact sheets, bulletins, pollution prevention case studies, software, videos, and training materials. The final phase of a

FIGURE 2-1: STEPS IN A CTSA PROJECT



DfE project is to disseminate CTSA results to businesses and other stakeholders, who may not have the resources to develop the information on their own. By providing a clear picture of the trade-offs among environmental, economic, and performance concerns, CTSA projects encourage continuous environmental improvement.

PREPARING THE SCOPING DOCUMENTS

The first task for the DfE project team is to conduct research and analysis to identify use clusters within an industry and the use clusters that would provide a productive project focus (EPA, 1995a). Two outcomes of these initial scoping exercises, the Industry and Use Cluster Profile and the Regulatory Profile, provide the foundation for selecting a use cluster and beginning a CTSA. *Printing Industry and Use Cluster Profile* (EPA, 1994a),[1] *Printed Wiring Board Industry and*

[1] The printing industry is frequently divided into industry sectors, depending on the type of printing process utilized. The five most common printing processes are lithography, letter press, flexography, gravure, and screen printing. The Printing Industry and Use Cluster Profile describes each of these industry sectors. EPA's DfE Program has worked with the screen printing and lithography sectors, and is currently working with the flexography sector.

Use Cluster Profile (EPA, 1995b), *Federal Environmental Regulations Potentially Affecting the Commercial Printing Industry* (EPA, 1994b), and *Federal Environmental Regulations Affecting the Electronics Industry* (EPA, 1995c) are examples of Use Cluster Profile and Regulatory Profile documents prepared during DfE industry projects.

Industry and Use Cluster Profile

The Industry and Use Cluster Profile gives market data for the industry, describes technological trends, and presents a summary of each of the use clusters within the industry. This information helps the project team to select a use cluster for evaluation in the CTSA. It also provides information to other sections of the CTSA, such as the exposure assessment. Table 2-1 lists some of the information typically included in an Industry and Use Cluster Profile and gives examples of how this information may be used in a CTSA.

TABLE 2-1: USES OF INFORMATION FROM AN INDUSTRY AND USE CLUSTER PROFILE

Type of Information	Potential Uses in a CTSA
Geographic distribution of industry by size (number of employees, sales) and function.	Determine the aggregate number of workers exposed, information needed in the exposure assessment.
Key industry processes, individual steps within processes, and chemicals typically used in each step.	Identify traditional chemicals and processes within the focal use cluster; provide the foundation for the source release assessment, exposure scenarios, and exposure pathways.
The set of readily identifiable substitutes for each step, which make up the use clusters.[a]	Preliminary pool of substitutes for evaluation in the CTSA.
Technology trends.	Identify potential substitutes; help select subset of substitutes for evaluation.

a) Well known or already documented substitutes may be presented in the Industry and Use Cluster Profile, but additional substitutes are usually identified as the CTSA process continues.

The first Industry and Use Cluster Profile document prepared by a DfE industry project, *Printing Industry and Use Cluster Profile* (EPA, 1994a), did not contain information on the substitutes in printing industry use clusters. However, as the process for conducting DfE industry projects has evolved, project partners have recognized the added benefit of profiling traditional as well as newer, or more novel alternatives. Thus, the Printed Wiring Board document includes limited information on substitutes. The same is true for Regulatory Profile documents, which now seek to include more information regarding substitutes that are readily identifiable in the early stages of a DfE industry project.

Regulatory Profile

The Regulatory Profile identifies the principal federal environmental regulations that may affect the industry under study and the factors that determine which regulations apply to any particular operation. Such factors might include the size of the operation; the location of a facility (i.e., in an ozone non-attainment area); the types of chemical products it uses; and the types, quantity, and toxicity of the emissions and waste streams it generates. For the purposes of a CTSA, the Regulatory Profile helps focus the selection of alternatives by:

- Providing project participants with consistent information on the regulatory requirements affecting an industry.
- Determining if implementing a substitute would reduce the overall regulatory burden of a facility.[2]
- Determining if implementing a substitute would shift the environmental impact across environmental media, such as from air to water, or from water to land.[3]
- Identifying impending chemical or technology bans, phase-outs or other regulatory actions that could affect the market availability and use of affected substitutes.

The Regulatory Profile also serves as a data source for the regulatory status section of the CTSA which evaluates in more detail the regulatory status of each of the potential substitutes selected for quantitative assessment in a CTSA.

SELECTING THE PROJECT FOCUS

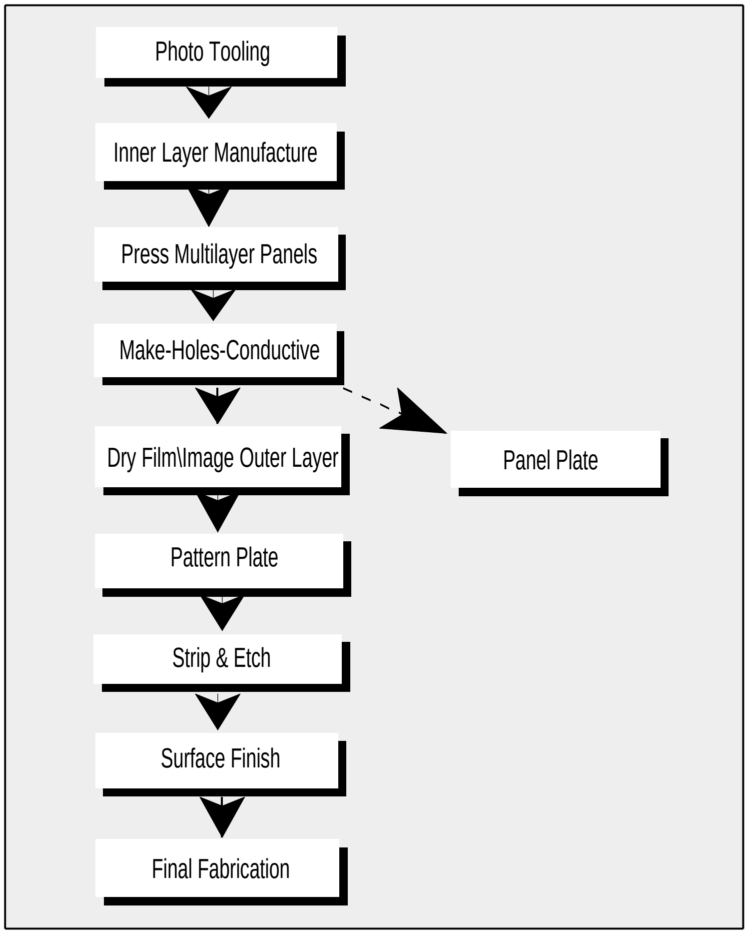
Each use cluster constitutes an area where the relative human health and environmental risk, performance, cost, and resource conservation of alternatives can be compared. For example, Figure 2-2 illustrates the basic functional steps in printed wiring board (PWB) fabrication. Each step can be performed using a discrete set of products, processes, or technologies that can substitute for one another to perform the desired function. And each of these sets of substitutes comprise a discrete use cluster.[4]

[2] To date, Regulatory Profile documents have not explicitly analyzed the regulatory effects of implementing a substitute, but the regulatory status data can be used by DfE project partners to determine what the effects might be.

[3] Since a principal objective of the overall DfE process is to identify and evaluate substitutes that have the greatest potential for reducing overall environmental impacts, attention is focussed on finding alternatives that prevent pollution instead of simply shifting pollutants from one environmental medium to another.

[4] Some of the steps in Figure 2-2 can be broken down further to more narrowly define the use clusters.

FIGURE 2-2: BASIC FUNCTIONAL STEPS IN PRINTING WIRING BOARD FABRICATION



For practical reasons, DfE project partners usually select one use cluster as the focal point for the project's technical work. The PWB Project partners selected the making-holes-conductive (MHC) use cluster, which is the process of depositing a conductive surface in the barrels of drilled though-holes prior to electroplating. When the technical analysis of a use cluster is complete, the project team can decide whether to extend the project to investigate other use clusters.

Factors to consider when selecting a use cluster for evaluation include the following:

- *The degree of risk associated with current practice in the use cluster:* Use clusters that involve greater exposure to highly toxic chemicals may pose greater human health and environmental risk and offer greater potential for improvement. EPA uses a relative risk ranking methodology to screen the relative health and environmental effects of different use clusters. The Use Clusters Scoring System ranks use clusters into broad concern categories (high, medium, or low) based on use volumes, total environmental releases of chemicals, health and environmental hazards, exposure potential and other factors (EPA, 1993a).

- *The degree of interest that industry and other stakeholders have in the use cluster:* DfE project teams typically represent different stakeholder communities with differing values. Understanding the interests of each of the partners is important to building consensus. The level of interest in the use cluster of each of the partners will also be an important factor motivating their participation. For example, the cooperation of suppliers in providing information on or samples of their products has proven to be essential to the success of past projects.

- *The availability of potentially cleaner substitutes:* The purpose of a CTSA is to evaluate the trade-offs among substitutes of human health and environmental risk, performance, cost, and other environmental effects. Viable substitutes within a use cluster that are in use or ready to be demonstrated are necessary for a CTSA to have the best potential for real environmental gains in the near-term. Processes or technologies that perform a similar function in other industries may also be viable substitutes. The DfE project team may elect to include new technologies that are still in the research and development stage, even though tangible environmental improvements from the use of these technologies may be less immediate.[5]

- *The degree to which a use cluster is tied to other process steps outside of the use cluster:* In some cases, implementing a substitute product, process, or technology might require changes in process steps outside of the use cluster. If so, the project team may need to evaluate these other changes as well to ensure that selection of a substitute does not adversely affect performance or cost outside of the use cluster or shift the environmental impacts from one part of the process to another. Project teams need to consider the time and resources they have available for the evaluation as well as the potential improvement opportunities of these more complex use clusters.

- *The status of other ongoing projects related to a use cluster:* If other projects are already evaluating a use cluster the project team should determine if a CTSA will add valuable information to information already being developed. In some cases, it may be possible to coordinate the work of a DfE project team with other efforts that are not considering the full range of issues evaluated in a CTSA.

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[5] This is not to discourage the application of environmental principles in research and development activities. It is simply to note that it may take longer to realize the environmental benefits. If today's trends continue, technologies of the future will undoubtedly be designed to minimize environmental impacts, and this methodology can be used to inform that design process.

Design for the Environment: Building Partnerships for Environmental Improvement (EPA, 1995a) also discusses factors for selecting a focal use cluster and how to solicit input from stakeholder sectors.

IDENTIFYING SUBSTITUTES WITHIN THE USE CLUSTER

The Use Cluster and Industry Profile, with its preliminary list of chemicals, processes and technologies employed in each use cluster, provides the initial pool of substitutes for evaluation in a CTSA. The identification of substitutes is not limited to this preliminary stage of a CTSA, however. Additional substitutes are identified as a CTSA progresses and more information is gained about the characteristics of the use cluster and of the industry.

The project team begins to identify additional substitutes after the focal use cluster is selected. All stakeholder groups are potential sources of information about additional substitutes. Manufacturers and suppliers of chemical products and technologies play an important role in substitute identification, since they frequently have an up-to-date understanding of current industry trends, and emerging products or technologies. Also, the participation of suppliers in the CTSA process is essential to developing generic chemical product formulations which may be used in the risk characterization if necessary to protect proprietary formulation information (see page 2-18 for a discussion of generic chemical product formulations).

At the same time, trade associations may be tracking new developments; their laboratories and research facilities may be currently developing alternatives. Universities and other research organizations also may be involved in applied or basic research on new alternatives. Public-interest groups concerned about human health risk or other environmental impacts may have independently searched for options to prevent pollution. International organizations may have information on alternatives used abroad. DfE project teams use all of these resources to develop a substitutes tree.

The Substitutes Tree

A substitutes tree is a graphical depiction of the substitute or alternative chemical products, technologies, or processes that form the use cluster and their relationship to each other within the functional category defined by the use cluster. In a DfE project, the terms "substitute" and "alternative" are used interchangeably to mean any traditional or novel chemical product, technology, or process that can be used to perform a particular function.[6] The substitutes tree developed for the DfE Dry Cleaning Project is illustrative of the thought processes that are employed in identifying substitutes.

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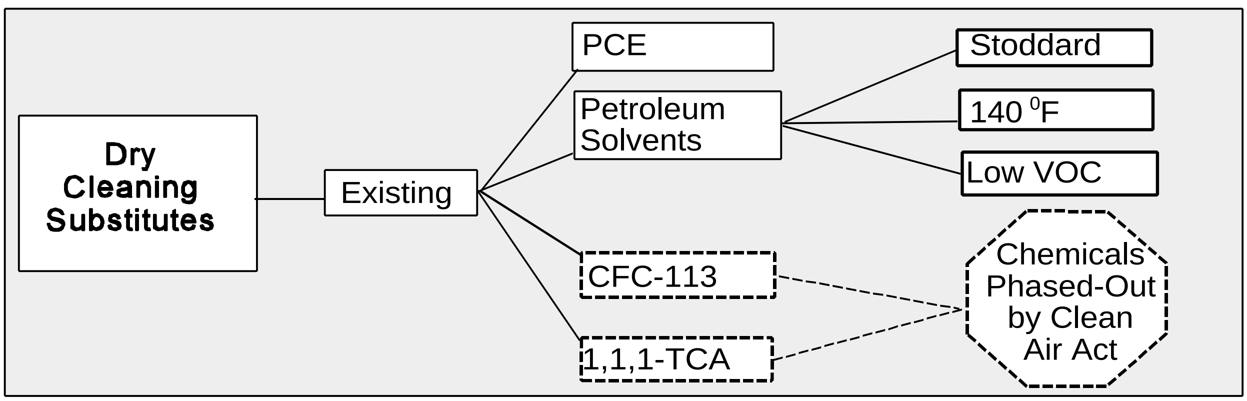
[6] In the context of a CTSA, the term "alternative" does not necessarily connotate a new or novel substitute. Instead it is used to denote the concept of having a choice, either between a traditional product, process, or technology, or a new or novel product, process, or technology. In this manner, the terms "alternative" and "substitute" are synonymous: either of them represents a choice that can be made between products, processes, or technologies that can be used to perform a particular function.

The Dry Cleaning Project evolved from several years of work by EPA with the dry cleaning industry to examine ways to reduce exposure to perchloroethylene (PCE). PCE, a suspected carcinogen, is the chemical solvent most frequently used to dry clean clothes (EPA, 1995a).[7] The dry cleaning process was originally developed to clean water-sensitive fabrics. If the function of dry cleaning is defined as solvent-based cleaning, a number of chemical substitutes can be readily identified that are currently used in dry cleaning facilities (Figure 2-3). When identifying alternatives in a use cluster, however, the project team must be careful to not define the function too narrowly or too broadly. The following discussion illustrates the limitations that would have been imposed on the dry cleaning project if the function had been defined as solvent-based cleaning.

FIGURE 2-3: TRADITIONAL DRY CLEANING CHEMICALS



Recall that a goal of a CTSA is to evaluate both traditional and novel chemicals, processes, or technologies that can substitute for one another to perform a particular function. The substitutes tree shown in Figure 2-3 is too narrow in its scope since it only illustrates traditional chemicals. Figure 2-4 shows the substitutes tree expanded to include newly available professional dry cleaning technologies, and dry cleaning chemicals and technologies that are currently under development. This also proved to be too narrowly defined.

Each of these substitutes or alternatives are *dry* cleaning processes, which is how the use cluster has been defined in Figure 2-4. In the Dry Cleaning Project, however, the project gained momentum when an alternative process called multi-process wet cleaning came to the attention of the project partners. This process primarily uses controlled application of heat, steam, and soap to clean garments, including garments made from water-sensitive fabrics. If the function of the use cluster is redefined as professional garment cleaning (excluding water-washable garments that are usually home-laundered), which is the ultimate function that dry cleaners provide and the service that consumers seek, a whole new array of potential alternatives can be identified.

[7] The dry cleaning process typically involves a solvent-wash step and a tumble drying step. The process is similar to residential laundering processes — except that a chemical solvent is the primary cleaning agent instead of water and detergent.

FIGURE 2-4: EXISTING AND EMERGING DRY CLEANING ALTERNATIVES

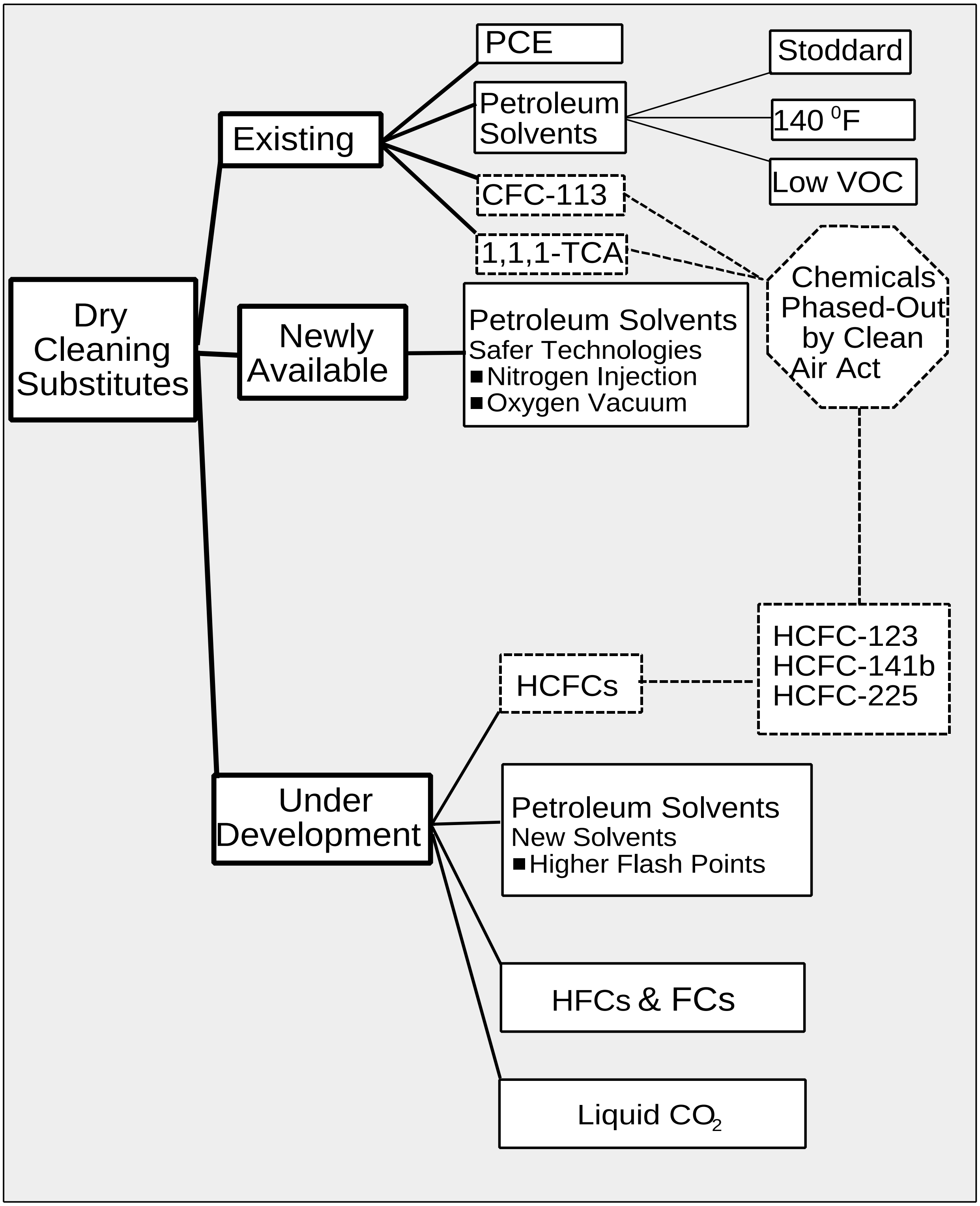
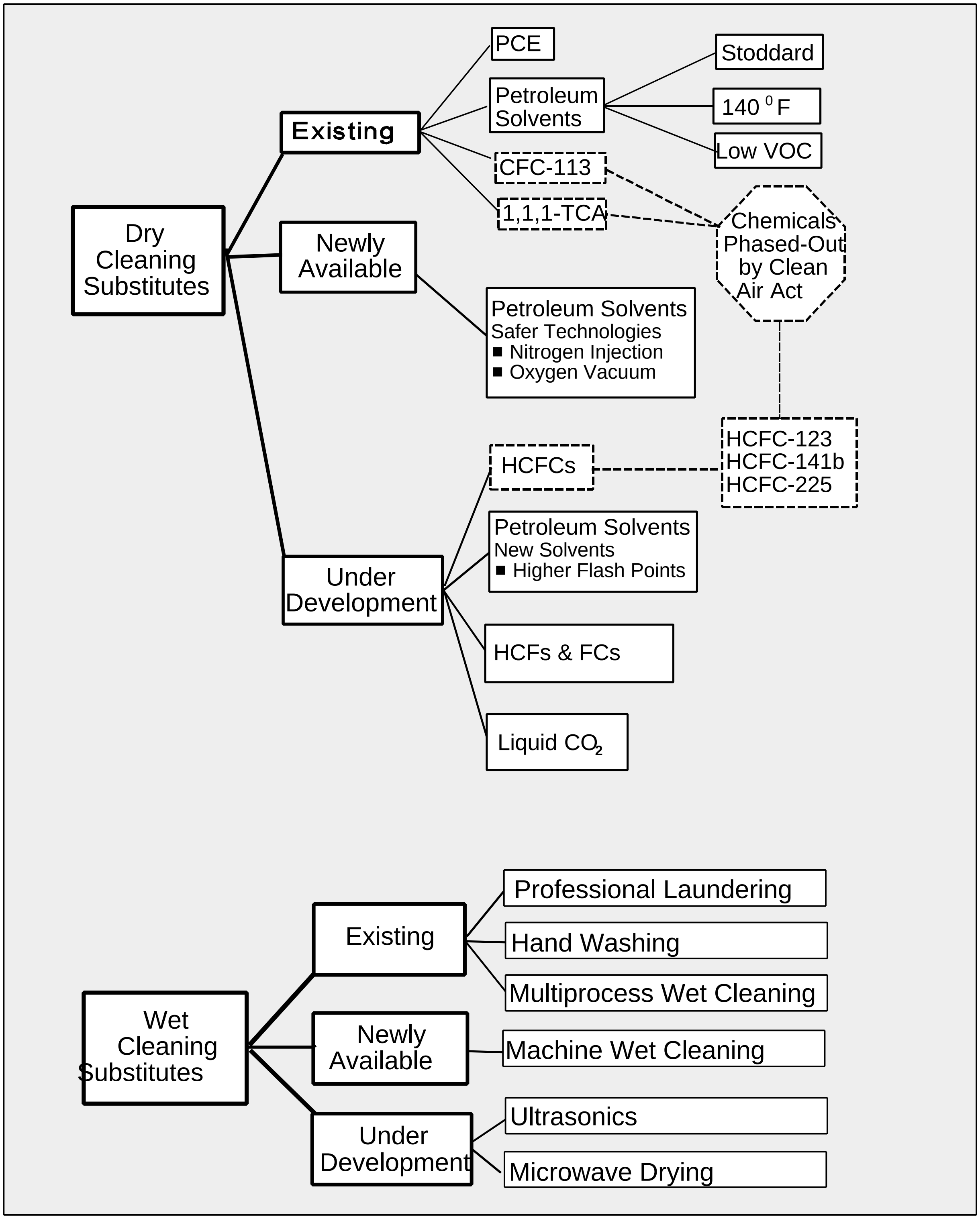


Figure 2-5 illustrates the final substitutes tree for professional garment cleaning that was developed during the Dry Cleaning Project.

FIGURE 2-5: GARMENT CLEANING ALTERNATIVES



Why Focus on Function?

The function of a product, process, or technology is the action for which it is especially fitted or used. Function implies a definite end or purpose that is served or a particular kind of work that is performed. By focussing on function, the CTSA process highlights the end served rather than the means to the end. This opens the evaluation to an array of functional alternatives that are often overlooked in traditional pollution prevention opportunities assessments. A focus on function also provides a unit of equivalency (for example, the amount of a chemical substitute required to perform a function) necessary to compare the risk, performance, and cost of alternatives. The complete list of products, processes, or technologies that can be used to perform a function is a use cluster.

Identifying Substitute Chemicals

The Industry and Use Cluster Profile typically lists the categories of chemicals (e.g., adhesive, cleaning solvent, surfactant, etc.) and the major chemicals in each use cluster. Early in the CTSA, project team members begin collecting data on the chemical and physical properties of these chemicals. A process description of the use cluster is prepared to help define the chemical properties of the chemical products which enable them to perform the desired function (e.g., the chemical properties of an organic solvent make it suitable for dissolving oily residues on clothes) and to identify any functional groups in the use cluster. A functional group is:

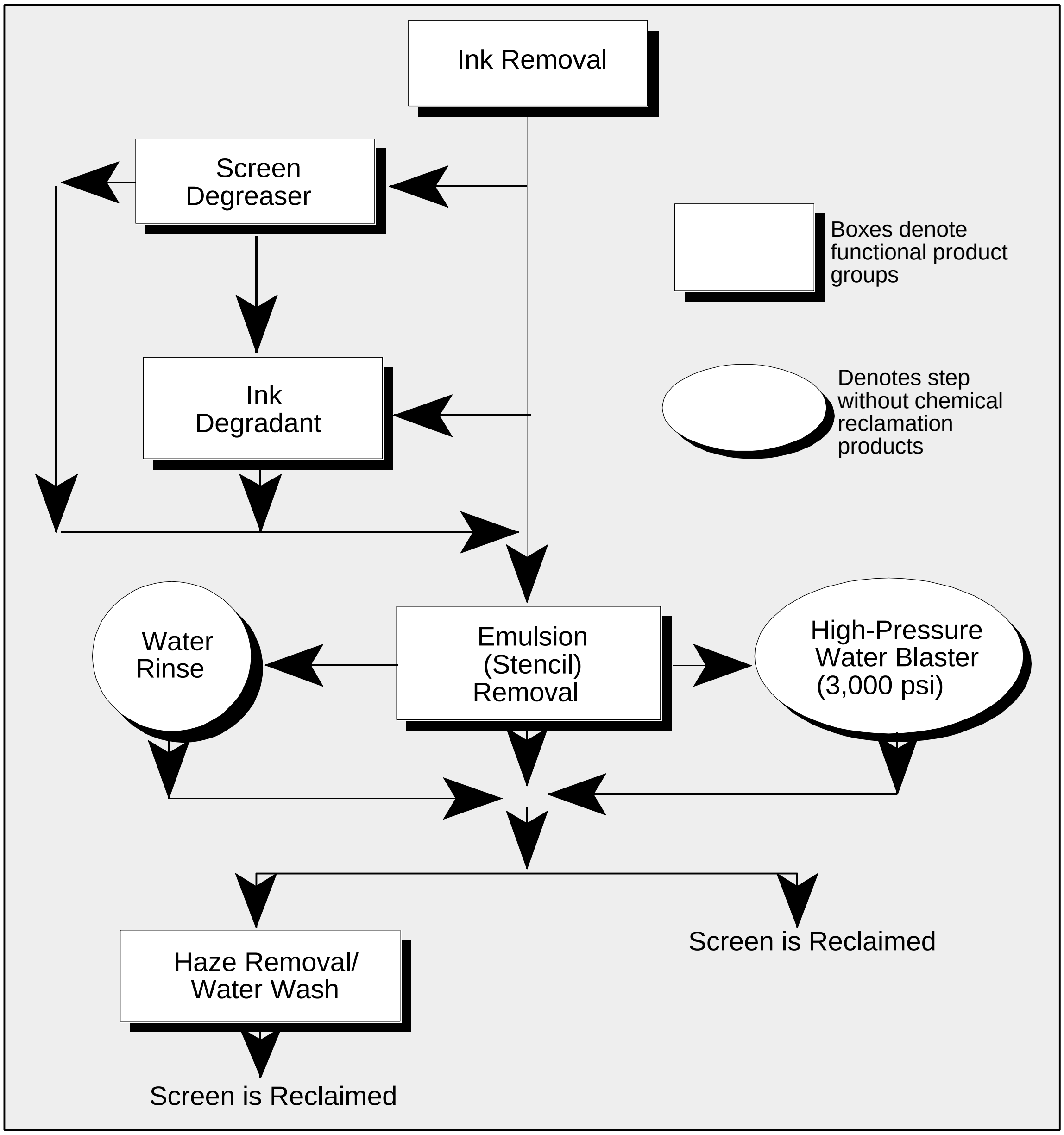
- A discrete, functional step of a multi-step process or system.
- The chemical components that can substitute for one another to perform a particular function of a chemical mixture.

For example, in the garment cleaning use cluster, the traditional dry cleaning process uses solvents to remove oils, stains, and odors. Although small amounts of water, detergent, and other additives may be used, chemical products in the dry cleaning process essentially employ one functional group: chemical cleaning solvents. On the other hand, the screen reclamation use cluster evaluated in the DfE Screen Printing Project typically consists of several steps to remove excess ink from a screen, remove the stencil that was used to block the ink, and remove any residual contaminants or haze to permit the screen to be reused.[8] Together these steps define two to three basic functions which must be performed to restore a used screen to a reusable condition:

[8] The screen printing process involves stretching a porous mesh material over a frame to form a screen. Part of the screen mesh is blocked by a stencil to define an image. A rubber-type blade is swept across the surface of the screen, pressing ink through the uncovered mesh to print the image defined by the stencil. The screen and its stencil can be used repeatedly to print the same image multiple times, after which the screen is reclaimed enabling a new stencil to be applied.

removal of ink, removal of emulsion (stencil), and removal of haze.[9] Two additional functions, screen degreasing and ink degrading, may be performed depending on the screen reclamation method used. Figure 2-6 is a graphical model of the integration of screen reclamation methods, depicting these five functional groups.

FIGURE 2-6: INTEGRATION OF SCREEN RECLAMATION METHODS



[9] Haze removal is required depending upon the type of ink used, effectiveness of ink removal and/or emulsion removal products, and the length of time that ink and stencil have been on the screen.

All of the chemical properties and data regarding the chemical properties which enable the chemicals to perform the desired function are analyzed together to identify alternative chemicals that have similar properties or that perform similar functions in other industries. In the Screen Reclamation CTSA, EPA looked at chemicals for which Pre-Manufacturing Notices (PMNs) required under the Toxic Substances Control Act (TSCA) had been filed in order to identify new or novel chemical substitutes. For potential substitutes that were identified, companies submitting PMNs were contacted to obtain permission to include these new chemicals in the assessment.

This valuable resource may not be available for CTSAs not carried out by EPA. EPA publishes Chemical-in-Progress Bulletins in the *Federal Register*, however, which are public sources of information that give generic chemical identities.[10] Routine searches of engineering and environmental literature, particularly for similar use clusters, also can be helpful.

Identifying Substitute Processes

During the Screen Printing Project, the project partners identified four main methods that are used to manually reclaim a screen. Because the actual process of screen reclamation can be performed using any of these methods, a variety of products used in each of these methods was evaluated. By comparing the chemicals used in the methods, as well as the methods themselves, a large array of choices becomes available. Figure 2-7 is a substitutes tree for screen reclamation, depicting the four main screen reclamation methods, the functional groups within each method, plus the additional alternatives of disposing of the screen mesh rather than reclaiming the screen, or using an automatic screen washer. A substitutes tree focussing on processes or methods can stimulate thought into how process steps can be combined, rearranged, or replaced to reduce risk and increase efficiency.

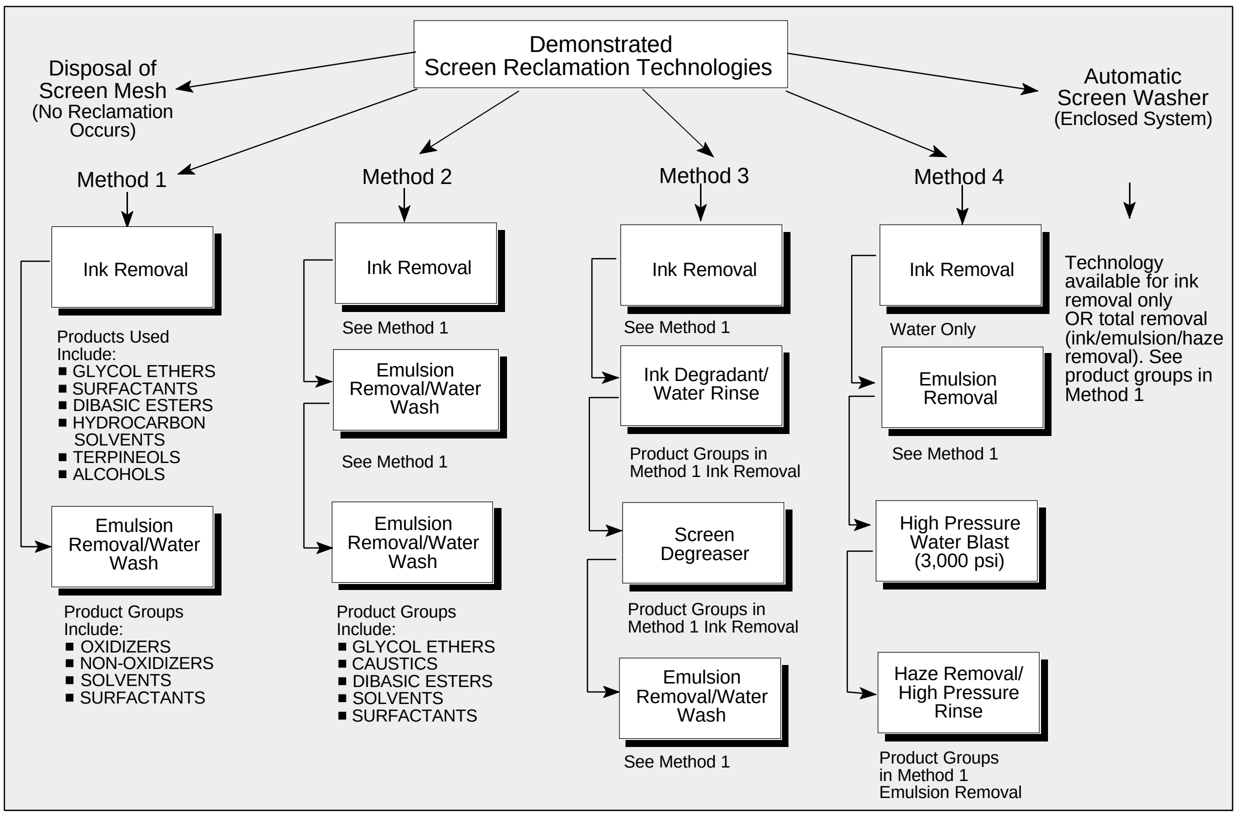
Method 2 in Figure 2-7 is the most common process used for screen reclamation, but each of the methods are currently used by the industry. An objective of the Screen Reclamation CTSA was to evaluate these alternative methods to provide standardized data on how well they work, what they cost, and their relative risk. Screen printers and other businesses are reluctant to change from a product or process that is time-tested to a new product or process unless there are demonstrated benefits. This illustrates the importance of including the range of traditional methods in a CTSA, since current industry practices may differ substantially in their environmental effects.

Identifying Substitute Technologies

Other industry sectors may also employ a number of different technologies to accomplish the same function. In the case of screen reclamation, most screen printers use some type of chemical cleaning procedure, but the project team wanted to stimulate thought on entirely new processes

[10] Chemical-in-Progress Bulletins can also be found on the World Wide Web at the following URL: http://www.epa.gov/docs/chemLibCIP.

FIGURE 2-7: SCREEN PRINTING SUBSTITUTES TREE OF DEMONSTRATED TECHNOLOGIES



or technologies that could perform the screen reclamation function. Thus, the project team examined the functional requirements of the screen reclamation process and reviewed literature sources for similar functional requirements in other industries. Figure 2-8 illustrates some of the technologies identified, primarily paint stripping technologies. Currently, some of these technologies are used in high-technology applications and may not be economically feasible for the average screen printing establishment. Others may be both technically and economically viable. For example, a preliminary performance demonstration of a pressurized sodium bicarbonate (baking soda) spray system indicated the technology may be feasible with appropriate equipment modifications.

As previously mentioned, the PWB Project is focussing on "making-holes-conductive," the process of depositing a conductive surface in the barrels of drilled through-holes in preparation for electroplating. PWB manufacturers have traditionally used an electroless plating process to make the drilled through-holes conductive, but new technologies that deposit carbon, graphite, or palladium are also employed. To date, the project has identified eight basic processes that use alternative technologies to perform the making-holes-conductive function (Figure 2-9). Each of these processes for making-holes-conductive is either currently used by the industry or being tested at PWB manufacturing plants.

SELECTING A SUBSET OF SUBSTITUTES FOR EVALUATION

Once several substitutes have been identified, the project team must decide which of these to evaluate. Traditional substitutes, those currently in widespread use, are usually selected for evaluation because they provide a baseline against which the risk, performance, and cost of all substitutes can be compared. In addition, dissimilar chemical formulations or methods within the range of traditional substitutes may pose vastly different risks. Nonetheless, if a substantial number of traditional substitutes are currently in use, the project team may have to place practical limits on the number evaluated. This is especially true for substitute chemical products.

The project team should also consider one or more new alternatives, depending on the project resources. Factors to consider when selecting new or novel alternatives include the following:

- The ability of an alternative to meet regulatory requirements in the application under review.

- The potential for reducing human health and environmental risk or net environmental impacts.

- The cost required to evaluate the alternative relative to others.

- The viability of the alternative in terms of its known relative cost or performance.

FIGURE 2-8: SCREEN PRINTING SUBSTITUTES TREE OF UNDEMONSTRATED TECHNOLOGIES

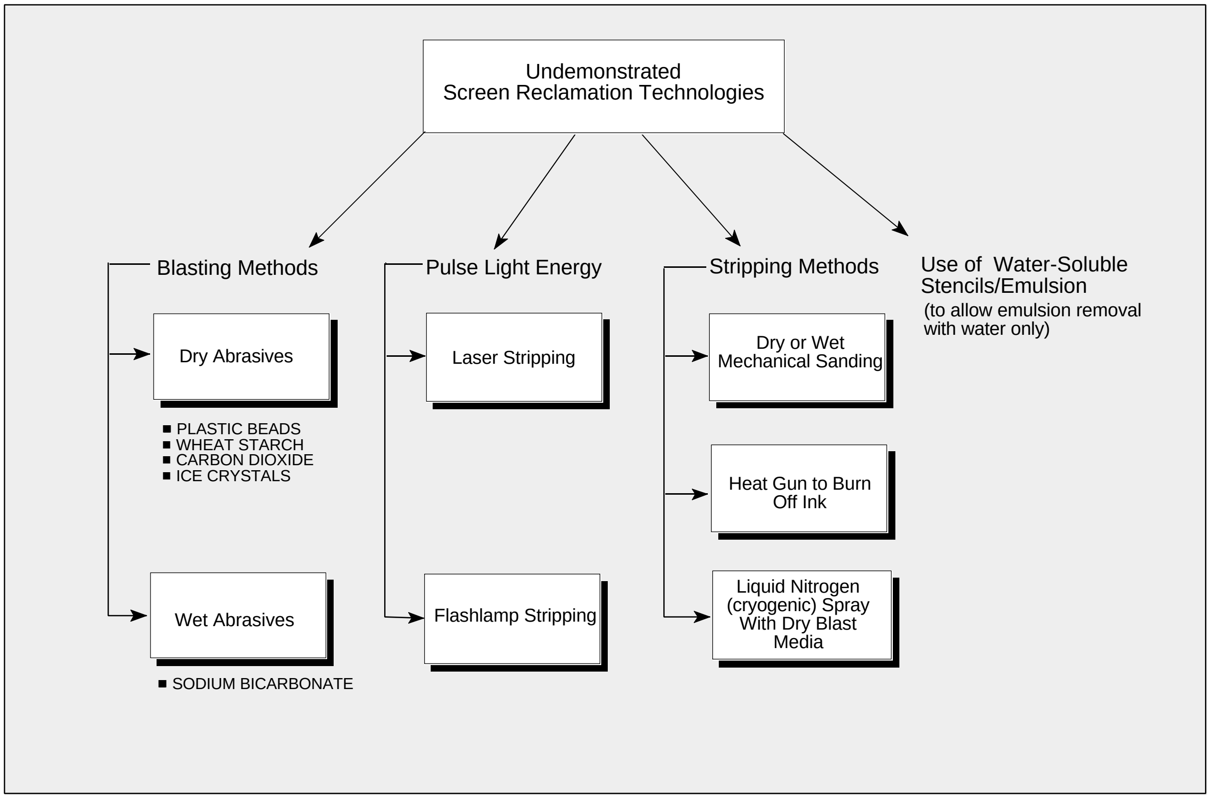
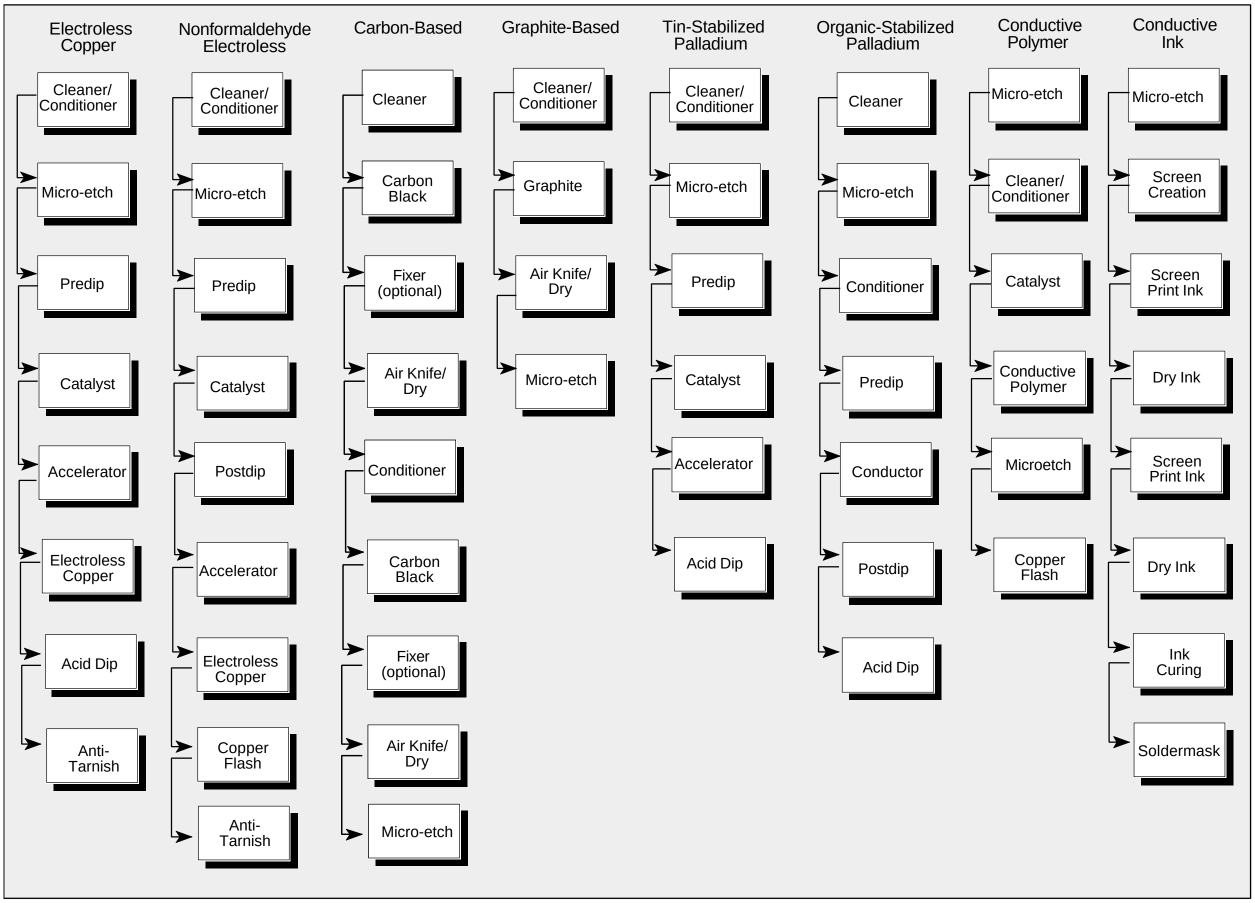


FIGURE 2-9: MAKING-HOLES-CONDUCTIVE SUBSTITUTES TREE



- The degree to which the suppliers or developers of the alternative are willing to participate in the project. Participation may include providing information or samples to the project.

- The applicability of the alternative to the industry as a whole.

- The degree to which the alternative is ready to enter the market (e.g., the research and development stage of the alternative).

- Whether or not implementing an alternative would require changes in process steps outside of the use cluster that would also have to be evaluated in the CTSA.

Participation by the developer(s) or supplier(s) of an alternative can be crucial to the project's success. For example, developers or suppliers of chemical products will need to provide information on their specific product formulations to conduct the risk characterization and samples of their products and material safety data sheets (MSDSs) for the performance assessments. Developers or suppliers of technologies will need to provide operating instructions in order to train staff of demonstration facilities in the correct use of the technology. Furthermore, if the technology has not been introduced to the market, the developer may need to provide one or more complete sets of equipment for the performance assessment.

Generic Chemical Formulations

The chemical formulations of commercial products containing several distinct chemicals are frequently considered proprietary. When undertaking a risk characterization or performance evaluation of such chemical products, the confidential nature of these formulations can complicate a CTSA analysis. Manufacturers of these products typically prefer not to reveal their chemical formulations because a competitor can potentially use the disclosed formulation to sell the product, often at a lower price, since the competitor did not invest the research and development resources in originally formulating and testing the product. In the DfE Screen Printing Project, suppliers of chemical products also did not want to list their brand name with the actual formulation because they feared a loss of market share if the product did not perform well in the performance demonstration or risk characterization. EPA was concerned about appearing to endorse brand name products that fared well in the CTSA evaluation. Due to these concerns, the project partners did not disclose the brand names or actual formulations of any chemical products in the Screen Reclamation CTSA.

However, to make the CTSA usable and flexible, the project partners devised a standard format for representing each chemical product with a generic product formulation. Each product was assigned a code name and each supplier was asked to give the confidential product formulation to EPA. While EPA used the confidential formulations to conduct a detailed risk characterization of each chemical product that appeared in the CTSA, the published CTSA represented a chemical product only by a code name and the generic formulation developed by EPA and the individual supplier. The generic formulations allow the users of the CTSA to compare different product systems while protecting the proprietary nature of the product formulation.[11] Without the generic product formulations, the suppliers in the DfE Screen Printing Project would not have participated in the submission of chemical products. While the generic formulations are important in obtaining supplier participation, they also make the CTSA a useful tool for evaluating other brand name products that may contain similar chemical constituents as those already evaluated. Given the formulation of a chemical product from a detailed MSDS, the human health risk, performance, and cost information can be compared with a product already evaluated in the CTSA. However, as a MSDS only lists chemical constituents which are hazardous to human health, environmental risks may not be able to be determined from the information presented solely on the MSDS.

A DfE team will usually ask suppliers to help develop the generic representative formulations since the suppliers are most knowledgeable of product components. A generic formulation may list only the primary chemicals and indicate the percent concentration of each chemical in a range, rather than the specific amount.[12] The team may agree to allow some proprietary chemicals to remain unidentified if they are present in small quantities (for example, less than one percent by weight) and not deemed hazardous in such a small quantity. However, some information about the chemical, such as the identity of a structurally similar compound, is necessary to determine if small quantities of the proprietary chemical could pose a hazard concern. Some of the chemicals may remain identified only by a generic family name, for example, replacing tripropylene glycol ether with the term propylene glycol series ether, although the risk characterization of the chemical product is still conducted using the specific chemical.

ESTABLISHING THE PROJECT BASELINE

A CTSA is a comparative evaluation requiring a baseline to compare the risk, performance, cost, and other environmental effects of alternatives (substitutes). DfE project teams select one or more alternatives that are currently in widespread use or familiar to most of the industry to serve as an industry standard(s) or project baseline(s). With a familiar baseline as the basis for comparison, the comparative data on risk, performance, cost, and conservation developed through the project will be understandable to the majority of industry. The number of alternatives selected depends on a number of factors, including the following:

[11] Because the brand names of the chemical products in the Screen Reclamation CTSA were not associated with their individual performance, cost, and risk data, it was difficult for a printer to locate the product that they wished to purchase. To alleviate this problem, the project partners published the name, address, and phone number of all the participating suppliers in the CTSA; a printer would need to call a supplier, state the generic formulation or code name from the CTSA, and ask the supplier if they sold the product. While this system involves some work by the printer, the project partners felt that it was the only way to meet the needs of all participants.

[12] If the percent volumes are reported as a range, the exposure assessment and risk characterization would have to be calculated based on some representative number within that range, usually the midpoint.

- *Is there a clear, industry-wide baseline?* For many industries, it may be difficult to establish a single product, process, or technology as the baseline. Returning to the example of the Screen Reclamation CTSA, a baseline was established for the four main methods used in Screen Reclamation. A variety of products and technologies used in each of these methods was evaluated.

- *Is the type of product, process, or technology used dependent on the size of a business?* The baseline may differ for small and large businesses. For example, automated technologies that are cost-effective for large companies may not be economically feasible for small businesses. The decision to include different project baselines for both small and large industry sectors will depend in part on the resources available to the project team and the primary environmental issues the project team plans to address (see Setting the Boundaries of the Evaluation, below).

- *Are different products, processes, or technologies required to meet end-user performance requirements?* Performance requirements and the alternatives typically employed to meet them may vary depending on the end-use of the product or service an industry sector provides. For example, the Screen Printing Project focussed only on printed plastic or vinyl substrates, as other substrates, such as textiles, required different types of inks, stencils, and reclamation chemicals to meet performance requirements. The DfE project team may need to establish a baseline for each set of performance criteria or narrow the focus of the project to one set of performance criteria.

- *Is the industry standard static or constantly changing?* Industry standard practice can change rapidly, especially in industries that are continuously evolving to meet increasing technological or other demands. If the industry standard changes rapidly, the project team needs to build flexibility into the project baseline to ensure that current and pertinent data are collected.

- *Are suppliers of the project, process, or technology participating in the project and willing to provide data?* To provide an adequate basis for comparison, data on the baseline must be at least as complete as the data on the alternatives. Again, suppliers are a crucial link to obtaining adequate information.

SETTING THE BOUNDARIES OF THE EVALUATION

The goal of designing for the environment is to design products and processes that minimize environmental impacts throughout their life cycles. Due to the complexity of the product life cycle, however, businesses often focus their environmental improvement efforts on the areas where the greatest environmental improvement opportunities lie and where they can most influence change. The CTSA methodology provides a flexible format that enables DfE teams to use this concept to set the boundaries of the evaluation before embarking on a CTSA. Setting the boundaries of the evaluation involves the following considerations:

- *What are the life cycle stages where the most significant environmental effects are believed to occur?* Environmental effects occur in each stage of the life cycle of a product or process, from extraction and processing of raw materials through manufacturing, use, and disposal. For practical purposes, past DfE projects have focussed on the use and disposal stages of the life cycle, where the greatest environmental impacts were believed to occur and the most data were available. Other project teams may choose to focus on other life cycle stages.

- *What are the primary environmental issues associated with the use cluster?* The DfE partners in the dry cleaning and printing projects were most concerned about the chemical risk from using toxic chemicals in dry cleaning and printing establishments. Partners working on other industry sectors may identify other issues, such as energy or nonrenewable resource consumption, as the primary environmental issues associated with a use cluster.

- *To what degree can project partners influence change?* DfE projects are designed to promote continuous environmental improvement. Due to time and resource constraints, project partners typically elect to focus their efforts on the areas where they can most influence change. Again, in DfE projects this has been in the use and disposal of chemicals at operating facilities. Other industry sectors may find that their proactive suppliers actively participate in the project by seeking ways to reduce the environmental impacts of the products and services they provide.

Each of these considerations is related. For example, the product life cycle must be reviewed to identify the primary issues associated with a use cluster. Without participation by suppliers or representatives from up-stream processes, the project team may find their ability limited to gather data as well as influence change in the up-stream process. The life cycle concept and each of these considerations are discussed in more detail below.

The Life Cycle Concept

Businesses, whether manufacturers of consumer products, commercial products, or commercial service industries, have traditionally defined the life cycle of the product, goods, or service they provide as beginning with product conception and moving through design, manufacturing, use, and disposal. Performance, quality, and cost requirements for the manufacturing, use, and disposal phases of the product life cycle are established during product conception. The product designer is charged with ensuring that these requirements are met.

In the 1990s, the term "product life cycle" has taken on new meaning. Environmental decision-makers in all stakeholder sectors have recognized that, to ensure the overall environmental improvement of a product or process, all stages of the life cycle where significant environmental impacts can occur should be considered. This can include the extraction and processing of the raw materials used to make the product, product manufacturing, transportation, use, recycling, and disposal. The concept of designing products and processes for the environment combines these two definitions of the product life cycle. The environmental effects of all significant stages of the product life cycle can be evaluated to incorporate environmental considerations into the design and redesign of products and processes.

"Extended product responsibility" is an emerging principle of pollution prevention that advocates this life cycle approach to identifying opportunities to prevent pollution and addresses the question, "How much can project partners influence change?" Under this principle, there is assumed responsibility for the environmental impacts of a product throughout the product's life cycle, also called the "product chain," including up-stream impacts inherent in the selection of materials for the product, impacts from the manufacturer's production process, and down-stream impacts from the use and disposal of the product. Thus, a shared "chain of responsibility" is borne by designers, manufacturers, distributors, users, and disposers of products. The greater the ability of the actor (i.e., designer, manufacturer, etc.) to influence the life cycle impacts of the product system, the greater the degree of responsibility for addressing those impacts should be. Because effective measures to reduce the life cycle environmental impacts of a product system usually involve changes in more than one link in the product chain, extended product responsibility creates a need and an opportunity for partnerships throughout the product chain (President's Council on Sustainable Development, 1996).

The CTSA process provides a framework for bringing together the actors throughout the product chain to address life cycle environmental impacts. From their origins in chemical risk management, CTSAs conducted under the DfE Program have, thus far, focussed on the life cycle stage where:

- The greatest chemical risk is believed to occur.
- The overall environmental impacts can most be affected by choices made by manufacturers and users of chemical products.

In the printing, dry cleaning, and printed wiring board industries, this has been in the manufacturing or commercial process itself and in the release or disposal of chemicals from manufacturing or commercial facilities. As conceptualized, however, the CTSA process is intended to use a more holistic life cycle approach, to include all stages of the product life cycle. The methods outlined in this publication focus on the use and disposal of chemicals by a particular industry, but they can also be applied to other stages of the life cycle, such as the manufacturing processes of industry suppliers.

Identifying Life Cycle Boundaries

To set the boundaries of the evaluation from a life cycle perspective, the project team might ask, "In which stage of the life cycle are the greatest environmental impacts believed to occur?" In some cases, this will be apparent, in others, it will not. For example, when considering the life cycle of the automobile, practitioners of life cycle assessment[13] agree that significant environmental impacts occur during the use of the automobile, due to the substantial amount of energy consumed and the emissions of air pollutants. In the case of pesticides, the manufacturing of chemical ingredients and use by consumers may be equally important, since pesticide products are intentionally released to the environment during use.

On a practical note, the time and resources available to conduct a CTSA may determine the degree to which up-stream or down-stream processes can be included in the evaluation. Due to time and resource constraints and the lack of readily available data, the chemical manufacturing process and other up-stream processes were not quantitatively evaluated in past CTSAs.

The following considerations may be helpful when identifying the life cycle stages on which to focus:

- *Are the natural resources used in the use cluster in abundant supply?* Resources that are being rapidly depleted are a serious concern. An industry dependent on scarce resources may wish to focus on the extraction and processing of raw materials to evaluate the environmental impacts, especially the social benefits and costs, of alternatives.

- *Do the natural resources occur only in low concentrations in their natural state?* The extracting and processing of raw materials that occur naturally in low concentrations may be of great environmental impact. For example, some metals that are found only in low concentrations in their ores may require more mining and processing of raw materials, more water and chemical use for extracting the metals, generate more mill tailings, and consume excessive energy.

- *Is use of the product likely to cause risk to consumers exposed to toxic chemicals?* Some products may have the greatest environmental impact during use by consumers. For example, the risk to workers manufacturing solvent-based paints could be small compared to the risk to persons using the paints who do not use personal protective equipment.

- *What are the environmental impacts of disposal of the product?* Some products are intentionally released to the environment by the consumer after use. For example, the aquatic toxicity of household cleaning products that are rinsed down the drain by the consumer could be of significant concern.

[13] Life cycle assessment (LCA) is another tool for evaluating the life cycle environmental impacts of a product or process. EPA defines LCA as follows: "A concept and methodology to evaluate the environmental effects of a product or activity holistically, by analyzing the whole life cycle for a particular product, process, or activity. The life cycle assessment consists of three complementary components — inventory, impact, and improvement — and an integration procedure known as scoping (EPA, 1993a)."

By focussing on the life cycle of the product, processes, or technologies in the use cluster, the project team will most likely identify many of the primary environmental issues associated with the use cluster, but in a holistic fashion.

Identifying Primary Environmental Issues

By involving representatives from up and down the product chain as well as public-interest groups, labor organizations, and other stakeholder communities, DfE partnerships provide an excellent forum for identifying the primary environmental issues associated with a use cluster. Diverse stakeholder groups bring different resources and unique perspectives to the table to ensure that important environmental issues are not overlooked. Examples of the issues the project team may elect to focus on include the following:

- Reducing risk to workers, surrounding populations (human and ecological), or consumers through use of substitutes, improved workplace practices that prevent pollution, or even pollution control technologies.

- Reducing energy impacts or conserving natural resources.

- Reducing workplace safety hazards.

The Dry Cleaning and Screen Printing Projects are good examples of the flexibility of the CTSA methodology in organizing information and in focussing on different types of environmental improvement opportunities. In the Dry Cleaning Project emphasis was placed on evaluating different types of pollution control methods as well as alternative cleaning technologies, whereas the screen printing project focussed on improving workplace practices and substituting chemical systems to reduce risk to workers.

Regardless of whether the focus is on alternative systems, technologies, or pollution control methods, the goal is to reduce risk, resource consumption, process safety hazards and/or other environmental effects, and provide tangible environmental improvements. The following are examples of questions a project team might ask to determine where the greatest improvement opportunities lie:

- *Where is a typical business located?* Facilities located in urban areas may have different impacts than those in rural areas. For example, dry cleaning facilities are typically located in or near residential areas. Therefore, the dry cleaning team elected to evaluate the risk to persons living near these shops.

- *Are many facilities located in areas with local or regional regulatory requirements?* Local or regional regulatory requirements may cause many businesses to seek alternative products or processes. For example, businesses that emit volatile organic compounds in non-ozone attainment areas may seek substitute chemical products that do not contribute to photochemical smog.

While these types of questions may identify the primary environmental issues associated with a use cluster, they will not necessarily identify the most significant problems for individual businesses. For example, a business located in a rural area where photochemical smog is not an overriding issue may be more concerned about the water releases to their septic system. Again, the flexible format of a CTSA is the key to providing sufficient information to enable individuals to make the best choices for their given situation.

Evaluating the Ability to Influence Change

DfE projects are action-oriented, designed to produce real, tangible environmental improvements. With limited resources available to the project, the project team needs to assess its ability to influence actors along the product chain to improve the environmental attributes of a product or process. In this regard, the project team may consider the following:

- *Which actors along the product chain are represented on the project team?* A DfE team strives to involve as many actors along the product chain as possible. Once again, suppliers are crucial to the project's success, not only for providing information on their products, but also for committing to strive to improve the environmental attributes of their products. In another example, public-interest groups can be instrumental in providing information to consumers on the improvements that businesses make when they implement a substitute.

- *What percentage of the overall market for the chemicals is used in the use cluster?* If the quantity of a chemical used by an industry is small relative to the overall market for the chemicals, the project participants may elect to not evaluate the environmental impacts and risks from the chemical manufacturing process. Their choice of whether or not to use that chemical would have only a slight effect on the overall risks from the chemical manufacturing process. The market information compiled in the Industry and Use Cluster Profile can be helpful when evaluating market share.

- *Is the CTSA project a priority of the project partners?* It is important to assemble project partners committed to an open, consensus-based evaluation process, but they must also be committed to the project at hand. If the selected use cluster is a low priority of the process partners, it may be difficult to accomplish the goals of a CTSA in a realistic time frame.

Each DfE project team will have a different set of questions or issues to address to set the boundaries of their own CTSA. While these questions and the questions in preceding sections may help the team to focus their project, an important point is that an open, consensus-oriented, cooperative evaluation process produces the best project design.