ALTERNATIVE ADHESIVE TECHNOLOGIES IN THE FOAM FURNITURE AND BEDDING INDUSTRIES: A CLEANER TECHNOLOGIES SUBSTITUTES ASSESSMENT

VOLUME 1: COST AND PERFORMANCE EVALUATION

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DISCLAIMER

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I. INTRODUCTION AND BACKGROUND

The Design for the Environment (DfE) Program in EPA's Office of Pollution Prevention and Toxics (OPPT) is a voluntary, cooperative program that works in partnership with industry to develop and distribute pollution prevention and environmental and human health risk information on alternative chemicals, processes and products. The DfE Program is a testing ground for new approaches to risk reduction through pollution prevention. The DfE approach uses cleaner technologies substitutes assessments (CTSAs) and life cycle tools to evaluate the performance, cost, and environmental and human health impacts of competing technologies.

A CTSA is a compilation of considerations and reference materials related to available and emerging technology in a given industrial sector. It serves as a guide for decision-makers and for industrial firms when they select technologies. The goal of the CTSA is to offer a complete picture of the cost, performance, environmental and human health exposure impacts associated with traditional and alternative chemicals, processes and products. The aim is to assist businesses in making more informed decisions that fit their situation.

This document describes a CTSA that focuses on the use of alternative adhesive technologies in the furniture and sleep products industries. Three sectors that rely heavily on porous substrate bonding adhesives were targeted for verification: foam fabrication, upholstered furniture manufacture and mattress manufacture. Regulations became much more stringent on the traditional solvent carriers in the adhesives commonly used by these industries to bond foam to various other substrates. A range of new and emerging alternatives that have different performance, cost, health and environmental characteristics are available. Many of the businesses in the targeted industries are small to medium sized and this project was structured to provide them with the information they would need to decide which alternatives were most suitable for their operations.

EPA has conducted several CTSAs that are very detailed. This project was designed as a streamlined CTSA which relies on a less rigorous methodology for evaluating the cost, performance and the environmental and human health implications. This document summarizes part of the CTSA, the part that focuses on the investigation of the cost and performance of the traditional and alternative technologies. It includes information on the verification of the alternative adhesive technologies.

The Institute for Research and Technical Assistance, a nonprofit organization located in Santa Monica, California, performed the research and conducted the analysis for this project. IRTA was established in 1989 to assist companies in adopting low- and non-solvent technologies in general cleaning, precision cleaning, dry cleaning, paint stripping and in coating, adhesive and ink operations. IRTA works with individual companies and with whole industry groups to test and demonstrate alternatives.

A project initiation meeting was held on September 15, 1998 to solicit input from a number of stakeholders on the project focus and design. The stakeholders included representatives from trade associations, adhesive formulation companies, companies that use adhesives, air, wastewater and hazardous waste regulatory agencies, the environmental community and a large electric utility. The list of attendees at the project initiation meeting is provided in Table 1-1.

IRTA made site visits to 32 facilities in the United States to investigate how adhesives were used in the processes and what alternatives companies had converted to or were planning to convert to. The verification facilities that supplied information on cost and

performance included 18 foam fabricators, nine upholstered furniture manufacturers and five mattress manufacturers. Table 1-2 shows the list of the companies and facilities IRTA visited for the data collection and verification. Four of the companies wish to remain anonymous and they are designated as Plant A, Plant B, Plant C and Plant D.

Table 1-1
Adhesives CTSA Project Stakeholders

Name	Affiliation
Shipra Bonsal	Communities for a Better Environment
Jack Broadbent	South Coast Air Quality Management District
Roger Coffey	Latex International West (representing Association of Woodworking & Furnishings Suppliers)
Larry Cozzo	Graco Inc.
Antonino Freitas	La-Z-Boy West
Bill Hanson	U.S. Environmental Protection Agency
Bill Hazelgrove	Imperial Adhesives
Ann Heil	Los Angeles County Sanitation Districts
Steven Isenhour	Hickory Springs
James Jones	National Institute for Occupational Safety and Health
Lori Kincaid	University of Tennessee Center for Clean Products & Clean Technologies
Mary Ann Lamascas	Atlas Spring (representing International Sleep Products Association)
Robert Ludwig	Cal/EPA's Department of Toxic Substances Control
Mike Magee	Upaco
John McCormack	California Bureau of Home Furnishings
Tom McCreery	3M Adhesives Division
Todd Mclntyre	Gulfstream
Ted Meinke	La-Z-Boy West
Jeff Miller	Atlas Spring
Mike Morris	Institute for Research and Technical Assistance
Bob Nylander	Foam Craft Inc.
David Pekelney	A&N Technical Services
Rick Peters	Covert Co., Inc.
Arlan Roll	Carpenter Co.
Pradeep Sharma	Southern California Edison
John Sparks	U.S. Environmental Protection Agency
Michael Stenburg	U.S. Environmental Protection Agency
Kenneth Stevanus	U.S. Occupational Safety and Health Administration
David Svendsgaard	U.S. Environmental Protection Agency
Gary Yee	California Air Resources Board
Katy Wolf	Institute for Research and Technical Assistance

Table 1-2
Project Site Visits

Company	Plant Type	Plant Location
American Seating	Upholstered Furniture	Grand Rapids, Michigan
Ashdale	Foam Fabrication	Conover, North Carolina
Blue Ridge	Foam Fabrication	Long View, North Carolina
Country Roads	Upholstered Furniture	Greenville, Michigan
Dixie Regency	Foam Fabrication	Conover, North Carolina
Foam Craft	Foam Fabrication	Cerritos, California
Four Seasons	Upholstered Furniture	El Monte, California
Guilford	Foam Fabrication	High Point, North Carolina
Hickory Springs	Foam Fabrication	Los Angeles, California Hickory, North Carolina
Highland	Foam Fabrication	Hickory, North Carolina
Independent Furniture Supply	Foam Fabrication	Tupelo, Mississippi
Jamison Bedding	Mattress Manufacture	Gallatin, Tennessee
Justice	Mattress Manufacture	Lebanon, Missouri
Latex International	Foam Fabrication	Santa Fe Springs, California
La-Z-Boy	Upholstered Furniture	Redlands, California
Leggett & Platt	Foam Fabrication	Lebanon, Missouri
Marsh- Armfield	Foam Fabrication	High Point, North Carolina Conover, North Carolina
Marx	Foam Fabrication	Hickory, North Carolina
McKinney	Mattress Manufacture	Springfield, Missouri
Plant A	Foam Fabrication	North Carolina
Plant B	Foam Fabrication	California
Plant C	Aircraft Seat Manufacture (considered part of Upholstered Furniture)	California
Plant D	Foam Fabrication	Michigan
Prestige	Foam Fabrication	Asheboro, North Carolina
Sit-On-It	Upholstered Furniture	Brea, California
Steelcase	Upholstered Furniture	Tustin, California Grand Rapids, Michigan
Southerland	Mattress Manufacture	Nashville, Tennessee
Trendway	Upholstered Furniture	Holland, Michigan
Vintage Bedding	Mattress Manufacture	Industry, California

On November 9, 1999, IRTA held a conference that was designed to update the stakeholders and other attendees on the results of the analysis and verification at that time. Panels of representatives from regulatory agencies and companies using adhesives provided information on the regulations that affect the alternative adhesives and on the issues involved in converting from one type of adhesive to another. IRTA prepared case studies including cost analysis that describe conversions 10 companies made to alternatives and these were handed out at the conference.

Several trade associations assisted in the project goals. Some of them provided information on the industries for this report; some were represented as stakeholders in the project; some assisted in identifying verification companies for site visits; and some helped by advertising

the November 9 conference. The trade associations that provided assistance during the project are listed in Table 1-3.

Table 1-3
Trade Associations That Assisted the Project

Adhesives and Sealants Council
Association of Woodworking & Furnishings Suppliers
Business and Institutional Furniture Manufacturers Association
International Sleep Products Association
Polyurethane Foam Association

This report presents the results of the performance and cost analysis of the alternative adhesives in the foam fabrication, upholstered furniture manufacturing and the mattress manufacturing industries. Section II provides background information on the targeted industries and on the characteristics of the alternative adhesive technologies. Section III presents the cost and performance analysis for 23 verification plants including 14 fabricators, five upholstered furniture manufacturers and four mattress manufacturers. Section IV, using the cost and performance analysis, discusses some of the findings of the project. Section V draws some conclusions and describes the next steps in the CTSA project.

II. BACKGROUND

This section focuses on the characteristics of the three industries that were targeted for this project. It also summarizes and compares the characteristics of the baseline and alternative adhesive technologies that are available. Typical examples of the adhesives are provided and discussed.

INDUSTRY CHARACTERISTICS

In 1997, about 830 million pounds of flexible polyurethane slabstock foam were produced. By 1998, slabstock foam production doubled to about 1.6 billion pounds. Slabstock foam is used in carpet underlay, furniture, bedding, packaging, transportation seating and other products where a durable and resilient cushioning material is required. There are 23 companies with about 75 pouring plants in the United States that manufacture the foam.

Slabstock foam is a low value, low density product, and foamers are generally located near their markets because of the high cost of transporting the foam. The major markets are predominantly carpet underlay, furniture and bedding. There is a large concentration of furniture manufacturers in the Southeastern United States and many foam plants are located in North Carolina, Tennessee, Arkansas and Mississippi. Flexible foam plants are also located in Southern California, another major furniture manufacturing center.

Slabstock foam lines are all designed to produce a bun of similar cross section. The foam line is generally between 50 and 200 feet long. A typical pouring operation is shown in Figure 2-1. The height of the bun ranges from about 30 to 54 inches. The width of the bun ranges from 65 to 88 inches. Foam plants cut and trim the buns into smaller pieces. Figure 2-2 shows a number of large buns finishing their cure and waiting to be shipped.

Figure 2-1
Flexible Slabstock Foam Manufacturing Operation

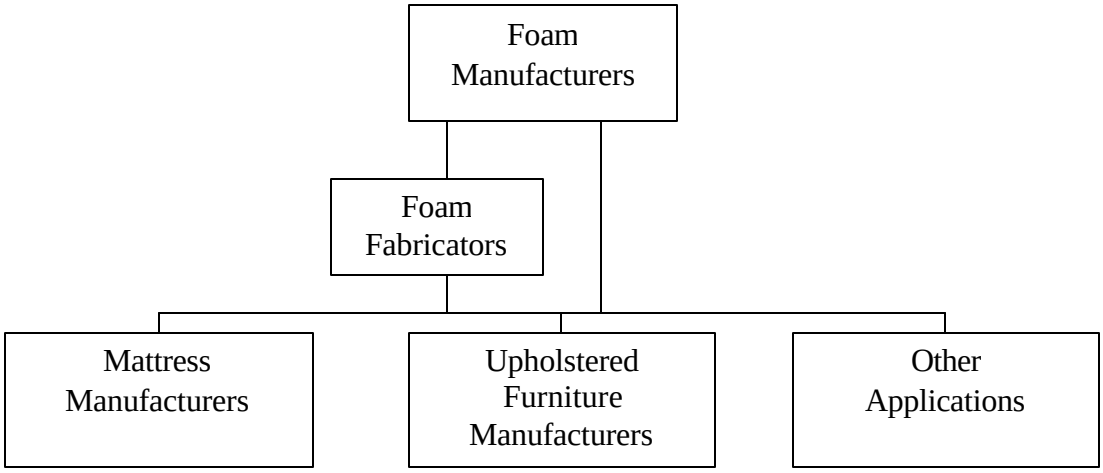
All of the foam that is manufactured is fabricated, a term that refers to cutting up the foam into pieces that are an important component in products like furniture and bedding. About half of the foam is fabricated in foam manufacturing facilities owned by foam

manufacturers. Most of the rest of the foam is fabricated by independent fabricators. Some of the foam is purchased directly by furniture and bedding manufacturers and fabricated at their sites.

Figure 2-2
Slabstock Buns Awaiting Shipment

Figure 2-3 shows the flow of the foam. Foam manufacturers produce the foam. Some foam manufacturers fabricate the foam. Independent foam fabricators purchase foam from the foam producers and fabricate it. End use sector manufacturers like upholstered furniture manufacturers and mattress manufacturers purchase fabricated foam from foam producers and from independent fabricators. Some of them fabricate the foam themselves.

Figure 2-3
Flow of Foam



Foam Fabrication

Independent foam fabricators purchase foam from foam manufacturers. There may be as many as 350 independent individual foam fabrication plants in the country. Many foam manufacturers with on- or off-site foam fabrication operations use the foam they manufacture in fabrication. All of these fabricators perform fabrication services for other companies that manufacture bedding, upholstered furniture and other products.

Some of the foam is fabricated using adhesives and some is not. In many cases, the foam requires a particular shape or a particular feel for an application. During fabrication, several different densities of foam or other materials like polyester fiber are bonded together to form a particular shape with specific characteristics. The foam used in sofa arms, for example, does not require adhesive. In contrast, different shaped pieces of foam are bonded together with adhesive to achieve a particular shape for sofa cushions. It is estimated that about one-third of the foam used in furniture manufacture and five percent of the foam used in bedding manufacture requires adhesive in the fabrication operation.

Fabricators use adhesive to bond foam-to-foam and foam-to-fiber. They generally spray the adhesives on the foam and/or fiber and bond the pieces together. Several views of a typical fabrication operation that uses adhesive is shown in Figures 2-4 through 2-6.

In a four county area in Southern California including Los Angeles County, Orange County, San Bernardino County and Riverside County, there are 121 foam fabricators. Eighty of these fabricators have fewer than 100 employees and only one of them has more than 500 employees. The Southern California fabricators account for about one-third of the nation's fabricators.

Upholstered Furniture Manufacture

Upholstered furniture manufacturers purchase foam from foam manufacturers or foam fabricators and they use the foam to manufacture their products. Some upholstered furniture manufacturers make home furniture, some make office furniture and some make both types of furniture. Other manufacturers make seating for use in arenas and public transportation vehicles like buses; some of these manufacturers also manufacture office chairs.

There are more than 2,600 upholstered home furniture manufacturers in the United States. Approximately 60 percent of these firms have fewer than 10 employees. Although all upholstered home furniture manufacturers use foam for their seat backs, arms, cushions and pillows, only about 10 percent of them use adhesives in their operations. They generally use adhesive to bond foam-to-fabric and foam-to-wood. Figure 2-7 shows an upholstered furniture manufacturing operation.

In a four county area in Southern California including Los Angeles County, Orange County, San Bernardino County and Riverside County, there are 38 wood home upholstered furniture manufacturers. Twenty-five of these manufacturers have fewer than 100 employees and only three of them have more than 500 employees.

There are about 950 companies that manufacture wood and non-wood office furniture. Approximately 90 percent, or about 850, of these manufacture seating. Perhaps 90 percent of these, or 765, use adhesives in their process. They use adhesives to bond foam to fabric, wood, metal and plastic and to bond fabric to wood, metal and plastic. Figure 2-8 shows an example of an upholstered office chair.

Figure 2-4
Fabrication Operation

There are about 14 stadium seating manufacturers in the United States. Thirteen of these manufacturers have fewer than 25 employees. There are 26 manufacturers in the United States that make seating for buses and other public conveyances. Some of these manufacturers also make stadium seating. About three-quarters of the companies have fewer than 25 employees. Stadium and transportation seating requires adhesives to bond various substrates including wood, metal and plastic. Figure 2-9 shows an arena seat and Figure 2-10 shows a bus seat.

Mattress Manufacture

There are an estimated 1,270 mattress manufacturers in the United States. Ninety percent of the mattresses are manufactured by 260 plants. Most manufacturers have between one and 50 employees. Perhaps 200 mattress manufacturers make pillow top mattresses which are generally considered a medium to high end bedding item. These mattresses are

Figure 2-5
Workers Bonding Foam and Fiber

Figure 2-6
Worker Spraying Adhesive

Figure 2-7
Upholstered Home Furniture Manufacturing

manufactured by using adhesive to bond the mattress itself to the pillow top. Figure 2-11 shows a pillow top mattress.

In a four county area in Southern California that includes Los Angeles County, Orange County, San Bernardino County and Riverside County, there are 84 mattress manufacturers. The vast majority -- 70 percent -- of these companies have fewer than 100 employees. As discussed above, about 16 percent of these companies or 13 of them, likely manufacture pillow top mattresses.

ADHESIVE ALTERNATIVES

Porous substrate bonding adhesives are adhesives used to bond one or more porous substrates together. Porous substrates include foam, fiber, fabric and, to some extent, wood. The foam fabrication industry generally bonds foam-to-foam or foam-to-polyester

Figure 2-8
Typical Upholstered Office Chair

fiber. The upholstered furniture industry bonds foam to other substrates like fabric, plastic or metal or wood. The mattress industry generally bonds fabric-to-fabric when they make pillow top mattresses.

The desirable performance characteristic of adhesives used in the fabrication industry is that the adhesive tack and bond fairly quickly. The bond should also be strong enough that the foam tears before the adhesive bond separates when the substrates are pulled apart. An important characteristic of adhesives in office furniture manufacture is that the adhesive bond fairly quickly but not so quickly that the workers cannot adjust the components. There is a tradeoff between the tack or bond time and the so-called open time, the time before the bond becomes permanent during which adjustments can be made. This characteristic is also important in pillow top bonding in the mattress manufacturing industry.

Most porous substrate bonding adhesives are liquid adhesives. They contain resins which function as the solids that are deposited on the substrate. They generally have a carrier which is either a solvent or water. The carrier is emitted during the application of the adhesives and the resins are left behind to maintain the bond. Some adhesives are 100 percent solids and they have no carrier.

In the 1980s and early 1990s, most of the adhesive used for porous substrate bonding in the industries of focus was based on 1,1,1-trichloroethane (TCA). TCA was an effective carrier for the adhesive because it evaporates rapidly leaving an instant bond. The

Figure 2-9
Typical Arena Seat

Figure 2-10
Typical Bus Seat

Figure 2-11
Pillow Top Mattress

chemical has a worker exposure level (a permissible exposure level or PEL) of 350 ppm. This level is relatively high, reflecting the fairly low toxicity of the chemical. TCA is not classified as a Volatile Organic Compound (VOC) that contributes to photochemical smog. The chemical does not have a flash point.

Primarily because of the chemical's status as exempt from VOC regulations, its relatively low toxicity and its lack of a flash point, it was used for many years by virtually all formulators of porous substrate bonding adhesives. A typical Material Safety Data Sheet (MSDS) for a TCA adhesive is shown in Appendix A; it is called "Kwikstik 2500." It contains about 77 percent TCA and small quantities of stabilizers. The balance of the adhesive, about 20 percent, is the solids that are left on the substrate to form the bond.

In the early 1990s, TCA was designated as a Class I ozone depleting substance and, in January, 1996, its production was banned worldwide under the Montreal Protocol. A substantial inventory of TCA remained and still remains today. A Federal tax was placed on ozone depleting substances in the U.S. to discourage use beginning in 1990. The tax was designed to increase over time. The TCA that remained became very expensive because of the tax and the adhesive formulators sought other chemicals that could function as carriers in their adhesives.

Adhesive vendors began offering formulations that were based on methylene chloride (METH). Like TCA, METH evaporates very quickly leaving a strong bond, does not have a flash point and is not classified as a VOC. Porous substrate bonding adhesives based on METH have been used for the last several years. An MSDS for a typical METH based adhesive is shown in Appendix A. This adhesive, called "Whisper Spray," contains 62 percent METH and six percent mineral spirits; the balance is various resins.

In January, 1997, the Occupational Safety and Health Administration (OSHA) issued a worker exposure regulation on METH because the chemical is a suspect carcinogen. The regulation lowered the PEL from 500 ppm to 25 ppm. It also established a so-called action level of 12.5 ppm. Companies that have worker exposure levels above 12.5 ppm, the action level, must monitor the exposure and must develop and implement a medical surveillance program.

The medical surveillance provisions have already become effective for all sectors where METH is used. The engineering controls for meeting the exposure levels were effective for large foam fabricators (more than 150 employees) in April, 1999. Small fabricators with fewer than 150 employees and any employer with fewer than 20 employees had until April of 2000 to install the engineering controls. Most foam fabricators have fewer than 150 employees so they were subject to the April, 2000 date. Many mattress manufacturers and upholstered furniture manufacturers have fewer than 20 employees and the April, 2000 date also applied to these companies.

In California, because of local air district regulations on toxics, companies could not use METH based adhesives at all. Most Southern California companies used TCA based adhesives for a much longer period than companies in other parts of the country. In about 1992, the formulators began developing water-based adhesives, at that time primarily for the Southern California market. More recently, they began offering acetone based adhesives. The chemical was deemed exempt from VOC regulations and it could be used in Southern California where the VOC regulations are very stringent. One hundred percent solids or hot melt adhesives were also being investigated to replace TCA based adhesives in California.

When the OSHA METH regulation was issued, the formulators began intensively investigating alternatives for the rest of the country as well. Acetone, water-based and hot melt adhesives that performed well were developed. In addition, the formulators began offering a new adhesive based on a chemical, n-propyl bromide (NPB), that was fairly new to the market.

NPB, like TCA and METH, readily evaporates and has no flash point. The chemical has unknown but likely high toxicity based on its structural similarity to other toxic brominated chemicals. The manufacturers have established a recommended worker exposure level of 100 ppm for NPB. The chemical is classified as a VOC and it has a small stratospheric ozone depletion potential. EPA's Significant New Alternatives Policy (SNAP) Program is evaluating whether to deem NPB an acceptable or an unacceptable alternative to other ozone depleting substances in the adhesives end use. In the meantime, NPB can be sold legally in the adhesives sector. Industrial grade NPB contains a contaminant 2-bromopropane (2-BP), a structural isomer. 2-BP is very toxic and it has caused reproductive problems in Korean workers. Some formulations contain a very high percentage of 2-BP.

OSHA and the National Institute for Occupational Safety and Health (NIOSH) have nominated NPB and 2-BP for testing under the National Toxicology Program. The two organizations have designated these two chemicals as their highest priority for testing based on the high exposure in the adhesives sector.

Two MSDSs for NPB based adhesives are shown in Appendix A. The first, called "non-Flammable Whisper Spray," contains 70 percent NPB (also called 1-PB). The second, called "Whisper Spray," contains 38 percent NPB. It also contains 25 percent trichloroethylene (TCE). TCE is classified as a VOC and is a suspect carcinogen.

Many formulators are offering acetone based adhesives. The chemical is low in toxicity and has a worker exposure level of 750 ppm. Like TCA and METH, acetone readily evaporates leaving a quick bond. The chemical has a very low flash point and measures must be taken to minimize the chance of fire or explosion. The National Fire Protection Association (NFPA) has rated acetone as an NFPA 704 level 3 flammability hazard. State building codes and fire codes are based on NFPA guidelines. The codes vary according to location and local fire departments have regulations that affect the amount of the adhesive

that can be stored and they require explosion proof motors and high air flow ventilation systems. Acetone is exempt from VOC regulations.

In Southern California, where the VOC regulations are very stringent, acetone based adhesives do not contain any other components. An MSDS of a typical acetone formulation, called "Slabond 523," is shown in Appendix A. It contains 75 percent acetone. Another acetone formulation, called "3694-0," also shown in Appendix A, contains only about 30 percent acetone. It also contains about 30 percent heptane which is classified as a VOC. This formulation and others with VOCs are used outside California.

In the early 1990s, formulators began developing one-part and two-part water-based formulations. The early one-part water-based adhesives were based exclusively on latex and they did not bond instantly like the solvent-borne adhesives. The two-part water-based adhesives were made from synthetics like polychloroprene. They were difficult to use in equipment but did bond instantly. Recently, the formulators have developed one-part water-based adhesives that are composed of latex and a small amount of synthetics. These adhesives bond more rapidly than the one-part water-based adhesives composed only of latex and they are also less costly than the two-part water-based adhesives. Because of these desirable characteristics, many adhesive users are likely to convert to the new adhesives in the next few years.

An MSDS for a synthetic two-part water-based adhesive, called "Fastbond 2000-NF," is shown in Appendix A. It contains 40 percent water and 30 percent polychloroprene and resins. An MSDS for a latex one-part water-based adhesive, called "Gen-Grip 1-S-4532," is also shown in Appendix A. It contains latex and a small amount of ammonia. Ammonia is used to treat latex when it is harvested so it will remain liquid and flow. Some portion of the population has an allergy to latex and workers with this allergy should not spray the latex adhesives. An MSDS for a one-part water-based latex with a small amount of synthetic, called "Fabond 858," is also shown in Appendix A.

In the 1990s, hot melt adhesives which are 100 percent solids began to be used more widely. They are heated to about 350 degrees F and are applied with specially designed spray guns. When the adhesive cools, it is cured. An MSDS for a typical thermoplastic hot melt adhesive, called "07270," is shown in Appendix A.

Virtually all companies that sprayed TCA and METH adhesives did so in the open without ventilation systems. Companies that wish to continue using METH adhesives would have to purchase and install effective ventilation systems that could reduce the worker exposure level to the new legal OSHA exposure limit of 25 ppm. Some companies that have converted to NPB adhesives have installed ventilation systems to reduce the exposure to the manufacturer recommended level of 100 ppm. Additional ventilation may be required to protect workers from the potentially toxic adhesive, particularly if 2-PB is present in the formulations. Companies that wish to convert to acetone based adhesives must install ventilation systems as part of fire department regulations to keep the concentration below the lower explosion limit. Water-borne adhesives that are sprayed form aerosols that can be annoying to workers. Companies that wish to convert to water-based adhesives should install ventilation to control the aerosol particulates. The only alternative system that does not require a ventilation system is hot melt adhesives.

Table 2-1 shows and compares the characteristics of the different adhesive types. It indicates whether the chemical or blend is classified as a VOC. It provides a qualitative measure of the chemical's toxicity. It indicates whether the chemical contributes to stratospheric ozone depletion. It designates those chemicals that have flash points. Finally, it summarizes one or more issues involved with using the alternative technology.

Table 2-1
Characteristics of Alternative Adhesive Systems

Adhesive System	Classified as VOC	Toxicity	Ozone Depleter	Flash Point	Issues
TCA	No	Medium	Yes	No	Production banned
METH	No	High	No	No	Suspect carcinogen; heavily regulated
NPB	Yes	In testing (NPB); High (2-BP contaminant)	Low	No	NPB has unknown but likely high toxicity; 2-BP has high toxicity
Acetone	No	Low	No	Yes	Fire regulations
Acetone Blends	Yes	Some high	No	Yes	Fire regulations
One-Part Water-Based	No	Low	No	No	Forms aerosols; allergy to latex
Two-Part Water-Based	No	Low	No	No	Forms aerosols; equipment problems
Hot Melt	No	Low	No	No	High temperature application

INDUSTRY USE OF ADHESIVE ALTERNATIVES

Not all of the different adhesive types are appropriate for use in the three sectors addressed in this study. In foam fabrication, where large quantities of adhesive are purchased, two-part water-based adhesives are not used. Hot melt adhesives are not appropriate for this sector either. Thus the alternatives to TCA and METH adhesives that are being used or are appropriate for this sector are adhesives based on NPB, acetone and acetone blends and water-based one-part adhesives.

In the upholstered furniture manufacturing sector, much of the industry has converted to hot melt adhesives. The industry is also using water-based one-part and water-based two-part adhesives. Some of the industry is testing acetone based adhesives for niche applications. Some companies with low volume operations are using acetone blends in aerosol adhesive products.

In the mattress manufacturing sector, again, much of the industry has converted to hot melt adhesives. Some companies with low production volume are using acetone blends in aerosol products. Another option being used by some pillow top mattress manufacturers is sewing. Instead of using an adhesive for bonding the pillow top to the mattress, these companies use an automated sewing process to join the two pieces.

Table 2-2 summarizes the options for each of the industry sectors.

Table 2-2
Alternatives to TCA and METH Adhesives by Industry Sector

Alternative Technology	Foam Fabrication	Upholstered Furniture Manufacture	Mattress Manufacture
NPB	X	-	-
Acetone	X	X	-
Acetone Blends	X	X	X
Water-Based One -Part	X	X	-
Water-Based Two-Part	-	X	-
Hot Melt	-	X	X
Sewing	-	_	X

III. COST AND PERFORMANCE ANALYSIS

This section focuses on the performance and the cost of the alternative adhesive technologies. IRTA made site visits to all of the facilities included here. The cost analysis was performed for 14 foam fabrication facilities represented by 12 companies, five upholstered furniture manufacturers, including one aircraft seat manufacturer and four mattress manufacturers.

PERFORMANCE AND COST ANALYSIS

In some cases, the companies included here were still using METH based adhesives. In most cases, the companies had made a conversion to alternative adhesive technologies at some stage in the last several years. IRTA collected information on the performance of the alternatives and compared the performance and cost of the traditional and new adhesive technologies. Performance and cost are intimately related. The companies selected the alternative technology based on its cost and on whether it could perform as well as the traditional solvent-borne technology. In many cases, the new technology required a learning curve and installation of new equipment.

Assumptions for Cost Analysis

IRTA attempted to collect cost information on the traditional and new adhesive technologies adopted by each company. In some cases, the information on the traditional technology was not available. In those instances, the cost data for the new technology is presented without comparative data for the traditional technology.

The cost information for the traditional and new adhesive technologies were compared on an annual basis. Several categories of information were collected. Each of these is discussed below.

Capital Cost. This type of cost generally involved purchase of new equipment for use with the alternative. Examples include ventilation systems and application equipment. In some cases, the companies paid cash for the equipment and these cash purchases were annualized over a ten-year equipment life. In other cases, the companies required a loan to make the purchase. In these instances, the cost was amortized over a ten-year equipment life; it was assumed that the cost of capital is five percent.

Adhesive Cost. These costs were determined by obtaining information on the amount of adhesive used in a year and the price each company paid for the adhesive.

Labor Cost. These costs were determined by obtaining information from each company on the average labor rate and the number of labor hours devoted to adhesive application annually.

Maintenance Cost. This cost included the cost of the cleanup solvent used for cleaning the application equipment. It also included the cost of the labor involved in the cleanup.

Electricity Cost. In a few cases, the companies knew their electrical costs. In most cases, however, they did not know the cost. If the cost involved installation of equipment, IRTA obtained information on the kilowatt (kW) rating of the motor or blower. IRTA also collected information on the usage rate of the equipment. In cases where the companies did not know their electrical rate, IRTA assumed an average rate of 12 cents per kilowatt hour.

Training Cost. In some cases, the companies incurred a training cost when they converted from the traditional to the new adhesive technology. IRTA obtained estimates from each company for this cost.

Regulatory Cost. In some cases, particularly for companies in California, adhesive operations require a permit from the local air district. Fees are often charged by the air district for the emission of certain types of chemicals, including TCA and METH. These costs are the actual cost paid by the facility.

Production Adjustment Cost. In two cases, the companies converted from the traditional to the new adhesive technology several years ago. Over that period, production increased substantially. The adjustment factor was estimated by the plant personnel. The production adjustment was made for the new adhesive technology to normalize it to the earlier production rate.

FOAM FABRICATION PLANTS

The cost analysis for 14 foam fabrication facilities operated by 12 companies is presented below. Case studies for five of the facilities operated by four companies are presented as stand-alone documents in Appendix B. The case studies focus on the conversions at Foam Craft, Prestige, Latex International and Hickory Springs.

Foam Craft Inc.

Foam Craft is a large foam fabricator located in Cerritos, California. The company historically used a TCA based adhesive for bonding foam-to-foam. Several years ago, the company began testing water-based adhesives and adopted a one-part water-based adhesive. The company reduced their cost by converting to the water-based adhesive. Foam Craft did not want to share the detailed cost information.

Prestige

Prestige used TCA until 1991 when the company switched to a water-based adhesive. They used a water-based one-part adhesive for a time and switched to a water-based two-part adhesive. They were not satisfied with either of the water-based adhesives and they have been testing several different technologies including acetone and n-propyl bromide. Currently one line uses a water-based one-part adhesive and the other line uses an n-propyl bromide based adhesive. The analysis below compares the cost of using the one-part water-based, the two-part water-based, the acetone and the n-propyl bromide adhesives.

Equipment purchases were necessary for the conversion to water-based adhesives. Prestige has two glue lines, each of which has 14 stations. They also have two additional stations. The company purchased 30 spray booths at a cost of $ 1,400 each. The total cost of the spray booths was $42,000. The company also purchased 30 HVLP spray guns at a cost of $700 each, for a total cost of $21,000. Two pumps at $2,800 each were also necessary for a total cost of $5,600. The total capital cost amounted to $68,600. These purchases would have been necessary for the acetone and the nPB as well. The acetone technology had an additional cost for spark arresters which carried a price of $6,000. The total cost for the acetone amounted to $74,600. Assuming a cost of capital of five percent and a 10-year equipment life, the annualized capital cost for all the technologies except acetone is $11,182. For acetone, the annualized capital cost is $ 12,160.

The firm used 93,750 gallons each year of the one-part water-based adhesive at a price of $7 per gallon. The annual cost of using the one-part water-based adhesive is $656,250.

The company used 67,800 gallons of the two-part water-based glue at a cost of $20 per gallon. The annual cost of this adhesive is $1,356,000. The company estimates that it would use 36,450 gallons of acetone adhesive at a price of $6 per gallon. The annual cost for the acetone glue is $218,700. The company also indicates that it would use the same amount, 36,450 gallons of nPB based adhesive, at a cost of $18 per gallon. The annual cost of this adhesive is $656,100.

In all four cases, the same amount of labor is required to apply the adhesive. Forty workers spray the glue full-time. Assuming a 40-hour work week and 50 weeks per year, each worker sprays for 2,000 hours per year. The total annual number of gluing hours is 80,000. At a labor rate of $9 per hour, the labor cost amounts to $720,000 annually.

The maintenance cost for all of the technologies is the same with the exception of the two-part water-based adhesive. In the other cases, 420 maintenance hours are required per year. At a labor rate of $9 per hour, the maintenance cost is $3,780 annually. For the two-part adhesive, 800 hours of maintenance per year are required. The maintenance cost for the two-part is $7,200 annually.

The electricity cost is the same for all four technologies. The plant uses 1,500 kWh per month. At a cost of 12 cents per kWh, the total annual electrical cost amounts to $2,160.

Training of the workers was necessary when the plant converted to water-based glues. In the case of the one-part and the two-part water-based adhesives, 30 employees had to be trained for about 40 hours each. Assuming a labor rate of $9 per hour, the training cost amounted to $10,800. That training cost should be spread over the useful life of the technology. In this case, it was spread over 10 years. This leads to an annual training cost of $1,080. The workers did not require training to use the acetone or nPB.

The plant has no regulatory cost for any of the technologies.

Table 3-1 shows the cost comparison for the four technologies. According to Prestige's estimates, the lowest cost option is acetone. The company plans to convert to this technology over the next year.

Table 3-1
Annual Cost Comparison for Prestige

	One-Part Water-Based	Two-Part Water-Based	Acetone Adhesive	n-Propyl Bromide Adhesive
Capital cost	$11,182	$11,182	$12,160	$11,182
Adhesive cost	$656,250	$1,356,000	$218,700	$656,100
Labor cost	$720,000	$720,000	$720,000	$720,000
Maintenance cost	$3,780	$7,200	$3,780	$3,780
Electricity cost	$2,160	$2,160	$2,160	$2,160
Training cost	$1,080	$1,080	$1,080	$1,080
Total cost	$1,394,452	$2,097,622	$957,880	$1,394,302

Latex International

Latex International fabricates foam and produces two types of foam bonded mattresses. The first type of mattress is a latex mattress for which the company bonds latex-to-latex. The second type of mattress is a polyurethane and latex mattress for which the company bonds latex-to-polyurethane foam. The company uses a one-part water-based adhesive for

the latex bonding and a different one-part water-based latex adhesive for the polyurethane foam bonding.

Early on, the company used a methylene chloride based adhesive. The firm converted to acetone based adhesives and then, finally, to the water-based adhesives they use today. Latex International used 4,884 gallons of acetone adhesive annually. At a cost of $7 per gallon, total annual costs for the acetone adhesive amounted to $34,188. The firm now uses 3,420 gallons per year of the one-part water-based latex adhesive. The cost of the water-based adhesive is $8 per gallon; the total cost of the water-based adhesives is $27,360 annually.

Latex International has 10 employees that apply adhesives. When the acetone adhesives were used, each employee worked 50 weeks per year and 40 hours per week. At a labor rate of $9.80 per hour, the labor cost was $196,000. The number of workers and labor hours has not changed with the conversion to water-based adhesives.

When the company used the acetone adhesives, 50 hours of maintenance were required each year. At a labor rate of $9.80 per hour, the total annual maintenance cost was $490. The water-based systems require less maintenance time, about 38 hours per year. The total maintenance cost of the water-based systems is $372 per year.

When acetone based adhesives were used, the company had to purchase spark arresters at a cost of $800. Assuming the company paid cash for these purchases and that they were used for two years, the annual cost amounted to $400.

The electricity cost remained the same when the company converted from acetone to water-based adhesives. The kWh usage is 1,000 per month or 12,000 per year. At a cost of 12 cents per kWh, the total electrical cost is $1,440 annually.

Latex Internationa] had a training cost for the workers so they could learn to apply the one-part latex. The synthetic water-based was easier to apply and there was no training required. Four workers required 120 hours each for training. At a labor rate of $9.80 per hour, the training cost amounted to $4,704. Assuming this training cost is spread over 10 years, the annual cost was $470.

Latex International has always had two large spray booths. There were permit fees for the acetone booth and for the water booths. Each booth permit costs $176 per year for a total annual permit cost of $352.

Table 3-2 shows the cost comparison for Latex International for the acetone and the water-based adhesives.

Table 3-2
Annual Cost Comparison for Latex International

	Acetone Adhesive	Water-Based Adhesive
Capital cost	$400	-
Adhesive cost	$34,188	$27,360
Labor cost	$196,000	$196,000
Maintenance cost	$490	$372
Electricity cost	$1,440	$1,440
Training cost	-	$470
Regulatory cost	$352	$352
Total cost	$232,870	$225,994

The cost to Latex International for using the water-based adhesives is three percent lower than the cost of using the acetone adhesives. The labor cost, which is the same in both cases, dominates the cost.

Hickory Springs--Conover

Hickory Springs has 16 stations where adhesive is applied. In the Conover, North Carolina plant, when the company used METH based adhesives, they had fans in the plant but no ventilation system as such. With the conversion to acetone based adhesives, Hickory Springs installed ventilation systems that collect from the floor at 11 of the stations and at five of the stations, a fan pulls the air outside.

The capital cost of the ventilation system equipment for use with the acetone adhesives was $11,000. Using a cost of capital of five percent and a 10 year life of the equipment, the annualized cost for the capital purchase is $1,793.

The Hickory Springs Conover plant used 11,000 gallons of METH based adhesives and still uses the same amount of acetone based adhesive. The cost of the METH adhesive was $5 per gallon for a total annual cost of $55,000. The cost of the acetone adhesive is $6 per gallon for a total annual cost of $66,000.

Sixteen employees apply the acetone adhesives, the same number that applied the METH adhesive. Assuming a 50 week year and 40 hours a week, the employees devote 32,000 hours to applying adhesives. At an average labor rate of $9 per hour, the labor cost amounts to $288,000 for both the METH and acetone based adhesives.

Hickory Springs indicates that 267 hours per year were devoted to maintenance for the METH based adhesives; the same amount of maintenance is required for the acetone adhesives. At a labor rate of $9 per hour, the maintenance labor in both cases is $2,403.

The electrical cost increased when the company converted from METH to acetone based adhesives. The company now uses 875 kWh per month. At a kWh cost of 12 cents, the annual electrical cost is $1,260.

There was no training cost because applying the acetone and METH adhesives is similar.

The conversion to acetone based adhesives did not change Hickory Springs' insurance premiums because of the flammability of acetone. There were no premium adjustments as long as the company met the insurance company recommendations.

Table 3-3 shows the cost comparison for Hickory Springs for the METH and acetone based adhesives.

Table 3-3
Annual Cost Comparison for Hickory Springs--Conover

	METH Adhesive	Acetone Adhesive
Capital cost	-	$1,793
Adhesive cost	$55,000	$66,000
Labor cost	$288,000	$288,000
Maintenance cost	$2,403	$2,403
Electricity cost	-	$1,260
Total cost	$345,403	$359,456

The figures show that the cost of using the acetone adhesives is higher by about four percent. The cost is higher primarily because the acetone based adhesive is slightly more costly than the METH based adhesive for the plant.

Hickory Springs--City of Commerce

The City of Commerce Hickory Springs plant in California exited the foam fabrication business from 1991 to 1998. In 1998, when the company decided to reenter the market, the company examined and adopted a water-based one-part adhesive. This adhesive was more difficult to use. When an acetone adhesive, which was more forgiving, became available, the company decided to convert to it. The cost analysis presented here compares the water-based one-part and the acetone based adhesive.

Hickory Springs has always had a spray booth for applying the adhesives. Thus no new booths were necessary for the conversion to water-based adhesives. The company had to move some of the electrical outlets 50 feet away from the acetone storage area and the booth. The cost of the improvements was about $1,000. Assuming the company paid cash for this work and assuming a 10-year equipment life, the annual capital cost amounted to $100.

When Hickory Springs used water-based adhesive, they used 1,080 gallons per year. At a cost of $7 per gallon, the annual adhesive cost was $7,560. After the conversion, the company used 1,200 gallons of acetone adhesive at a cost of $6.50 per gallon. The annual adhesive cost amounted to $7,800.

Ten employees have always applied the adhesives. The plant manager indicates that there was much more maintenance time required for the water-based adhesives. He kept records of the workers' labor time and he estimates that 1,944 hours were devoted to applying the water-based adhesives and maintenance activity annually. At the company's average labor rate of $12.26 per hour, the annual labor cost with the water-based adhesive was $23,833. The number of labor and maintenance hours used for the acetone based adhesives is less, at 1,296 hours per year. The annual labor and maintenance cost for the acetone based adhesives is $15,889.

When the company used water-based adhesives, the monthly electrical usage was 149 kWh. At a cost of 12 cents per kWh, the annual cost of electricity was $215. The electrical usage declined to 99 kWh per month after the conversion to acetone adhesives. The annual cost of electricity with acetone adhesives is $143.

Similarly to the Conover plant, there were no acetone related insurance premium adjustments at the City of Commerce plant. The plant met the insurance company recommendations.

The plant manager estimates that the company is more efficient after the conversion to acetone based adhesives. The company was only three-fourths as efficient when the water-based adhesive was used. Thus the cost figures must be adjusted using a production factor. The costs for the acetone adhesive provided below were adjusted by multiplying by 0.75.

Table 3-4 compares the costs for Hickory Springs for the acetone and the water-based adhesives. The cost to Hickory Springs of using the water-based adhesive was 43 percent higher than the cost of using the acetone based adhesive.

Table 3-4
Annual Cost Comparison for Hickory Springs--City of Commerce

	Water-Based Adhesive	Acetone Adhesive
Capital cost	-	$100
Adhesive cost	$7,560	$7,800
Labor/maintenance cost	$23,833	$15,889
Electricity cost	$215	$143
Total cost	$31,608	$23,932
Production adjusted total cost	$31,608	$17,949

Marsh-Armfield—Conover

Marsh-Armfield is a foam fabricator located in Conover, North Carolina. The company used a TCA based adhesive for several years. When the chemical became expensive, the company tried a one-part water-based adhesive but it didn't work well for them. Marsh-Armfield has converted to a NPB based adhesive and is using it exclusively today.

Prior to the conversion, Marsh-Armfield used 32 drums or 1,760 gallons of TCA based adhesives. At a cost of $7.65 per gallon, the total adhesive cost was $13,464 annually. At this stage, the company uses 24 drums of NPB adhesive per year at a cost of $16 per gallon. The total cost of purchasing the NPB adhesives amounts to $21,120 annually.

The company has 12 glue stations, and 12 workers apply the adhesives. Assuming a 50 week year and a 40 hour workweek, each worker devotes 2,000 hours per year to the spraying operation. The company's total labor hours amount to 24,000. Marsh-Armfield's labor rate is $8.25 per hour. The total labor cost with both the TCA and NPB adhesives is $198,000.

There has been no change in the cost and frequency of maintenance with the conversion from TCA to NPB adhesives. No training was required to make the conversion from TCA to NPB adhesives.

Marsh-Armfield installed booths when they tested the water-based adhesives. The company fabricated their own ventilation system which is now used together with the booths with the NPB adhesive. Each of the booths has a one-third horsepower blower. The electric load is 375 kWh per month or 4,500 kWh per year. Assuming an electricity cost of 12 cents per kWh, the total electrical cost of using the NPB adhesive is $540 annually.

Table 3-5 shows the cost comparison for the TCA and the NPB adhesives for Marsh-Armfield. The cost of using the NPB adhesive is four percent higher than the cost of using the TCA adhesive.

Table 3-5
Annual Cost Comparison for Marsh-Armfield--Conover

	TCA Adhesive	NPB Adhesive
Adhesive cost	$13,464	$21,120
Labor cost	$198,000	$198,000
Electricity cost	-	$540
Total cost	$211,464	$219,660

Marsh-Armfield--High Point

Marsh-Armfield, located in High Point, North Carolina, is an independent fabricator with 35 employees. Much of their foam goes into seat backs for buses. The company used METH based adhesives for many years and about a year and a half ago converted to an NPB adhesive. The NPB adhesive also contains trichloroethylene (TCE).

The company has always had a ventilation system and no additional ventilation was installed after the conversion.

Marsh-Armfield used about 5.5 drums per month of the METH adhesive. This amounts to 3,630 gallons per year. At a cost of $8 per gallon, the annual adhesive cost was $29,040. After the conversion to the NPB/TCE adhesive, the company reduced their adhesive use to about 3.5 drums per month or 2,310 gallons per year. The cost of the NPB/TCE adhesive is $16 per gallon. The total annual adhesive cost for the company is now $36,960.

Marsh-Armfield has 13 adhesive application stations and seven of them are used every day. Nine workers apply the adhesive during one shift per day and their labor rate is $8 per hour. Assuming the workers work a 40 hour week 50 weeks per year, the total annual labor cost is $144,000. The labor cost has not changed since the conversion to the NPB/TCE adhesive.

The workers spend about 25 hours a year maintaining the spray equipment. At a labor rate of $8 per hour, the labor maintenance cost is $200 annually. The workers used 100 gallons of METH for cleanup. At $6 per gallon, the cleanup solvent cost was $600 annually. The total maintenance cost is $800 per year and the plant manager indicates that this cost has not changed with the conversion.

The company uses about 500 kWh per month to run the ventilation system. At a cost of 12 cents per kWh, the annual electricity cost amounts to $720. This cost has not changed since the conversion to the NPB based adhesive.

Table 3-6 presents the cost comparison for the METH and NPB adhesive for Marsh-Armfield. The cost of using the NPB based adhesive is about five percent higher than the cost of using the METH adhesive.

Table 3-6
Annual Cost Comparison for Marsh-Armfield--High Point

	METH Adhesive	NPB Adhesive
Adhesive cost	$29,040	$36,960
Labor cost	$144,000	$144,000
Maintenance cost	$800	$800
Electricity cost	$720	$720
Total cost	$174,560	$182,480

Plant A

Plant A, an independently owned foam fabricator, is located in North Carolina. The company fabricates between 500 and 700 pieces per day and one-third of their volume is used by one chair manufacturer. In the past, the company used a METH based adhesive. Plant A has tested several different types of adhesives but recently converted to an acetone adhesive.

Plant A installed four spray booths in anticipation of the conversion to acetone. The cost of the spray booths amounted to $25,000. Assuming a cost of capital of five percent and an equipment life of 10 years, the annual capital cost is $4,075.

The company used about one drum of METH adhesive every four days or 3,438 gallons per year. The cost of the METH adhesive was $8 per gallon. The total cost of the METH adhesive was $27,504 per year. About seven percent less acetone adhesive or 3,197 gallons are required annually. At an adhesive cost of $11 per gallon, the total annual cost of the acetone adhesive is $35,167.

Four workers spray adhesives and the average labor rate is $13 per hour. Assuming each worker works a 40-hour week for 50 weeks per year, the total labor cost is $104,000. The labor with the METH and the acetone adhesives is the same.

The workers spend 50 hours per year in maintaining the spray equipment. At the labor rate of $13 per hour, the labor maintenance cost is $650 per year. About 50 gallons of paint thinner at a cost of $4 per gallon are used for the cleanup. The total annual maintenance cost amounts to $850. The maintenance practices did not change with the conversion from METH to acetone adhesives.

The ventilation system uses 625 kWh per month. At a cost of 12 cents per kWh, the electricity cost amounts to $900 annually.

Table 3-7 shows the cost comparison for the METH and acetone adhesives for Plant A. The cost of using the acetone adhesive is about 10 percent higher than the cost of using the METH adhesive.

Table 3-7
Annual Cost Comparison for Plant A

	METH Adhesive	Acetone Adhesive
Capital cost	-	$4,075
Adhesive cost	$27,504	$35,167
Labor cost	$104,000	$104,000
Maintenance cost	$850	$850
Electricity cost	-	$900
Total cost	$132,354	$144,992

Guilford Fabricators

Guilford, a small fabricator with about 25 employees, is located in High Point, North Carolina. The company historically used a methylene chloride based adhesive but recently converted to an NPB based adhesive.

Guilford installed five spray booths at the adhesive stations to provide ventilation to the workers when they spray the adhesives. The booths each cost $1,000. Assuming a 10-year lifetime for the equipment and a five percent cost of capital, the annualized cost of the capital investment is $815.

Guilford used 1,375 gallons annually of the METH based adhesive. At a cost of $8.50 per gallon, the total annual cost of using the METH adhesive was $11,688. The company reduced their adhesive use to 460 gallons after the conversion to the NPB adhesive. The cost of the NPB adhesive is $16.50 per gallon and the total annual cost for purchasing the adhesive is $7,590.

Five workers spray the adhesives. Guilford pays the workers an average rate of $7.50 per hour. Assuming the workers spray eight hours per day for 50 weeks per year, the total annual labor cost amounts to $75,000. The labor cost has not changed since the conversion from METH to NPB based adhesives.

The workers spent about 50 hours per year on maintenance of the spray equipment when the METH adhesives were used. At a labor rate of $7.50 per hour, the labor maintenance cost amounts to $375 annually. Guilford indicates that the cost of the chemical used in maintenance is negligible. In the case of the NPB adhesive, about three hours per month or 36 hours per year are required to change the filter material for the ventilation system in addition to the cleanup labor. The total labor hours are now 86. At a labor coat of $7.50 per hour, the labor cost with the NPB adhesive is $645.

The ventilation system uses 500 kWh of electricity per month. Assuming a cost of 12 cents per kWh, the annual electricity cost is now $720.

Table 3-8 below shows the cost comparison for Guilford for the METH and the NPB adhesives. The cost of using the NPB adhesives is 2.6 percent less than the cost of using the METH adhesive.

Table 3-8
Annual Cost Comparison for Guilford Fabricators

	METH Adhesive	NPB Adhesive
Capital cost	-	$815
Adhesive cost	$11,688	$7,590
Labor cost	$75,000	$75,000
Maintenance cost	$375	$645
Electricity cost	-	$720
Total cost	$87,063	$84,770

Marx Industries

Marx, an independent foam fabricator, is located in Conover, North Carolina. The company used a METH based adhesive in the past and converted to an NPB adhesive about a year and a half ago.

When Marx converted to the NPB adhesive, they installed four fans to provide ventilation for the workers spraying the adhesive. Each of the fans cost $800 for a total cost of $3,200. Assuming a 10-year lifetime for the fans and a five percent cost of capital, the annualized capital cost amounts to $522.

Marx used about nine drums per week of the METH adhesive. Assuming the company operates 50 weeks per year, the total adhesive use is 24,750 gallons annually. The cost of the METH adhesive is $7.70 per gallon. The total annual cost of the METH adhesive was $190,575. Marx estimates that they now used half the amount of NPB adhesive or 12,375 gallons per year. The cost of the NPB adhesive is $15 per gallon. The total cost of using the NPB adhesive is $185,625 annually.

Sixteen workers apply the adhesives. The average labor rate is $9.50 per hour. Assuming the workers work a 40 hour week for 50 weeks a year, the total labor cost for applying both the METH and the NPB based adhesive is $304,000.

The workers spent 800 hours a year on maintenance of the spray equipment. Using the average labor rate, the maintenance labor cost with the METH and the NPB adhesives is $7,600. About 200 gallons of METH were used for cleaning the spray equipment and the same amount of NPB is used today. The cost of the METH and the NPB is $6 and $12 per gallon respectively. The total maintenance cost with the METH adhesive was $8,800 annually. The total maintenance cost with the NPB adhesive is $10,000 annually.

The electricity use after installation of the ventilation system is 1,200 kWh per month. At a cost of 12 cents per kWh, the electricity cost is $1,728.

Table 3-9 shows the cost comparison for Marx in using the METH and the NPB based adhesives. The cost of using the two types of adhesives is comparable.

Table 3-9
Annual Cost Comparison for Marx Industries

	METH Adhesive	NPB Adhesive
Capital cost	-	$522
Adhesive cost	$190,575	$185,625
Labor cost	$304,000	$304,000
Maintenance cost	$8,800	$10,000
Electricity cost	-	$1,728
Total cost	$503,375	$501,875

Ashdale Foam

Ashdale Foam has used a METH based adhesive for many years. For the last year or so, the company has been testing NPB based adhesives. Half of the production currently is METH adhesives and half is NPB adhesives. When one drum of adhesive is empty, the company switches to the other kind of adhesive. The analysis below compares the costs of using METH adhesive exclusively and the cost of using all NPB adhesive exclusively.

When Ashdale began using NPB based adhesives, they installed a ventilation system at a cost of $11,000. Assuming a 10-year equipment life and a five percent cost of capital, the annual cost of the ventilation system is $1,793.

Ashdale uses about one drum of adhesive every three weeks or 953 gallons per year. The cost of the METH adhesive is $9.70 per gallon. The annual cost of using the METH adhesive is $9,244. The company uses the same amount of NPB adhesive which is much more costly, at $14 per gallon. The total annual cost of using the NPB based adhesive is $13,342.

Ashdale has six glue stations and five workers apply the adhesives. The company's average labor rate is $7.50 per hour. The company works one shift and, assuming each worker spends 40 hours a week 50 weeks a year applying adhesive, the total annual labor cost is $75,000. The labor cost is the same with the METH and the NPB based adhesives.

About 200 labor hours a year are required for equipment maintenance. At the labor rate of $7.50 per hour, the labor cost is $1,500. About 200 gallons of METH is used for the cleanup activities. At a METH cost of $6 per gallon, the chemical cost is $1,200. The total maintenance cost for the METH adhesive is $2,700. If the company converted exclusively to NPB based adhesives, the labor cost of maintenance would be the same, at $1,500. About 200 gallons of NPB would be required for maintenance. At a cost of $14 per gallon, this amounts to $2,800. The total maintenance cost assuming a complete

conversion would be $4,300 annually.

The ventilation system installed to control exposure to NPB uses 500 kWh per month. Assuming an electricity cost of 12 cents per kWh, the electricity cost for the NPB based adhesives is $720 annually.

Table 3-10 compares the cost of using METH and NPB based adhesives exclusively for the company. The labor cost dominates the total costs. Even so, the cost of using the NPB adhesives is more than nine percent higher than the cost of using the METH adhesives.

Table 3-10
Annual Cost Comparison for Ashdale Foam

	METH Adhesive	NPB Adhesive
Capital cost	-	$1,793
Adhesive cost	$9,244	$13,342
Labor cost	$75,000	$75,000
Maintenance cost	$2,700	$4,300
Electricity cost	-	$720
Total cost	$86,944	$95,155

Plant B

This company is located in the Southern California area. Plant B uses a METH based adhesive to bond foam-to-foam which is used in seat cushions for furniture. The company produces as many as 250,000 pieces per year.

Plant B uses 400 gallons of METH adhesive per month or 4,800 gallons per year. The cost of the adhesive is $9.80 per gallon. The total annual cost of adhesive is $47,040.

Plant B operates for one shift during which four employees spray adhesives. Assuming each worker sprays for 8 hours a day 50 weeks a year, the total labor hours are 8,000. The average labor rate ranges from $5 to $7 per hour. Assuming a labor rate of $6 per hour, the total annual labor cost is $48,000.

Each of the four workers spends about 25 hours a year for maintenance. Assuming a labor rate of $6 per hour, the annual maintenance cost is $600.

Table 3-11 shows Plant B's costs for using the METH based adhesive.

Table 3-11
Annual Cost for Plant B

	METH Adhesive
Adhesive cost	$47,040
Labor cost	$48,000
Maintenance cost	$600
Total cost	$95,640

Blue Ridge

Blue Ridge is a foam fabricator located in Longview, North Carolina. The company has two operations. In the first operation, the company bonds foam to medium density fiberboard (MDF); in the second operation, the company bonds foam-to-foam. In the foam-to-MDF

operation, Blue Ridge is currently using a two-part water-based adhesive. In the foam-to-foam operation, Blue Ridge is using a one-part water-based glue. The company plans to convert to an acetone based adhesive in both operations. The analysis presented here compares the cost of using the two-part water-based and the acetone based adhesives.

When Blue Ridge converted to the water-based adhesive, they installed ventilation equipment at a cost of $22,000 for controlling the aerosols. Assuming a cost of capital of five percent and a 10-year equipment life, the annual capital cost amounts to $3,586. Conversion to the acetone adhesive requires a capital expenditure of $36,000. Making the same assumptions as before, the annual cost of the capital equipment for the acetone adhesive is $5,868.

Blue Ridge uses 1,375 gallons of the two-part water-based adhesive each year. The cost of the adhesive is $16 per gallon. The total cost of using the two-part adhesive is $22,000 annually. Blue Ridge estimates the company will use the same amount of acetone adhesive after the conversion. The cost of the acetone adhesive is lower, at $8 per gallon. The total annual cost of using the acetone adhesive is $11,000.

Four workers apply the adhesives today and the same number of workers would apply the acetone adhesives. The average labor rate is $8.25 per hour. Assuming the workers work 50 weeks a year and five days a week, the annual labor cost amounts to $66,000.

About 50 hours per year are devoted to maintenance for the two-part water-based system. The same level of maintenance is expected after the conversion to acetone based adhesives. There are no chemical costs for the water-based adhesive cleanup. It is estimated that about 20 gallons of acetone will be required for the cleanup each year. At a cost of $4 per gallon for acetone, this amounts to $80 annually. Assuming a labor rate of $8.25 per hour, the total yearly maintenance cost for the water-based adhesive is $413. The total yearly maintenance cost for the acetone based adhesive is $493.

The ventilation system currently uses 900 kWh per month. At a cost of 12 cents per kWh, the annual electricity cost is $1,296. The company expects the electricity cost to remain the same after the conversion to acetone adhesives.

Blue Ridge trained their workers when the company converted to the water-based adhesives. Each of the four workers received three days of training. Assuming the labor rate of $8.25 per hour, the training cost was $792. Spreading this cost over 10 years indicates that the training cost amounts to $79 per year. Blue Ridge does not expect the workers will require training when the company converts to acetone adhesives.

Table 3-12 shows the cost comparison for the two-part water-based and the acetone adhesives. The cost for the two-part water-based adhesive is higher than the cost of the acetone adhesive, largely because of the adhesive price. It is worth noting that the one-part water-based adhesive used by Blue Ridge is $8 per gallon, the same price as the acetone adhesive. The cost comparison for the one-part water-based adhesive and the acetone adhesive would be comparable.

Table 3-12
Annual Cost Comparison for Blue Ridge

	Water-Based Two-Part Adhesive	Acetone Adhesive
Capital cost	$3,586	$5,868
Adhesive cost	$22,000	$11,000
Labor cost	$66,000	$66,000
Maintenance cost	$413	$493
Electricity cost	$1,296	$1,296
Training cost	$79	-
Total cost	$93,374	$84,652

Dixie Regency

Dixie Regency is a foam fabricator located in Conover, North Carolina. The company is part of Hickory Springs, a larger foam manufacturer and fabricator. The company produces about 540,000 pieces annually. The company has been using acetone adhesives for some time.

Dixie Regency has two operations. In one, a traditional spray operation, foam is bonded to fiber. In the other operation, an automated laminator is used to bond foam-to-foam. This analysis summarizes the cost to the company of using the acetone adhesive in the laminator.

The cost of the automated laminator was $80,000. Assuming a 10-year equipment lifetime and a five percent cost of capital, the annual cost of the equipment is $13,040.

Dixie Regency uses about 3,000 gallons of adhesive per year. The cost of the adhesive for the automated laminator is $4.95 per gallon. The total annual adhesive cost amounts to $14,850.

Three workers are involved in the laminator operation. The labor rate is $9 per hour. Assuming a 40 hour work week and that the workers work 50 weeks per year, the labor cost is $54,000 annually.

The workers spend about 40 minutes each day on maintenance of the equipment. Assuming a labor rate of $9 per hour, the annual maintenance labor cost is $1,500. About 200 gallons of acetone are used to clean the equipment each year. At a cost of $5 per gallon, the total chemical cost is $1,000. The total maintenance cost is $2,500 annually.

The laminator uses 375 kWh per month. At a cost of 12 cents per kWh, the total annual electricity cost is $540.

Table 3-13 shows the cost to Dixie Regency for using the acetone adhesive.

Table 3-13
Annual Cost for Dixie Regency

	Acetone Adhesives
Capital cost	$13,040
Adhesive cost	$14,850
Labor cost	$54,000
Maintenance cost	$2,500
Electricity cost	$540
Total cost	$84,930

ANALYSIS OF UPHOLSTERED FURNITURE MANUFACTURERS

Cost analysis is presented for five companies. One of these companies--La-Z-Boy West--manufactures upholstered home and office furniture. Sit-On-It manufactures upholstered office chairs. Country Roads manufactures and remanufactures public seating. American Seating makes seating for office, auditorium and transportation applications. Plant C manufactures aircraft seating. Individual stand-alone case studies for La-Z-Boy West, Sit-On-It, American Seating and Country Roads are presented in Appendix C.

La-Z-Boy West

La-Z-Boy converted from TCA based adhesives to water-based adhesives on January 2, 1992. For the last several years, the company has used both a one-part and a two-part water-based adhesive for their bonding applications. The two-part adhesive was used for batting-to-foam applications because the one-parts available at the time were too slow to tack and they matted the batting against the polyurethane foam. The new one-part water-based adhesives are faster and now are used in all of La-Z-Boy's residential applications. A two-part water-based adhesive is still used in limited quantities in office seating applications. The cost analysis performed here compares the TCA adhesive with one-part water-based adhesive used in residential applications.

La-Z-Boy installed ceiling fans and pressure pots when they converted to the water-based systems so they wouldn't have to use the pump. After the conversion to the one-part water-based adhesives, the pumping system and pressure pots were no longer used since the adhesives are delivered with a gravity feed system. The cost of the fans which are still in use was $600. Assuming an additional 5-year lifetime for the fans, the annual capital cost is $120.

Prior to the conversion, the company used 2,880 gallons of TCA adhesives each year. At an adhesive cost of $10 per gallon, the total cost of the TCA adhesives was $28,800 annually.

The company converted to a combination of a one-part water-based and a two-part water-based adhesive. Through optimization, they reduced their adhesive use by more than half. With the conversion to the one-part water-based exclusively, La-Z-Boy is using two 110 gallon totes each month. The total adhesive use is now 2,640 gallons annually. At a cost of $6 per gallon, the total yearly cost of the adhesive is $15,840.

The company had three workers when the TCA adhesives were used. At this stage, the company still has three workers that apply adhesives. Assuming the three workers spend 50 weeks per year at 40 hours each week at a labor rate of $18.90 per hour, the labor cost amounts to $113,400 annually.

For the TCA adhesives, maintenance requirements were 80 hours per year for draining the lines and guns once a month. At a labor rate of $18.90 per hour, the maintenance labor cost was $1,512 annually. The company also used 40 gallons of TCA annually for cleanup. At a cost of $7.20 per gallon, the TCA cost amounted to $288 per year. Total annual costs for the solvent and the cleanup labor hours were $1,800 per year. With the conversion to the one-part adhesive, the labor requirement is about 260 hours per year. Assuming a labor cost of $18.90, this amounts to $4,914 annually. Plain water is now used for the cleanup.

With the TCA adhesives, La-Z-Boy used 750 kWh per month of electricity. At a cost of 12 cents per kWh, the total annual cost of electricity amounted to $ 1,080. The electricity use from running the fans increased with the adoption of the water-based adhesive. After the conversion to the one-part water-based system, the electricity costs amounted to $3,600 annually.

A training cost was incurred to make the transition to the water-based systems. It took La-Z-Boy's best employee about three weeks or 120 hours to optimize the system. At a labor rate of $18.90 per hour, the total training cost was $2,268. Over the 10-year system life, this amounts to $227 annually.

La-Z-Boy had three spray booths when they used the TCA adhesive and they still have three spray booths. The permit fees on the booths amount to $176 each. La-Z-Boy paid about three cents per pound for TCA emissions and pays nothing in emission fees today. The total regulatory cost with the water-based adhesives is $528 annually. It is assumed that TCA accounted for 70 percent of the 2,880 gallons of TCA adhesive used by the company each year. On this basis, the emission fees for TCA were 2,016 gallons or 22,176 pounds annually. At a cost of three cents per pound, the emission fees were $665 per year. The total regulatory cost with the TCA adhesives was $1,193 annually.

Over the last eight years, La-Z-Boy has increased their production from 550 units per day to 800 units per day. The production has increased by 45.5 percent. It is necessary to account for the production increase by the facility over the last several years.

Table 3-14 shows the cost comparison for La-Z-Boy for the TCA and the one-part water-based adhesive scenario. A production adjustment has been made on the total costs in the TCA adhesive scenario. The TCA costs have been multiplied by 1.455 to account for the 45.5 percent production increase since TCA based adhesives were used.

Table 3-14
Annual Cost Comparison for La-Z-Boy

	TCA Adhesive	Water-Based Adhesive
Capital cost	-	$120
Adhesive cost	$28,800	$15,840
Labor cost	$113,400	$113,400
Maintenance cost	$1,800	$4,914
Electricity cost	$1,080	$3,600
Training cost	-	$227
Regulatory cost	$1,193	$528
Total cost	$146,273	$138,629
Production adjusted cost	$212,827	$138,629

The cost of using the water-based adhesives is lower by about 35 percent than the cost of using the TCA adhesive after the production adjustment is made.

Sit-On-It

Sit-On-It was started in 1996 and makes only office chairs at the Brea facility in California. The owner worked at other manufacturing facilities where TCA based adhesives were used. When he started up the business, he considered using METH, water-based and hot melt adhesives. He decided on hot melt and has changed glues three times to optimize the adhesives for Sit-On-It's process.

About 70 percent of the 200,000 chairs that are produced each year are made on an automated line and 30 percent on a manual line. The glue is used to bond foam-to-wood and foam-to-fabric. The capital cost of the conveyorized automated line the company purchased to use the hot melt adhesives was $50,000. Assuming a 10-year life for the equipment and a cost of capital of five percent, the total annual equipment cost is $8,150.

Sit-On-It uses 50,000 pounds per year of two different types of hot melt adhesive. The weighted cost of the adhesive is about $1.86 per pound. The total cost of the adhesive is $3,300 annually.

Four employees are involved in applying the adhesive and upholstering. Each employee devotes 50 weeks per year and 40 hours per week to applying adhesive. At a labor rate of $11 per hour, the total labor cost is $88,000 annually.

The employees spend about 40 hours per year in maintaining the equipment. This involves cleaning the belt every day and changing the filter in the head every three weeks. At a labor rate of $11 per hour, this maintenance cost amounts to $440 per year.

The electricity use for the operation amounts to 2,150 kWh per month. At a cost per kWh of 10 cents, the rate paid by Sit-On-It, the total annual electrical cost is $2,580 per year. Gas is used for the hot melt application. Eight therms per month are used at a cost of 62 cents per therm. The total annual cost for using gas is $60.

In this case, since the company used only hot melt adhesives since it began operation, the cost analysis shown in Table 3-15 includes only the cost of using only the one kind of adhesive. The values of Table 3-15 show that the cost of production amounts to about $0.965 per chair.

Table 3-15
Annual Cost for Sit-On-It

Capital cost	$8,150
Adhesive cost	$93,700
Labor cost	$88,000
Maintenance cost	$440
Electricity cost	$2,580
Gas cost	$60
Total cost	$192,930

American Seating

American Seating makes seating for transportation, office and auditorium applications like arena and bus seating. The company manufactures 500 seats per day. American Seating uses adhesive to bond foam-to-metal, foam-to-vinyl and vinyl-to-metal.

The company uses an acetone/hexane adhesive but would like to identify and implement a water-based system. The company uses 5,270 gallons of the solventborne adhesive per year. At a cost of $12.50 per gallon, the annual adhesive cost is $65,875.

Three employees apply adhesives. Assuming 50 weeks per year and 40 hours per week, 6,000 labor hours are used in the application of adhesives. At an hourly labor rate of $19.50, the annual cost of labor is $117,000.

About 75 hours per year of maintenance time are required. Again assuming a labor rate of $19.50 per hour, the annual maintenance labor is $1,463. About 55 gallons of cleanup solvent are used in the maintenance operation. At a cost of $8 per gallon, the solvent cleanup cost is $440 per year. Total labor and solvent maintenance cost is $1,903 annually.

Electrical usage for applying the adhesives is 8,000 kWh per month. At a cost of 12 cents per kWh, the total annual electrical cost is $11,520.

Table 3-16 shows the costs for American Seating's adhesive operation. The company makes bus seats which are much larger than office chairs. Assuming the company makes 500 seats per day, 250 days per year, the total number of seats manufactured annually is 125,000. The values of Table 18 show the cost for producing each chair is about $1.57.

Table 3-16
Annual Cost for American Seating

Capital cost	-
Adhesive cost	$65,875
Labor cost	$117,000
Maintenance cost	$1,903
Electrical cost	$11,520
Total cost	$196,298

Country Roads

Country Roads manufactures and remanufactures public seating for arenas, auditoriums and theaters. The firm produces 200,000 chairs per year. Country Roads has two spray booths for spraying adhesive used to bond foam-to-wood, foam-to-steel and foam-to-plastic fabric.

In the past, the company used METH based adhesives. Country Roads is in the process of converting to alternatives. At this stage, the company has identified a hot melt adhesive that is suitable for 90 percent of their operation. Country Roads is still in the process of testing alternatives for the foam-to-plastic fabric application. The costs for the hot melt alternative are not available because the company has not yet completed the conversion. The analysis here focuses on the costs of using METH adhesives.

About 2,200 gallons of METH adhesive were used annually. At a cost of $11.50 per gallon, the total cost for purchasing adhesive amounted to $25,300 per year.

Eight employees are involved in applying the adhesive. Assuming each employee works 50 weeks per year and 40 hours per week, the labor hours amount to 16,000 annually. At a labor rate of $11.20 per hour, the yearly labor cost is $179,200.

Methylene chloride was used to clean the application equipment. About 50 gallons were used each year. At a cost of $5 per gallon for METH, the total annual cost for cleanup solvent is $250. Maintenance required about 13 hours per year. At a labor rate of $11.20 per hour, the annual labor cost is $146. The total maintenance cost considering the cleanup solvent and the labor cost is $396.

The plant's electrical use with the METH adhesives was 250 kWh per month. At a cost for electricity of 12 cents per kWh, the annual electrical cost is $360.

Table 3-17 presents the costs of using the METH adhesive for Country Roads. The cost to Country Roads for producing each chair is about $1.03.

Table 3-17
Annual Cost for Country Roads

Capital cost	-
Adhesive cost	$25,300
Labor cost	$179,200
Maintenance cost	$396
Electricity cost	$360
Total cost	$205,256

Plant C

Plant C manufactures aircraft in Southern California. As part of that manufacturing operation, the company makes aircraft seats. The company has two operations that use adhesives. These include the seat manufacturing shop and the trim shop.

In the seat manufacturing operation, Plant C uses a VOC aerosol adhesive in the manufacture of 360 aircraft seats annually. The company uses 3,240 cans of adhesive per year. At a cost of $10 per can, the total cost of the aerosol adhesive is $32,400 per year.

Three workers apply the adhesives. Each worker spends about 125 hours per year applying adhesive. At an average labor rate of $19.60 per hour, the total annual labor cost is $7,350.

In the trim shop, Plant C uses a VOC adhesive that is sprayed. The company currently uses 125 gallons of adhesive per year. At a cost of $7 per gallon, the total annual cost of the adhesive is $875.

Numerous different workers apply the adhesive over the course of a year. Total hours spent in the spray operation amount to 1,500 per year. The average labor rate is $19.60 per hour. The total labor cost is $29,400 annually.

The spray application equipment is cleaned once per day. The maintenance time amounts to 15 minutes. Annual maintenance labor costs assuming the $19.60 per hour labor rate are $1,225. The cost of the cleanup solvent is $6 per gallon and 31 gallons are used each year. The solvent maintenance cost is $186. The total annual maintenance cost is $1,411.

Plant C pays $176 per year for a permit from the air district to operate the spray equipment. They also pay $120 per year to dispose of the waste generated in the operation. The total regulatory costs are $296 annually.

Table 3-18 shows the costs for Plant C's two adhesive operations.

Table 3-18
Annual Cost for Plant C

	Seat Manufacturing	Trim Shop
Adhesive cost	$32,400	$875
Labor cost	$7,350	$29,400
Maintenance cost	-	$1,411
Regulatory cost	-	$296
Total cost	$39,750	$31,982

ANALYSIS OF MATTRESS MANUFACTURERS

Cost analysis for four companies is presented here. These include Jamison Bedding, Justice, McKinney Bedding and Southerland Inc. All of these companies manufacture pillow top mattresses. Stand-alone case studies for three of the companies--Jamison Bedding, Justice and McKinney Bedding--are presented in Appendix D.

Jamison Bedding

Jamison makes mattresses and is the largest private label in the U.S. The company makes contract bedding for hotels and motels. In the past, the company used METH and TCA based adhesives. They converted to hot melt adhesives but are not completely satisfied with the process. Jamison bonds the inner mattress to the non-woven fabric and the foam surface to the non-woven quilted material. The company makes 300 to 400 mattresses per day and 150 of them involve gluing.

The company had to purchase new equipment when they made the conversion to hot melt adhesives. They purchased two hot melt spray guns at a cost of $2,500 each. They also purchased a more advanced piston spray gun at a cost of $7,000. Finally, they purchased a $4,500 benchmark spray gun. The total cost of the equipment was $16,500. Assuming a cost of capital of five percent and a 10-year equipment life, the annualized capital cost is $2,690.

When the company used TCA based adhesives, they used about 10 55-gallon drums each year. At a cost of $8.69 per gallon, the annual cost of the TCA adhesive amounted to $4,780. The company now uses about 1,500 pounds of hot melt adhesive each year. At a cost of $1.69 per pound, the total annual hot melt adhesive cost is now $2,535.

Over the last several years, before and after the conversion to hot melt adhesives, the company has had three employees that apply adhesives. Jamison indicates that the three employees spend 6,120 hours per year applying the adhesives. At a labor rate of $10 per hour, the total annual labor cost is $61,200.

There is essentially no maintenance involved in using the hot melt adhesive. About 77 hours per year were spent in maintenance activities when the company used TCA based adhesives. At the company's labor rate of $10 per hour, this amounts to $770 per year. About 100 gallons of TCA was used annually for the maintenance activities. At a cost of $5.50 per gallon, the annual cost of TCA for maintenance was $550. The total maintenance cost with the TCA adhesives was $1,320 per year.

The electricity cost has increased with the use of the hot melt adhesives. The electricity cost for the TCA adhesives was negligible. The company now uses 1,632 kWh per month. At a cost of 12 cents per kWh, the total annual electrical cost with the hot melt adhesives is $2,350.

Table 3-19 shows the cost comparison of the TCA and the hot melt adhesives for Jamison. The cost of using the TCA and hot melt adhesives is comparable. The cost increased by about two percent when the hot melt adhesive was adopted.

Table 3-19
Annual Cost Comparison for Jamison Bedding

	TCA Adhesive	Hot Melt Adhesive
Capital cost	-	$2,690
Adhesive cost	$4,780	$2,535
Labor cost	$61,200	$61,200
Maintenance cost	$1,320	-
Electricity cost	-	$2,350
Total cost	$67,300	$68,775

McKinney Bedding

The company has 45 employees. They make a line called Restonic and also make 100 different styles of contract bedding. About five percent of their mattresses are pillow tops. They use adhesive on the non-pillow top beds to bond the foam to fabric, to the insulator pad and to the quilted material. A METH based adhesive in pressurized containers is used to bond the pillow tops. The company is investigating whether acetone aerosol cans would be less costly.

McKinney currently uses 1,328 pounds of METH based adhesive in pressurized containers each year. The cost of the adhesive is $2.08 per pound. The total cost of using the pressurized METH cylinders is $2,762 annually.

The company indicates that it requires 20 percent less of the acetone/heptane adhesive than the METH adhesive. For the conversion, it was assumed that 1,062 pounds of acetone/heptane aerosol adhesive would be required annually. The aerosol cans are priced at $4.14 per pound. The total cost of using the aerosol adhesive would be $4,397 annually.

Three employees currently apply the adhesives. They work on the adhesive operation for a total of 120 hours per year. At a labor rate of $10 per hour, the total annual labor cost is $1,200. The labor cost would not change if the company converted to the aerosol adhesives.

To continue using the METH based adhesive, the company would likely have to install a ventilation system to lower the exposure of the workers. If the exposure level were lowered to the action level of 12.5 ppm, then the company would not have to perform medical surveillance of the employees and conduct regular monitoring. It is estimated that a ventilation system that would reduce the worker exposure level to 12.5 ppm would carry a capital cost of at least $3,000. Assuming a cost of capital of five percent and a 10-year equipment life, the annual cost of the ventilation system would amount to $489.

Table 3-20 shows the cost comparison for McKinney Bedding for the METH pressurized containers and the acetone aerosol adhesive. The values show that the cost of using the acetone aerosol adhesive would be 24 percent higher than the cost of using the METH adhesive in pressurized containers. The cost of the ventilation system for the METH adhesive could be much higher than is estimated here. In that event, the transition to acetone aerosol adhesives would make more economic sense.

Table 3-20
Annual Cost Comparison for McKinney Bedding

	METH Adhesive	Acetone Adhesive
Capital cost	$489	-
Adhesive cost	$2,762	$4,397
Labor cost	$1,200	$1,200
Total cost	$4,451	$5,597

Justice

Justice makes both furniture and bedding. In 1992, the company stopped all their adhesive operations. At this stage, the company sews all of their pillow top mattresses. They changed their whole method of operation. The company sews the nonwoven material to the ticking, polyester and polyurethane. The company manufactures an average of 325 mattresses each day or 81,250 mattresses each year.

The company uses no adhesive. They have two employees who are involved in the sewing. In order to convert to the sewing operation, the company made a capital investment in equipment. The cost of this investment was $45,000. A company representative indicates that Justice reduced their cost by $15 per mattress by converting from adhesive to sewing. No additional data on costs were available.

Southerland Inc.

Southerland is a mattress manufacturer located in Nashville, Tennessee. Until a few years ago, the company used small quantities of a methylene chloride based adhesive. When they began manufacturing significant numbers of pillow top mattresses, the company adopted a hot melt adhesive process. In 1998, Southerland manufactured 39,000 mattresses. Pillow tops account for 22.5 percent of production.

The company uses 9,700 pounds of hot melt glue annually in their pillow top operation. At a cost of $1.48 per pound, the total annual adhesive cost is $14,356.

There are four glue stations at Southerland and eight glue guns. The hot melt guns were purchased at a cost of $40,000. Assuming a 10-year equipment life and a five percent cost of capital, the annual capital cost for the hot melt equipment is $6,520.

Eight workers apply the adhesives and are paid by the piece. Workers receive 35 cents for applying adhesive to a mattress. Last year, 8,970 mattresses required adhesive so the total labor cost involved in the adhesive application was $3,140.

The plant manager estimates that the cost of maintenance is about $1,500 per year.

The hot melt equipment uses 2,400 kWh of electricity per month or 28,800 kWh per year. At a cost of 12 cents per kWh, the annual electricity cost is $3,456.

Table 3-21 below shows the costs of Southerland's adhesive operation. The total cost amounts to $27,572 annually.

Table 3-21
Annual Cost for Southerland Inc.

Capital cost	$6,520
Adhesive cost	$14,356
Labor cost	$3,140
Maintenance cost	$1,500
Electricity cost	$3,456
Total cost	$28,972

IV. DISCUSSION OF PERFORMANCE/COST ANALYSIS

Different alternative technologies are appropriate for the three sectors considered here. In the course of the project, varied viewpoints about which of the technologies is viable were encountered in different parts of the country. A discussion of these observations, based on the analysis presented in Section III, is presented here.

FOAM FABRICATION

Table 4-1 lists the foam fabrication facilities that participated in the project. It also lists the adhesive technology the company used in the past and the alternative technology the facility has adopted or plans to adopt.

The conversion choices and the cost analysis for the foam fabricators raise some interesting issues. The first issue is that the fabricator's location in the country and the size of the fabricator appears to influence the selection of alternatives. The second issue is the optimization of the alternative technology. The third issue is the costs of the different technologies. Each of these issues is discussed below.

Plant Location

As mentioned earlier, the fabricators located in Southern California could not use METH based adhesives because of state and local regulations on toxics. These companies used TCA based adhesives until they could identify, test and implement a suitable alternative. Foam Craft Inc. was a pioneer in testing some of the first one-part water-based adhesives that came on the market in the early 1990s. Companies like Foam Craft worked with the formulators to solve the problems that arise with the use of any new and innovative technology. It took the company several years to implement the change.

Latex International West, also located in Southern California, first adopted acetone but did not want to continue using a solvent-borne technology. The company tested one-part water-based adhesives extensively and adopted two of them for their processes.

California fabricators that are using the one-part water-based adhesives are very happy with their choice. They have learned how to optimize their use of the adhesive and both Foam Craft and Latex International reduced their costs through the conversion. Water-Based adhesives have very different requirements than solvent-borne adhesives and companies must be committed to resolving issues and understanding these requirements to successfully use the new adhesives.

With solvent based adhesives, if two pieces of foam are to be bonded together, only one of the foam pieces needs to be sprayed and the pieces can be brought together and they will bond. With water-based adhesives, both pieces of foam must be sprayed with adhesive, the worker must wait for a period for the adhesives to tack and then the two pieces of foam can be joined. Workers in plants where the management is committed to converting to water-based adhesives quickly learn how to deal with the differences. They generally spray up several pieces of foam. When they are finished, the foam pieces they sprayed first are beginning to tack and they can join them. The bonding requires the same amount of labor but the procedure is different.

Other issues arise with the use of the one-part water-based adhesives. One of the keys to successful use is that the adhesives should be gravity fed. Plants elevate totes of the water-

Table 4-1
Foam Fabrication Facility Adhesive Technologies

Facility	Original Technology	New Technology	Change in Cost
Foam Craft Inc.	TCA	Water-Based One-Part	Reduction
Prestige	Water-Based One-Part; Water-Based Two-Part; NPB	Acetone	Reduction
Latex International	Acetone	Water-Based One-Part	Reduction
Hickory Springs--Conover	METH	Acetone	Increase
Hickory Springs--City of Commerce	Water-Based	Acetone	Reduction
Marsh-Armfield--Conover	TCA	NPB	Increase
Marsh-Armfield--High Point	METH	NPB	Increase
Plant A	METH	Acetone	Increase
Guilford Fabricators	METH	NPB	Reduction
Marx Industries	METH	NPB	Reduction
Ashdale Foam	METH	NPB	Increase
Plant B	METH	None	-
Blue Ridge	Water-Based Two-Part	Acetone	Reduction
Dixie Regency	Unknown	Acetone	-

based adhesive and the adhesive is fed by gravity to the spray equipment. Another key is to minimize the adhesive use. Because both of the foam pieces need to be sprayed with the water-based adhesives, it would be expected that companies using these adhesives would double their adhesive use. In fact, many companies try to use too much adhesive and find that the foam does not bond well. Both Foam Craft and Latex International figured out how to apply minimal amounts of the water-based material for optimal bonding. In both cases, the companies use less of the water-based adhesive than they did of the solvent-borne adhesive in spite of the fact that they must now spray both pieces of foam.

Hickory Springs, the other fabricator in California, used a one-part water-based adhesive when they started up their fabrication operation but could not get it to work well for their application. In the end, the company adopted an acetone based adhesive. Since acetone is exempt from VOC regulations, it can be used in Southern California where the VOC regulations are stringent. Hickory Springs in Conover also adopted acetone; the company uses acetone as an auxiliary blowing agent in foam manufacture and was very familiar with its characteristics.

Prestige, the other large fabricator that participated in the project, tested virtually all the different adhesive technologies. The company did not like the water-based technologies and could not get them to work for their operation. Prestige was somewhat concerned about the regulatory future of NPB and decided not to use NPB based adhesives. Ultimately, the company decided to convert to an acetone based adhesive.

The four largest fabricators--Foam Craft, Latex International, Hickory Springs and Prestige--located in Southern California and North Carolina, adopted either water-based or acetone based adhesives. Of the remaining nine smaller fabricators, three adopted acetone adhesives, five adopted NPB adhesives and one is still using a METH adhesive.

None of the smaller manufacturers converted to a water-based adhesive. One fabricator, Blue Ridge, used a two-part water-based adhesive but converted to an acetone adhesive. Some of them had tried the water-based one-part adhesives and could not make them work. These plants indicated that the water-based adhesives did not bond well or simply did not work. In contrast to the Southern California plants that ended up using water-based adhesives, these companies had no need to make the water-based adhesives work. Because the VOC regulations are less stringent in North Carolina, these companies had the option of using NPB adhesives.

Some of the five companies that converted to NPB had problems with worker illness and they installed ventilation systems designed to better control worker exposure. These companies all indicated they liked the NPB because it was easy to use and behaved like METH. Two of the five companies reduced their cost when they converted from METH to NPB adhesives. They indicated that they use less of the NPB adhesive than the METH adhesive. Because these adhesives contain roughly the same percent of solids, the only conclusion that can be drawn is that when the companies adopted the more expensive NPB adhesive, they paid attention to the amount of adhesive they used and ended up using less.

In summary, the California fabricators adopted water-based and acetone technologies in part because of the stringent regulations there. None of the larger foam fabricators converted to NPB based adhesives. They expressed a concern for the potential toxicity of the chemical. Several of the smaller fabricators, however, readily adopted the NPB adhesives. Thus, location and size appear to influence the choice of alternatives.

Technology Optimization

In may industries, including foam fabrication, when a solvent based product is more heavily regulated, the easiest path is for the company to simply convert to another solvent based technology that is a "drop-in." The fact that most foam fabricators converted to METH based adhesives when TCA production was banned is evidence of this. The closest drop-in to the METH based adhesives is NPB adhesives and many companies, to minimize the transition problems, converted to this option.

The next closest option is acetone. Acetone adhesives behave like other solvent based adhesives and are forgiving. The workers do not have to change the way they apply the

adhesives or the application equipment. The only process change that is required to adopt acetone adhesives is to implement measures to control flammability.

Very few companies adopted water-based adhesives because their use requires more extensive process changes. The workers must learn different application techniques and the adhesives must be gravity fed. A lot of experimentation is required to optimize the use. Companies in Southern California where the regulations are more stringent were willing to take on these challenges because they had little choice. Once they did resolve the issues and optimized their processes, they reduced their costs. They no longer have to worry about worker exposure to chemicals, VOC emissions or flammability controls. They have converted to a permanent solution.

Technology Cost

For all of the companies included in this analysis, the labor cost dominates the total cost of using the adhesive technologies. The cost of purchasing the adhesives is generally the next largest cost. All of the adhesive technologies evaluated have roughly the same amount of solids or resins. This means when a company converts from one technology to another, they can achieve the same coverage. METH, acetone and water-based one-part adhesives are in the $6 to $10 per gallon range. NPB based adhesives are higher cost, at between $15 and $18 per gallon.

The companies that converted to NPB adhesives are generally smaller fabricators. They began paying close attention to minimizing their use of the adhesives because of the higher cost of the NPB adhesive. Many of them reduced their adhesive use in the conversion. This is not because the NPB adhesives have higher solids but rather is a result of process optimization.

UPHOLSTERED FURNITURE MANUFACTURE

Table 4-2 lists the upholstered furniture manufacturers that were part of this project. It also provides information on the original technology used by the companies and the technology they adopted. The table also indicates whether the company reduced or increased their cost in the transition.

In the case of upholstered furniture manufacture, the case studies presented here demonstrate that location, optimization and cost are less important factors than they are in foam fabrication. Only one company, La-Z-Boy West, made a conversion and provided cost data indicating they reduced their cost through the conversion. Three of the companies did not make a conversion and Country Roads has made a conversion but has not yet collected cost information.

Two of the companies, Sit-On-It and Country Roads, converted to hot melt technologies and one, La-Z-Boy West, to a water-based technology. Like Foam Craft, La-Z-Boy was a pioneer in testing and helping the vendors to develop and optimize the water-based formulations. Again the company is located in California and had no options for using a solvent based technology in the early 1990s. At that time, acetone was not exempt from VOC regulations and acetone based adhesives were not yet available. Sit-On-It, also located in California, started up operations in 1996 and decided to use hot melts to minimize environmental problems. Again, the company is located in California. Plant C, also located in California, uses aerosol products which are not regulated by the local air district.

Table 4-2
Upholstered Furniture Facility Adhesive Technology

Facility	Original Technology	New Technology	Change in Cost
La-Z-Boy West	TCA	Water-Based One-Part	Reduction
Sit-On-It	None	Hot Melt	-
Country Roads	METH	Hot Melt	Unknown
American Seating	Acetone Blend	None	-
Plant C	VOC Solvent Aerosol	None	-

Country Roads and American Seating are located in Michigan where the environmental regulations are less stringent than in California. Country Roads was using METH based adhesives but recently converted to a hot melt. American Seating is using a VOC solvent based adhesive but is actively investigating alternatives including hot melt and water-based adhesives.

As was true for foam fabrication, labor costs are a large component of total costs for the upholstered furniture industry. The adhesive cost also represents a significant fraction of the total cost. La-Z-Boy reduced their total adhesive cost substantially through the conversion from TCA to water-based adhesives.

In summary, the upholstered furniture industry has clearly decided that hot melt and water-based adhesives are the alternatives of choice. Water-based adhesives appear to be a good alternative in the home upholstered furniture sector while hot melts appear to be the best option for office chair and public seating.

MATTRESS MANUFACTURE

Table 4-3 lists the mattress manufacturers that participated in the project and shows the original and current technology the company is using.

The labor cost is a less important factor in the total cost than the cost of the adhesive in this sector. Two of the companies that participated in the project have adopted hot melt technology and this technology is widely applicable for mattress manufacturers. One of the companies adopted an automated sewing method several years ago. It is not clear whether this technology is as widely applicable as the hot melt technology for pillow top bonding. Some mattress manufacturers use only a small amount of adhesive in their bonding; aerosol products based on acetone are an option for these companies.

Table 4-3
Mattress Facility Technology

Facility	Original Technology	New Technology	Change in Cost
Jamison Bedding	TCA	Hot Melt	Increase
Justice	Unknown	Sewing	Reduction
McKinney Bedding	METH	Acetone Aerosol	Increase
Southerland	None	Hot Melt	-

V. CONCLUSIONS AND FUTURE WORK

Foam fabricators, upholstered furniture manufacturers and mattress manufacturers historically used porous substrate bonding adhesives based on TCA for bonding foam-to-foam, foam to other substrates and fabric-to-fabric. When TCA production was scheduled to be banned because the chemical contributes to stratospheric ozone depletion, adhesive formulators began developing adhesives for these sectors based on METH. METH is a suspect carcinogen and is heavily regulated as a toxic. In 1997, OSHA issued a stringent regulation on METH which was widely used in porous substrate bonding adhesives by that time.

This project was designed to investigate and compare the cost and performance of METH and TCA adhesives and their alternatives in the foam fabrication, upholstered furniture and mattress manufacturing industries. The aim was to provide assistance to small and medium sized companies in the three industrial sectors to help them select alternatives to METH based adhesives. IRTA conducted site visits to more than 30 verification facilities in Southern California, the Southeastern United States and Michigan. IRTA developed cost information on 14 foam fabrication facilities, five upholstered furniture manufacturers and four mattress manufacturers and compared this information with the cost of the alternative technologies they adopted.

Eleven stand-alone case studies were developed based on the analysis in this document. These case studies are available in this document and also under separate cover. They are included in three brochures that are intended for distribution to companies in the three industry sectors. The decisions made by the 11 companies should help similar companies make informed decisions on which alternative technology would be most suitable for their operations.

In the foam fabrication industry, most large foam fabricators have converted to water-based and acetone based adhesives. The cost of these technologies is comparable to the cost of METH and TCA based adhesives. Some of the smaller fabricators have converted to NPB based adhesives. NPB has unknown but likely high toxicity and the adhesives based on the chemical are more costly than the other technologies. In the upholstered furniture manufacturing industry, the preferred technologies are water-based and hot melt adhesives. In the mattress manufacturing industry, alternatives include hot melt adhesives, acetone aerosol adhesives and sewing. In these two latter sectors, the costs of the new technologies are comparable to the traditional adhesive technologies.

Cleaner Technologies Substitutes Assessments generally include both a cost and performance evaluation and an investigation and analysis of the health and environmental effects of alternatives. This document reports on the cost and performance evaluation and future work will focus on the health and environmental effects of the alternatives.

In the next phase of the project, IRTA will develop representative alternative adhesive formulations with assistance from the adhesive suppliers. These formulations will be used in the exposure analysis and in the evaluation of the environmental effects. The University of Tennessee Center for Clean Products and Clean Technologies will conduct an exposure assessment of the alternatives with assistance from NIOSH. EPA staff will provide toxicity and environmental profiles of the chemicals in the different adhesive formulations. IRTA will assist in the exposure evaluation and will help to provide information on the environmental effects of the chemicals.

Appendix A
Material Safety Data Sheets for Typical Adhesive Formulations

Appendix B
Case Studies for Selected Facilities

FOAM FABRICATOR HELPS PUSH WATER-BASED ADHESIVE TECHNOLOGY

Foam Craft Inc., located in Cerritos, California, employs 160 people. The firm started operation in 1965 and was bought by Future Foam, a flexible slabstock foam manufacturer, in 1994. Foam Craft fabricates foam for use in packaging, furniture and bedding. Products like futons, recreation vehicles, trucks, tractors and dog beds use the foam fabricated by Foam Craft.

Several years ago, like most of the industry, Foam Craft used methylene chloride (METH) based adhesives for bonding foam-to-foam in their fabrication operations. Because of air regulations put in place by the South Coast Air Quality Management District, Foam Craft converted their processes from METH to 1,1,1-trichloroethane (TCA) based adhesives. Like other companies in Southern California, Foam Craft used TCA based adhesives until the cost of the chemical became prohibitive. TCA contributes to stratospheric ozone depletion and production was banned in 1996. A congressional tax placed on the chemical made it extremely expensive to use.

"We have completely converted to water at this stage," says Bob Nylander, Foam Craft's plant manager. The company began investigating water-based adhesive alternatives about six years ago when it became clear that TCA would be phased out. At that time, the water-based products were new to the market and Foam Craft went through a long learning curve to optimize their use. Foam Craft and the vendors, in a partnership, were able to solve all the problems that arose during a long testing phase.

Foam Craft emerged as one of the industry pioneers for water-based foam bonding adhesives. The company spent two years of intensive testing to determine the best methods of using the new adhesives. They began work with a one-part adhesive made by Upaco. Foam Craft found that the adhesive did not dry as fast as the solventborne adhesives so they tested different application techniques. Instead of spraying two pieces of foam and putting them together for an instant bond, the workers now spray a stack of foam pieces and then join them. Worker application time is virtually identical now to what it was before the conversion.

Foam Craft had to work out several other problems over the two-year period. They had difficulty developing an adhesive feed system for their eight stations that had a total of 32 spray booths and guns. Going to a gravity feed system eliminated shearing issues.

They also found that at first they used about 1.6 times as much of the water-based adhesive than the solventborne adhesive. With experience, they were able to optimize the application process and now they use about three-fourths as much water-based adhesives. This reduction in materials use means that the cost of doing business for Foam Craft was reduced by the switch to water-based adhesives.

Foam Craft is now testing new water-based products to see if they can reduce their costs further. The company is also investigating new cutting processes that could help eliminate some of the requirements for adhesive use altogether.

"The ban on TCA was a good thing. It forced us to examine our process and find a better alternative for workers and the environment," says Bob Nylander. "We've provided information to the other Future Foam plants in the country. They are planning to use our example to convert now that methylene chloride can't be used. We're investigating other methods to reduce our costs further."

PRESTIGE EVALUATES SEVERAL GLUE TECHNOLOGIES

Prestige is one of the largest foam fabricators in North Carolina. The company also manufactures polyurethane slabstock foam in Asheboro. About 80 percent of the foam the company manufactures is used in the fabrication operation and 20 percent is sold to other firms.

The foam pouring and fabrication operations were located in the same building until recently; the foam fabrication now takes place in a separate 200,000 square foot facility. Prestige does fabrication for a variety of furniture manufacturers. Adhesive is used to bond the foam-to-foam in the fabrication operation. The company also manufactures sleeper mattresses for sofa beds but, in this case, has found that lifetime testing results are better with sewing for those products.

Prestige has a very large fabrication operation with 30 gluing stations. The company has 250 employees and about 40 of them apply adhesive. In 1991, the company used a 1,1,1-trichloroethane (TCA) based adhesive. Prestige started evaluating alternative technologies when it became clear that TCA production would be banned because of the chemical's contribution to ozone depletion.

The company converted to a one-part water-based adhesive and has been using it for several years. They also used a two-part water-based adhesive for critical bonding applications on furniture arms, ears, seams and other complex parts. "We never liked the performance of the water-based glue," says Danny Sykes, General Manager at Prestige. "It took four to six weeks for the workers to learn to spray the water-based glues and six to eight weeks to get their speed up," he says. The company purchased and installed 30 spray booths when they converted from TCA to the water-based adhesives.

Recently, the company began using an n-propyl bromide adhesive on the line where they used the two-part water-based glue. The two-part adhesives are very costly to maintain. "We like the performance of the n-propyl bromide glue but are concerned about possible regulation," says Joe Wingfield, President of Prestige.

The company has also evaluated the costs of acetone based adhesives and are considering using them. "I think we'll go with acetone glues," says Joe Wingfield. "Acetone is flammable but it has low toxicity and the glues perform well. The cost of using acetone glues is also lower than the cost of using the n-propyl bromide products."

Annual Cost Comparison for Prestige

	One-Part Water-Based	Two-Part Water-Based	Acetone Adhesive	n-Propyl Bromide Adhesive
Capital cost	$11,182	$11,182	$12,160	$11,182
Adhesive cost	$656,250	$1,356,000	$218,700	$656,100
Labor cost	$720,000	$720,000	$720,000	$720,000
Maintenance cost	$3,780	$7,200	$3,780	$3,780
Electricity cost	$2,160	$2,160	$2,160	$2,160
Training cost	$1,080	$1,080	$1,080	$1,080
Total cost	$1,394,452	$2,097,622	$957,880	$1,394,302

SANTA FE SPRINGS FOAM FABRICATOR CONVERTS TO WATER-BASED ADHESIVES

Latex International, a large manufacturer of latex foam, has two manufacturing plants worldwide. The company has a fabrication plant in Santa Fe Springs, California with 50 employees where they fabricate foam used primarily in the bedding industry.

In the 1980s, like other companies in the country, Latex International used methylene chloride based adhesives in their fabrication operation. More recently, as methylene chloride was more heavily regulated by the local air district, the company converted to an acetone based adhesive. Latex International did not want to continue to use solventborne adhesives and initiated work on water-based products. Today, the company is exclusively using water-based adhesives.

The latex foam cores that are used in mattresses are manufactured in Latex International's plant in Conneticut. The ingredients are poured into molds of various types. Two twin molded cores are glued together to form a king sized core. The plant in Santa Fe Springs receives latex foam cores from the Conneticut plant and bonds two types of foam products. In one operation, latex is bonded to latex to form the foam core of a high end mattress. The latex foam takes the place of springs that are commonly used in lower end mattresses. The company also uses glue to attach aluminized "cigarette tape" to the edges of the mattress to prevent cigarette fires. In the second operation, Latex International uses adhesives to bond "racetracks" which are smaller cores of latex foam with an outer perimeter of polyurethane. These cores are used in less expensive bedding.

In the polyurethane foam-to-latex operation, Latex International uses a one-part latex water-based adhesive which does not have an immediate tack. In the latex-to-latex operation, a different one-part water-based adhesive which has a shorter tack tune is used. The latex is less porous than polyurethane foam so a faster tack adhesive is required.

Says Ron Bruneau, Plant Manager at Latex International West, "our adhesive use has been reduced by about 30 percent since we converted from acetone to water-based adhesives." The cost of using the water-based adhesives is roughly the same as the cost of the acetone adhesives. "We are testing other water-based adhesives to see if we can lower our costs," says Ron Bruneau.

Roger Coffey, President of Latex International West, is pleased with the conversion and continued work to find lower cost adhesives. "We're an environmentally conscious company. "We did a lot of testing and converted away from solvent based adhesives entirely," he says. "The water-based adhesives work effectively and they are better for the workers and the community."

Annual Cost Comparison for Latex International

	Acetone Adhesives	Water-based Adhesive
Capital cost	$400	-
Adhesive cost	$34,188	$27,360
Labor cost	$196,000	$196,000
Maintenance cost	$490	$372
Electrical cost	$1,440	$1,440
Training cost	-	$470
Regulatory cost	$352	$352
Total cost	$232,870	$225,994

HICKORY SPRINGS DECIDES ON ACETONE ALTERNATIVE

Hickory Springs is a major manufacturer of flexible slabstock polyurethane foam. The company has six pouring plants in the country, including Conover, North Carolina and City of Commerce in California. The foam is used in diverse applications like packaging, bedding, furniture and recreational vehicles.

In addition to manufacturing the polyurethane foam, Hickory Springs also has a number of fabrication operations. The company has fabrication operations in all of their foam pouring plants; in addition, Hickory Springs owns about 30 separate fabricating companies. About half the foam the company produces is used in their own fabrication operations. In all, the company has about 2,000 employees who manufacture and fabricate foam.

Hickory Springs historically used methylene chloride (METH) as an auxiliary blowing agent in their slabstock foam production operations. Because of more stringent toxic regulations on METH, the company began investigating alternatives in the early 1990s. In 1993, Hickory Springs patented a new blowing agent process that used acetone as the auxiliary blowing agent in foam manufacture in place of METH. A few years, later, when acetone was deemed exempt from VOC regulations, the company converted all of their pouring plants from METH to acetone.

Like other companies, Hickory Springs used TCA based adhesives in the early 1990s. When the production ban on TCA was announced and the price of TCA increased, the company converted to METH based adhesives for their fabrication operations.

In 1990, the pouring plant in City of Commerce used TCA based adhesives. From 1991 to 1998, the company decided not to continue fabrication at that site. In 1998, the company decided to reenter the fabrication market. At that stage, METH was heavily regulated by the local air district and Hickory Springs investigated and adopted water-based adhesives. "We tried for about a year to make the water-based adhesives work for us but we were unsuccessful," says Steve Isenhour, Plant Manager at the City of Commerce plant. "We're using acetone adhesives now and we've had no problems," he says.

When the Occupational Safety and Health Administration (OSHA) regulated METH more stringently, Hickory Springs decided to convert away from METH in their fabrication operations throughout the country. In the Conover plant, the company converted to water based adhesives for a short time. In 1998, the company began testing acetone based adhesives in their fabrication operation at the pouring plant. "The company was very familiar with acetone because it was used as a blowing agent in our pouring plants," says Bobby Bush, Vice President of the Foam Products Division at Hickory Springs. "People are nervous about acetone because of its combustibility," he remarks. "Our insurance rates did not go up; we had to install a ventilation system but we would have had to do that with water or METH adhesives too."

The Conover plant has 16 stations where adhesive is applied. With the conversion to acetone, the company installed ventilation systems that collect from the floor at 11 of the stations; at the remaining five stations, a fan pulls the air outside. At the City of Commerce plant, which has a much smaller fabrication operation, the company has always had one spray booth and no additional ventilation was necessary for the conversion to acetone adhesives.

In the Conover plant, the company uses an adhesive formulation that is a blend of acetone and heptane. In the City of Commerce plant, the company uses a straight acetone based

adhesive because of the more stringent local air district regulations on VOCs. "Acetone low in toxicity and it's as effective as METH as a blowing agent and in the glues," says Bobby Bush. "We think it's the best overall solution."

At the City of Commerce plant, the company reduced their costs in converting from water-based to acetone adhesives. The company's production efficiency is much greater with the acetone based adhesive. The table below shows that the production adjusted cost of using acetone adhesives is about 43 percent less expensive than the cost of using the water-based adhesives.

Annual Cost Comparison for Hickory Springs--City of Commerce

	Water-Based Adhesive	Acetone Adhesive
Capital cost	-	$100
Adhesive cost	$7,560	$7,800
Labor/maintenance cost	$23,833	$15,889
Electrical cost	$215	$143
Total cost	$31,608	$23,932
Production adjusted total cost	$31,608	$17,949

At the Hickory plant, the company's costs increased slightly through the conversion from METH to acetone based adhesives. The table below shows a cost increase of four percent.

Annual Cost Comparison for Hickory Springs--Conover

	METH Adhesive	Acetone Adhesive
Capital cost	-	$1,793
Adhesive cost	$55,000	$66,000
Labor cost	$288,000	$288,000
Maintenance cost	$2,403	$2,403
Electrical cost	-	$1,260
Total cost	$345,403	$359,456

LA-Z-BOY WEST A PIONEER IN WATER-BASED ADHESIVES

La-Z-Boy West, part of the La-Z-Boy chain with 14 U.S. plants, established operations in Redlands, California in 1966. Today the Redlands facility has about 400 employees in a 190,000 square foot building that manufactures 800 pieces of furniture each day. In addition to the recliner chairs for which La-Z-Boy is famous, the firm also manufactures sofas, tables and office furniture. The Redlands plant manufactures 53 different styles in 30 different variants. A few years ago, the plant began making contract office furniture, a part of the business that is expected to grow substantially.

La-Z-Boy brings in the fabric, wood, metal and foam used to assemble the furniture. The Redlands operation includes three paint booths where a stain and a one or two topcoats are applied. They also have three adhesives spray booths where adhesive is applied to bond foam-to-foam and foam-to-fabric. The primary fabric used is muslin but some dacron and duon is employed as well. The foam is used to make chair seats, backs, arms and legrests.

In 1988, La-Z-Boy decided they wanted to convert from the solventborne coatings and adhesives they used at the time to water-based systems. They elicited the cooperation of their suppliers and also approached other suppliers. They spent the next three years testing water-based coatings and adhesives.

In January, 1992, the experimental work was completed and La-Z-Boy converted, in one shot, to a full water-based coating system and a one-part and two-part water-based adhesive system. More recently, La-Z-Boy has reassessed their adhesive system and has now converted away from the two-part adhesive. All of the adhesives used in the plant today are water-based one-parts. According to Ted Meinke, Plant Supervisor, "We worked very hard on the conversions much earlier than other companies. We're pleased that we eliminated solvents from our plant."

In terms of the new adhesive system, Ted Meinke does not believe the company lost anything in the conversion. "Although there were problems with the two-part system, now that we're in the one-part system throughout, we've really minimized our costs."

At first, the workers did not like the water-based adhesives. They were used to solvents which have a very short tack time. Workers are paid by piecework and they did not want to wait between spray operations because it would reduce their pay. The employee charged with optimizing the conversion quickly figured it out. She could spray up two stacks of foam and by the time she was finished, she could begin bonding the first stack. On balance, the throughput remained about the same even though the tack time of the water-based adhesives is longer. At this stage, all three of the adhesive sprayers, Mary, Rosalina and Sylvia, much prefer the water-based adhesives because of their reduced exposure to solvents.

The early efforts of the La-Z-Boy Redlands plant helped the company convert to water-based systems in their other plants nationwide. "The new water-based process is better from an environmental and worker exposure standpoint. The most important thing is that the process is technically effective," says Ted Meinke.

The cost comparison for L-Z-Boy for the TCA based adhesives and the water-based one-part adhesives is shown below. The figures account for the fact that La-Z-Boy's production has increased since 1992 when the plant converted away from the TCA based adhesives. The values show that use of the water-based adhesives is 35 percent less costly than use of the TCA based adhesive.

Says Tony Freitas, a Production Supervisor involved heavily in the conversion, "I wouldn't want to convert back to the solvent based glue even if we could. The water-based system we have today is great."

Annual Cost Comparison for La-Z-Boy

	TCA Adhesive	Water-Based Adhesive
Capital cost	-	$120
Adhesive cost	$28,800	$15,840
Labor cost	$113,400	$113,400
Maintenance cost	$1,800	$4,914
Electrical cost	$1,080	$3,600
Training cost	-	$227
Regulatory cost	$1,193	$528
Production adjustment	1,455	-
Total Cost	$212,827	$138,629

OFFICE CHAIR MANUFACTURER STARTS UP WITH HOT MELT GLUES

Mike Mekjian started a new business in February 1996. The company, called Sit-On-It, manufactures office chairs and is located in Brea, California. Between 100,000 and 200,000 chairs are manufactured each year and the company is one of the top 25 office chair manufacturers in the country. Today, Sit-On-It has a 31,000 square foot facility with 60 employees.

"I worked at another larger office furniture manufacturer for several years," says Mike Mejian. While he was there he analyzed a variety of different gluing processes that used 1,1,1-trichloroethane, methylene chloride, water-based and hot melt adhesives. "When I started up Sit-On-It, I wanted it to be completely clean from the beginning so I decided to go with hot melt adhesives," says Mike Mekjian. "I didn't want environmental problems down the line."

In the office chair production process, Sit-On-It bonds foam-to-wood and foam-to-fabric. Particularly for bonding foam-to-wood, an aggressive adhesive is needed. In bonding the foam-to-fabric, the adhesive must have a two to three minute "open time." This allows a period for the workers to adjust the foam and fabric properly. This is especially important when the fabric has patterns or a geometric design. Another requirement for the adhesive is that it have a high heat release rate. This is to ensure that high temperatures would not reactivate the adhesive. The company has changed glues three times to get the hot melt with the best properties for their application.

Originally the company applied all the adhesive in a batch operation. Last year Sit-On-It purchased a conveyorized system. At this stage, about 30 percent of the bonding is done on a manual line and 70 percent on an automated line. All of the foam-to-wood bonding is done on the conveyor line. Pressure is applied and the glue dries instantly. Then the conveyor applies glue to the foam and to the fabric. Four workers staff the three upholstery assembly stations where the foam and fabric are adjusted properly.

"We grew 600 percent in 1997 and 300 percent in 1998," says Mike Mekjian. "The investment in the conveyor line was worthwhile. It's very efficient. Hot melt adhesives were the right choice for us. We've been able to expand and do the right thing for the workers and the environment," he says.

Annual Cost of Hot Melt Adhesives for Sit-On-It

Capital cost	$8,150
Adhesive cost	$93,700
Labor cost	$88,000
Maintenance cost	$440
Electrical cost	$2,580
Gas cost	$60
Total cost	$192,930

BUS SEATING MANUFACTURER SEARCHES FOR ALTERNATIVE ADHESIVE

American Seating manufactures transportation, office and auditorium seating at their production plant in Grand Rapids, Michigan. The company has 700 employees today and has operated at the same location since 1888. American Seating has a 95 percent market share in the manufacture of seats for tour and inner city buses; about 200 employees work in the transportation seating division. They also manufacture auditorium and sports seating, seats for colleges and major league teams. The company production amounts to between 500 and 1,000 seats per day.

American seating uses slabstock polyurethane and molded foam in their bus seating. Their operations involve bonding foam-to-metal, foam-to-vinyl, foam-to-fabric, vinyl-to-metal and vinyl-to-fabric. The product used by the company currently is a solventborne adhesive containing acetone and various other organic solvents. Two or three people apply adhesive during the two 12-hour shifts the company operates.

American Seating has been testing alternatives to their solvent based adhesives for years. They would like to identify a suitable water-based alternative. The water-based products they have tested give good results in bonding foam-to-metal and foam-to-vinyl but not for vinyl-to-metal. The "green strength" or bond strength of the water-based adhesives they have tested so far do not meet the company's standards. The company has also tried hot melt adhesives that did not bond well to the metal.

"We would convert to a water-based adhesive tomorrow if we could find one that met our requirements," says Warren Zimmerman, Manager of the Production Operations Group. "We're not happy with a solvent glue. If we could use a water-based glue, it would be better for the workers, the community and the environment," he says.

Annual Cost of Solvent Adhesive for American Seating

Capital cost	-
Adhesive cost	$65,875
Labor cost	$117,000
Maintenance cost	$1,903
Electrical cost	$11,520
Total cost	$196,298

PUBLIC SEATING COMPANY CONVERTS AWAY FROM SOLVENT ADHESIVE

Hot Melts Appropriate for Most of Production

Country Roads is located in Greenville, Michigan. During the winter, the company has 80 employees that work one shift. During the summer, Country Roads hires 40 additional workers and the company operates two shifts.

Country Roads manufactures and remanufactures public seating for arenas, auditoriums and theaters. During the refurbishing process, the seats are pulled apart. All of the metal and most of the wood they contain is reused in the process. New foam and fabric are used on the refurbished seats which are put back in use. The company remanufactures about 200,000 chairs a year.

As part of the refurbishing process, the company used a methylene chloride based glue to bond foam-to-wood, foam-to-steel, foam-to-fabric, steel-to-fabric and foam-to-vinyl. Three workers applied the adhesive in two spray booths. The company started aggressively investigating alternatives in the last year. After a significant amount of testing, the company found that hot melt glues best satisfied their requirements for about 90 percent of their production. The company is in the process of converting from the METH based adhesives to the hot melt glues.

"The hot melt glues look very good for most of our production," says Dave MacMillen, Plant Superintendent at Country Roads. "We still need a good adhesive for bonding plastic to metal," he says. "We plan to test an acetone glue for those applications. We're going to make a full conversion away from methylene chloride."

Annual Cost of Methylene Chloride Adhesives for Country Roads

Capital cost	-
Adhesive cost	$25,300
Labor cost	$179,200
Maintenance cost	$396
Electrical cost	$360
Total cost	$205,256

MATTRESS MANUFACTURER CONVERTS TO HOT MELT ADHESIVE

Jamison Bedding has four plants in the United States. The company makes a mid to high end product and is the largest private label mattresses manufacturer in the country. They sell their retail bedding primarily east of the Mississippi. Jamison is the fourth largest contract bedding manufacturer and sells to hotels like the Marriott chain and motels. In the past, the company had their own spring machinery but today they purchase the springs that are used in the production process.

Jamison operates a plant near Nashville, Tennessee which employs 75 people. About 50 of the employees work in the factory. Approximately 95 percent of the workforce has been with Jamison for many years. The plant makes 300 to 400 mattresses each day but only a few are of the same type. An average of 75 pillow top mattresses require gluing per day. The pillow top market has blossomed and likely will continue to grow.

In the manufacture of the bedding, the company uses adhesive for two types of bonding. First, glue is used to bond the inner mattress to a non-woven material which functions as an inner cover. Second, the glue is used to bond the foam surface of the mattresses to the non-woven quilted material.

Historically Jamison used METH and TCA based adhesives. A few years ago, when TCA adhesives were used, Jamison decided to make a conversion to hot melt adhesives. Today the company uses a pressure sensitive hot melt glue but is not entirely satisfied with the results. "The problem we face in the manufacturing is to get a long enough open time with the glue so the workers can reposition the mattress components," says Clay Finney, the Manager of the Nashville plant. "Another problem is that the adhesive sometimes remains tacky and the people that sleep on the mattresses will hear a velcro sound when they lie down on them," he says.

The company purchased several spray guns to apply the hot melt adhesives. Two of the inexpensive guns have proved inadequate for the process but the more expensive spray equipment has worked well. The company does not have to clean the application equipment since they converted to hot melt glues. When the company used solvent based adhesives, the maintenance time was substantial.

Jamison is investigating non-pressure sensitive hot melt glues as well as water-based adhesives to try to improve their process further. "We are not interested in using solvent based adhesives again," says Clay Finney. "The workers did not like the solvent products. They complained about the smell. Even though the hot melts are not ideal, the workers like them better. The hot melts are also better for the environment."

Jamison's costs for using the hot melt glues and the TCA based adhesives are comparable. The table below shows the costs of both processes.

Annual Cost Comparison for Jamison Bedding

	TCA Adhesive	Hot Melt Adhesive
Capital cost	-	$2,690
Adhesive cost	$4,780	$2,535
Labor cost	$61,200	$61,200
Maintenance cost	$1,320	-
Electrical cost	-	$2,350
Total cost	$67,300	$68,775

BEDDING COMPANY USES HOT MELT AND SOLVENT BASED ADHESIVES

McKinney Bedding Company is located in Springfield, Missouri. The company makes high, medium and low end bedding. About 80 percent of the mattresses are sold under the trade name Restonic and 20 percent under the trade name Futurama.

McKinney makes 100 different styles of contract bedding and produces between 250 and 500 pieces per day. Pillow top mattresses represent about five percent of their total production.

McKinney uses hot melt adhesives on their lower end line. The hot melts are used to bond foam-to-fabric, foam-to-insulator pads and foam-to-quilted material.

McKinney is currently using a methylene chloride based adhesive for bonding the pillow top mattresses and for bonding the soft side water beds. The solvent adhesives used by the company come in a 26 pound pressurized container. Spray guns are attached to the pressurized container and the adhesive is sprayed on the bedding.

The company has compared the cost of continuing to use the methylene chloride based adhesive in pressurized containers with the cost of using acetone aerosol adhesives. Because of the Occupational Safety and Health Administration (OSHA) regulation on methylene chloride, the company would have to make an investment in a spray booth to reduce the worker exposure to the chemical. Even with this capital investment, the cost of using acetone aerosol adhesives is higher because aerosol packaging is an expensive product.

"We're looking at the costs of all the options right now," says Lloyd McKinney, owner of McKinney Bedding. "We know the aerosol cans work for our applications and we are considering converting to them even with the higher cost," he says.

Annual Cost Comparison for McKinney Bedding

	Methylene Chloride Adhesive	Acetone Aerosol Adhesive
Capital cost	$489	-
Adhesive cost	$2,762	$4,397
Labor cost	$1,200	$1,200
Total cost	$4,451	$5,597

BEDDING MANUFACTURER CONVERTS AWAY FROM GLUES ALTOGETHER

Justice is an upholstered furniture and bedding manufacturer located in Lebanon, Missouri. About 15 employees are involved in the bedding operation and 45 to 50 in furniture manufacturing. The company makes recliners, sofas, loveseats, chairs and mattresses.

Justice makes mid and high end bedding. The company manufactures between 250 and 400 pieces of bedding each day. They purchase the foam and fabricated foam for their manufacturing process from Leggett & Platt, located across the street from Justice.

Until 1992, Justice used adhesive in their mattress manufacturing line for bonding pillow tops to their mattresses. At that stage, the company decided to make an investment in an alternative technology for making mattresses. The company now uses sewing to join the nonwoven material to the ticking, the polyester and the polyurethane in their mattresses.

"We decided we didn't want to use the glues any longer," says Dan Wampler, Plant Manager at Justice. "The solvents in the adhesives have all kinds of problems and we just didn't want to deal with that any longer."

In spite of the capital investment the company made for the sewing equipment, Justice has saved money through the conversion. "I estimate we have cut our costs by about $15 per mattress by adopting the sewing process," says Dan Wampler.