

**DIAPERS: ENVIRONMENTAL IMPACTS  
AND LIFECYCLE ANALYSIS**

by

**Carl Lehrburger  
Jocelyn Mullen  
C.V. Jones**

**January 1991**

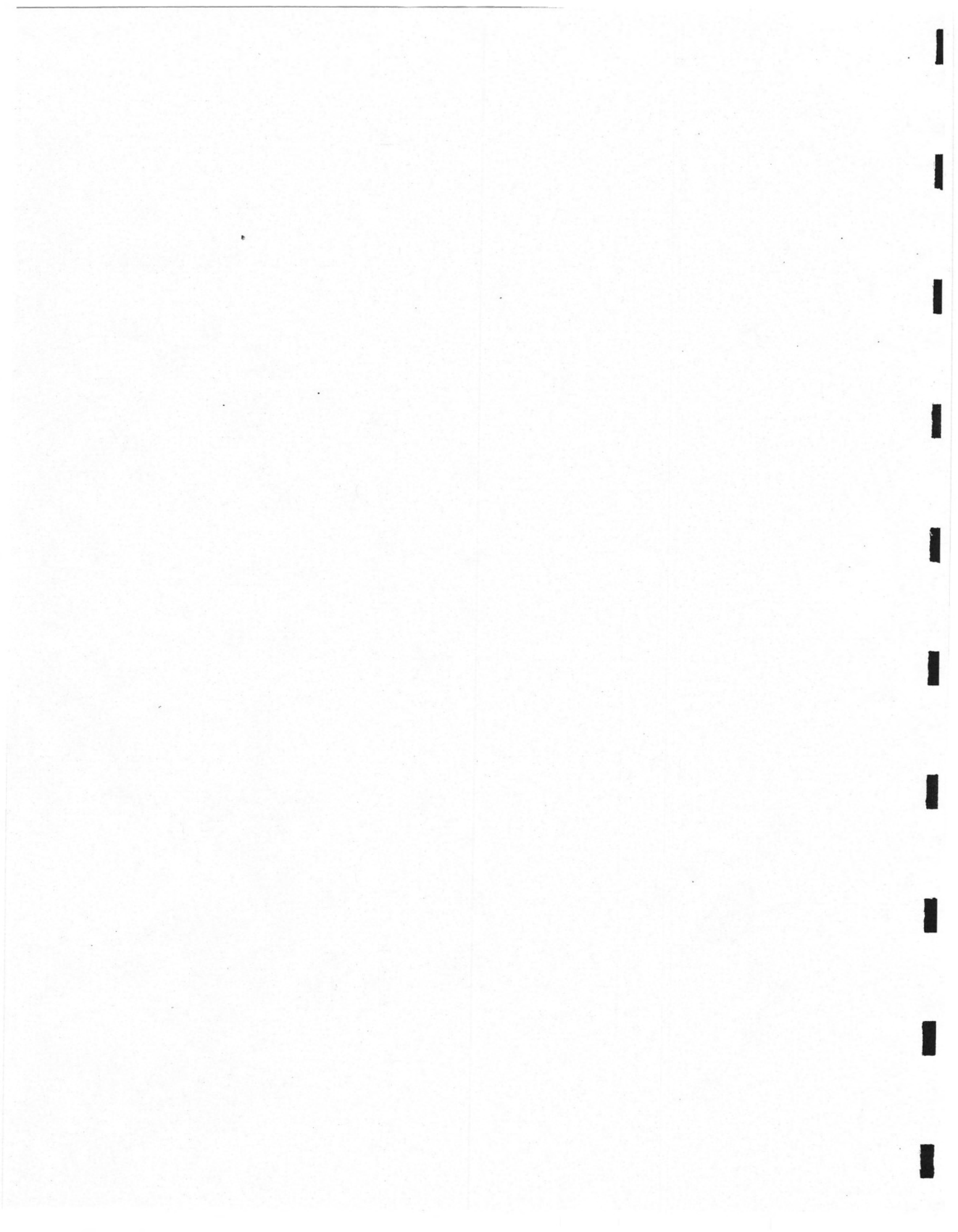
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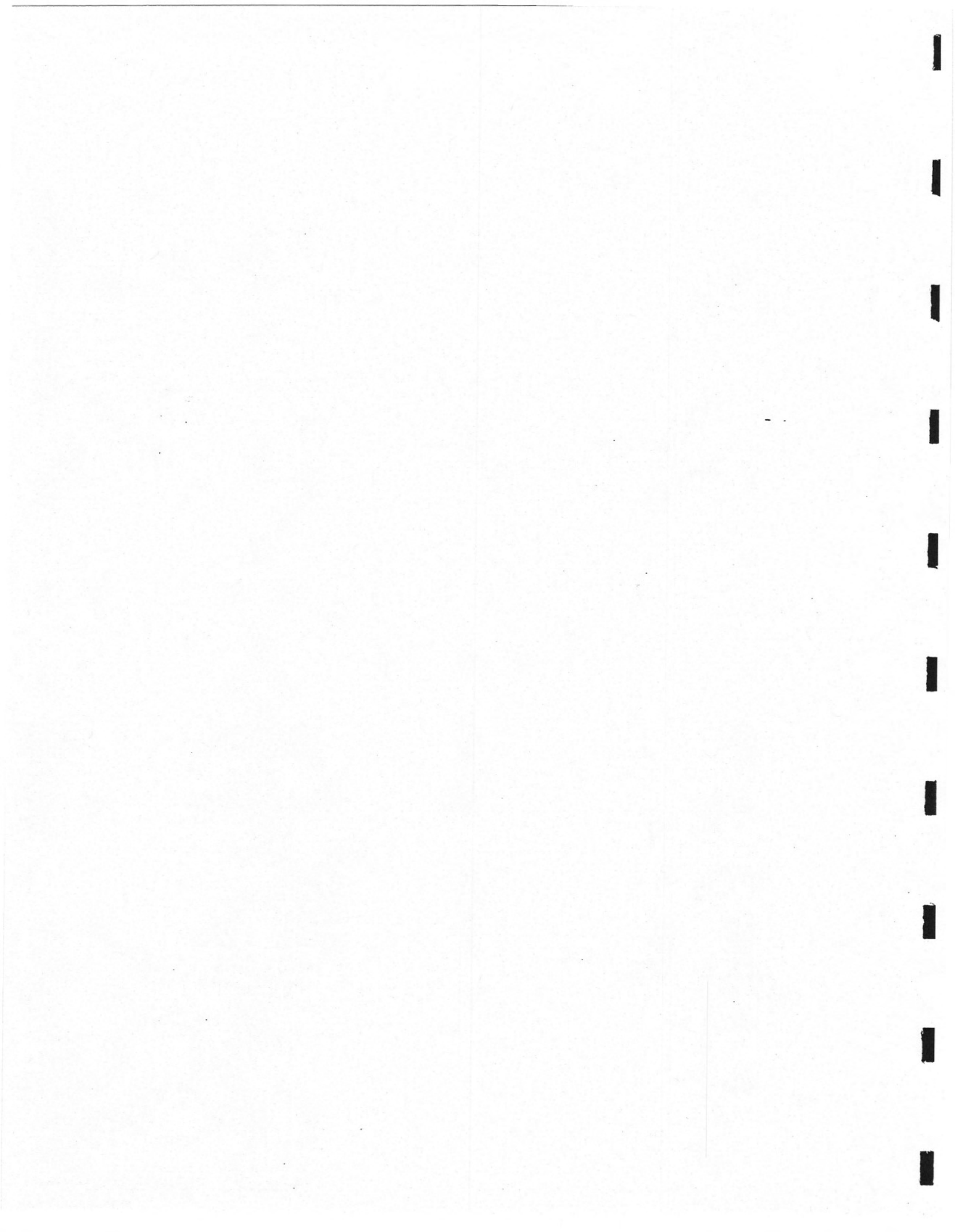






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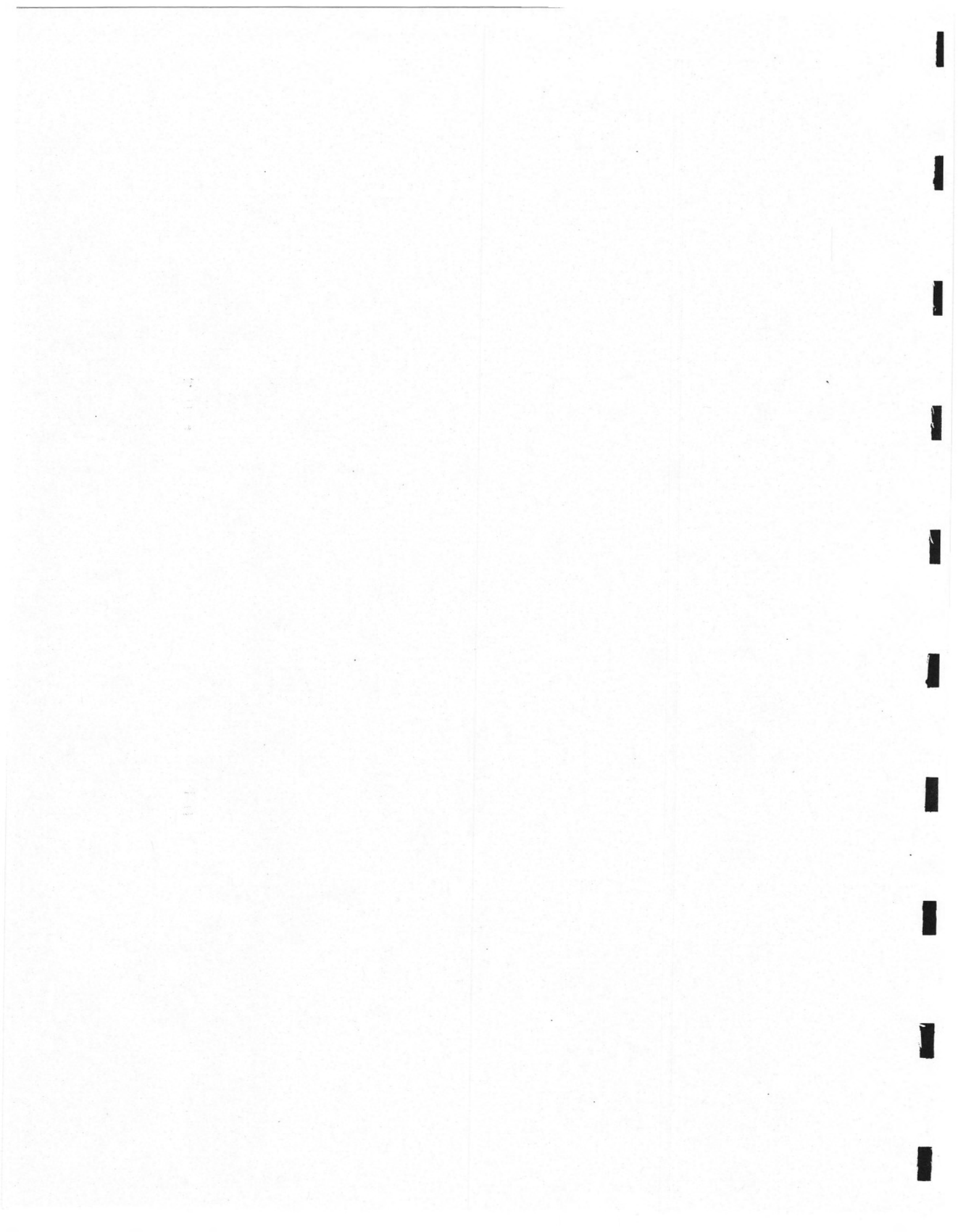
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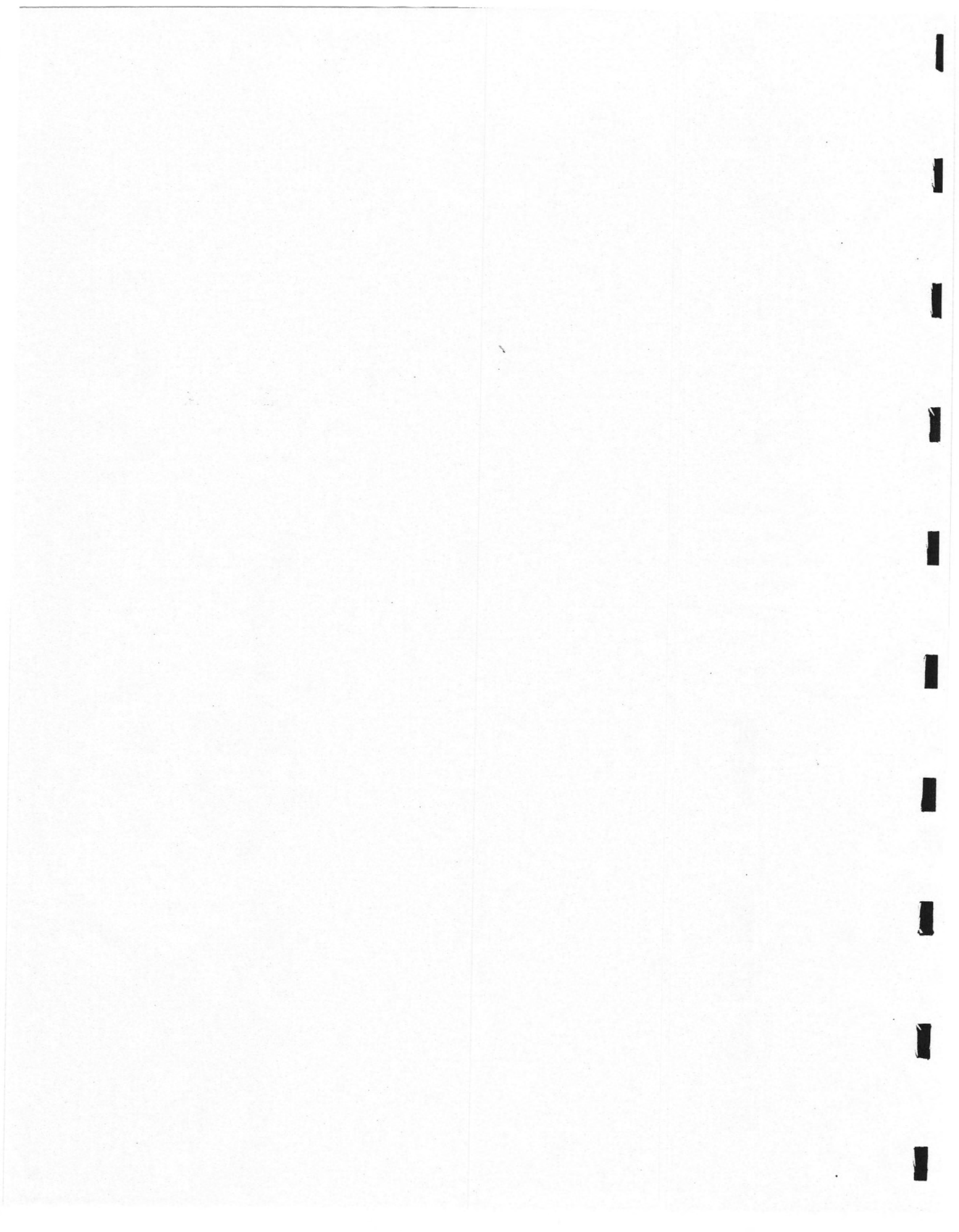
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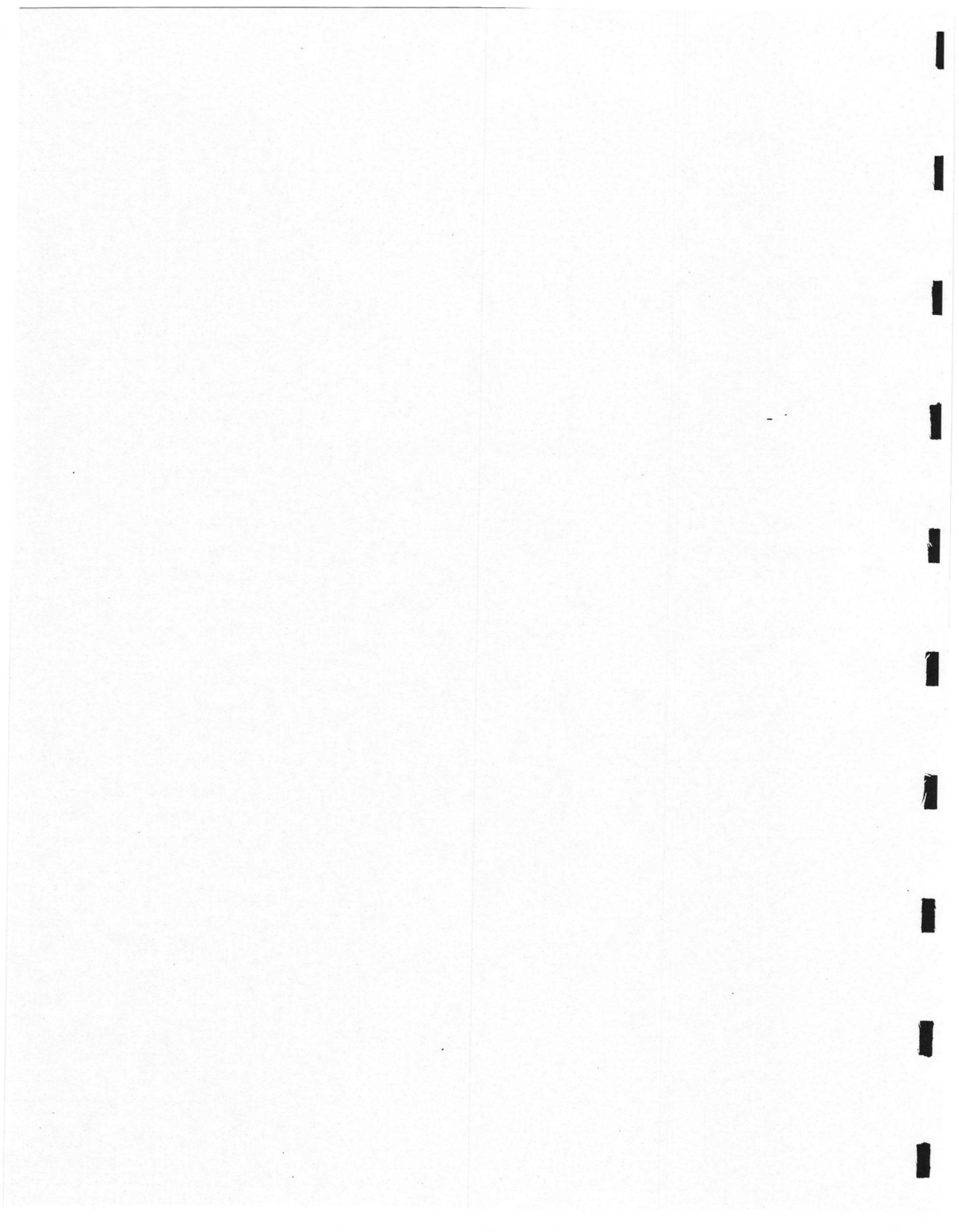
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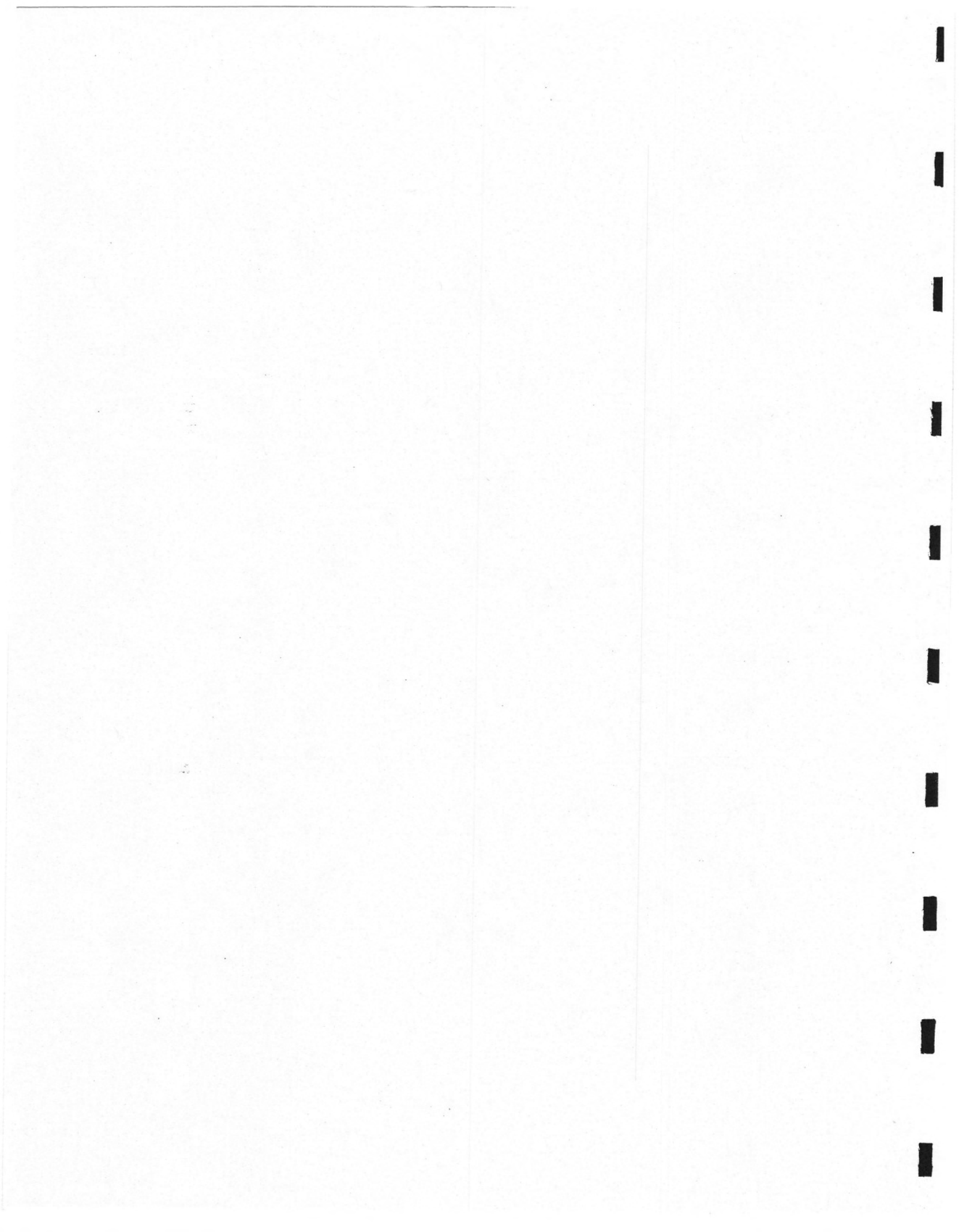
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# I. EXECUTIVE SUMMARY

## A. Abstract

A product lifecycle analysis has been undertaken comparing single-use disposable diapers with reusable cotton diapers.<sup>1</sup>

The analysis catalogs resource consumption for energy, water and raw materials, and environmental releases in the form of solid waste, and air and water emissions. Once the relative environmental burdens of each diapering mode are understood, recommendations for minimizing overall environmental burden can be developed, perhaps catalyzing or adding to the formation of public policy in the solid waste arena.

The central conclusion of this study is that single-use diapers have a greater overall environmental impact than reusable diapers when all aspects of diaper production and use are taken into account. Single-use diapers are shown to generate significantly more solid waste, to consume greater quantities of energy and raw materials, and to generate more potentially toxic pollutants on a per-diaper-change basis.

With respect to water use, the results are not as conclusive. Commercially laundered reusable diapers use 30 percent less water than single-use diapers when toilet disposal of soiled single-use diapers is included and 60 percent less water than home laundered reusables. However, when water usage for commercial and home reusables is averaged, reusable diapers are shown to require more water than single-use diapers. Reusables create a greater quantity of water pollution than single-use diapers, primarily from the laundry cycle. From a relative resource impact perspective the waste water burdens of reusable diapers are more readily treated and pose less of a threat to the environment and public health than do waste waters generated by the paper and plastics industries.

Although using single-use diapers generates notably more carbon monoxide and particulate air emissions, both single-use and reusable diapers produce nitrogen oxide, sulphur oxide and hydrocarbon emissions in similar ranges.

Considering the overall environmental burdens, and most notably the higher volumes of solid waste produced and energy and raw materials consumed by single-use diapers, reusable diapers are determined to be superior from an environmental perspective.

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<sup>1</sup> Throughout this report, **single-use** is the term used to refer to disposable diapers, while **reusable** is used to refer to cotton or cloth diapers.

## B. Background

The environmental impacts and costs of single-use (disposable) diapers and reusable (cotton) diapers have become a source of heated debate in recent years. This controversy, which has involved environmentalists as well as public policy makers, has recently entered the technical arena of product lifecycle analysis and environmental assessments.

Today, single-use diapers account for about 82 percent of baby diaper changes in the U.S.<sup>2</sup> Since their introduction in 1961, they have become so popular that the word diaper itself has nearly become synonymous with single-use disposables. To many, single-use diapers have come to symbolize the convenience of modern-day products.

However, with growing public awareness of environmental problems such as burgeoning solid waste issues, air and water pollution and the greenhouse effect, consumers are now paying greater attention to the environmental impacts of products they use. In this context, single-use diapers are increasingly viewed as conspicuous waste in a wasteful society.

The following charts contrast reusable and single-use diapers by the number of units sold and by the percentage of diaper changes made in the U.S. among infants.

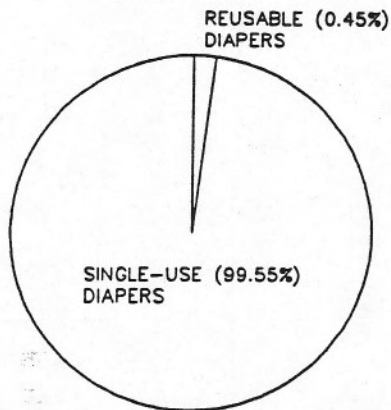


Figure 1.  
Diaper market in units sold:  
single-use/reusables

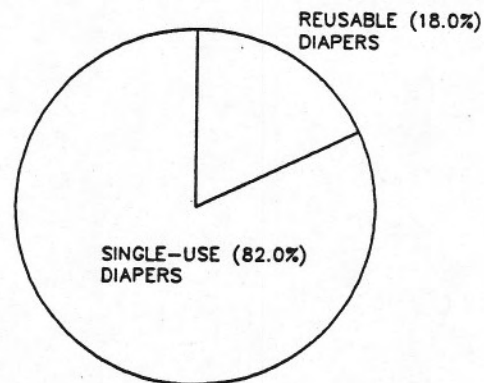


Figure 2.  
Number of diaper changes:  
single-use/reusables

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<sup>2</sup> Dr. Paul M. Smith and Keith D. Sheeran, "Summary: A Profile of Consumer Preference for Baby Diapers," University of Washington, Division of Forest Products and Engineering, (Seattle: University of Washington, July 1990).

## C. This Study's Approach

The present product lifecycle analysis comparing single-use to reusable diapers was commissioned by the National Association of Diaper Services. Three fundamental questions arose at the outset:

1. What are the environmental impacts of each diaper system and which diaper is least damaging to the environment?
2. Which waste treatment system is more appropriate for processing diaper waste: waste water or solid waste?
3. Which diapering system is more economical from the perspective of out-of-pocket expenses to consumers?

The primary goal of the investigation was to answer the first question, that is, to determine which diapering mode is less burdensome to the environment based on the impacts of the following categories:

- solid waste generation
- energy production and consumption
- water quantity
- water quality
- air quality
- resource consumption.

This study tracks the resource requirements and environmental burdens of each process involved in the manufacturing, use and disposal/reuse of super absorbent single-use diapers and conventional cotton reusable diapers. A lifecycle or cradle-to-grave analysis identifies the systems or processes to be studied, then catalogs materials and energy flows in and out of the defined system. Processes studied in the diaper lifecycle include raw materials acquisition, fuels refining, intermediate processing, such as fertilizer and propylene, diaper manufacturing, use practices, disposal or reuse systems including laundering, and incidental packaging. The systems under study are shown in figures 3 and 4 on pages 15 and 16.

Values for resource requirements and environmental releases in each category in the defined system were then combined and summarized to create the tables in this study.

Although a significant portion of cotton diapers are manufactured outside the U.S. under varying environmental controls, this study assumes that U.S. practices are followed for all steps of cotton growth, harvest, and diaper manufacture. While this is unlikely, it is impossible to study the environmental impacts of these steps in other nations for the purposes of this study.



Recognizing that the two diapering modes have different associated use patterns, basic assumptions regarding use parameters were developed, based on user surveys, marketing and sales data and published literature. These assumptions are fully described in section IID. Data was collected for each process and converted to a 1,000 equivalent use basis for comparison. The equivalent use measurement incorporates the use of multiple reusable diapers per change.

Since single-use and reusable diapers differ dramatically in their manufacturing and use patterns in each of the six categories evaluated, precise comparisons are difficult. For example, while one single-use diaper is used per diaper change, a parent may use one or more reusable diapers for each diaper change. Once used, a single-use diaper is disposed of, but a reusable diaper will be reused many times, potentially over many years, depending on type of diaper and whether it is laundered at home or by a diaper service.

The analysis shows that when the effects of manufacturing and use on the above resource categories are compared, reusable diapers have notably lower environmental impacts than single-use diapers. These impacts are summarized in sections ID and IIE, and given full treatment in sections VI and VII of the complete study.

In comparing the environmental impacts of diapers, the authors note the fundamental difference between the two diapering modes in disposal of diaper contents: single-use diapers rely on the solid waste system and reusable diapers rely on the waste water or sewage waste system. It has sometimes been overlooked that diaper wastes from single-use diapers are a primary exception to processing human sewage through the waste water treatment system. This study concludes that the waste water treatment system is more economical and performs more efficiently in collecting, transporting and processing diaper waste when compared with the solid waste stream.<sup>3</sup>

In addition to assessing environmental impacts, an economic comparison was completed. Single-use diapers, reusable diapers washed at home, and reusables laundered by diaper services were compared with respect to out-of-pocket expenses to consumers, including disposal and other environmental criteria. This comparison shows that single-use diapers are the most expensive diaper option, even when the cost of labor is included in home laundering of reusables.

This study uses available information and estimates to determine reusable diaper use patterns. Basic assumptions are in section IID and are documented where possible.

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<sup>3</sup> Solid waste processing and waste water treatment co-exist and can be interrelated, however. This is the case with sewage sludge disposal from waste water treatment systems ending up in solid waste processing facilities, such as composting and landfilling. Similarly, waterborne wastes from solid waste processing operations sometimes receive treatment at waste water treatment facilities.

This study does not encompass a public health comparison between reusable and single-use diapers. Although some public health issues are addressed, a complete analysis would include a rigorous investigation of epidemiological, toxicological, sociological, and medical studies, which were beyond the scope of this study.

## D. Conclusions

The central conclusions of this study are as follows:<sup>4</sup>

1. Single-use diapers create over 7 times more post-consumer solid waste and over 3 times more manufacturing or process solid waste than do reusable diapers. Unlike single-use diapers, reusable cotton diapers are used many times and incorporate both waste reduction and product reuse practices. Greater reliance on reusable diapers represents the obvious way to reduce solid waste created by disposable diapers.
  - Reusable diapers create less than 13 percent of the solid waste generated by single-use diapers, most of which is sludge generated at waste water treatment facilities.
  - Single-use diapers comprise approximately 2 percent of the U.S. municipal solid waste stream. Not only is the quantity of solid waste from reusable diapers 87 percent less, but the relative loads or resource impacts of reusable diaper wastes are lower than those associated with single-use diapers.
2. More energy is consumed in the lifecycle of single-use diapers than in the lifecycle of reusable diapers.
  - On a per-diaper-change basis, manufacturing of single-use diapers requires nearly 6 times the amount of energy used in manufacturing reusable diapers.
  - Commercially laundered reusables use half the energy of home reusables and one-third the energy of single-use diapers on a per-use basis.
  - On a per-use basis, the laundering cycle for reusable diapers consists of washing and drying the diaper, and treatment of the water involved. Even

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<sup>4</sup> Refer to section IID for basic assumptions used to derive these conclusions, and IIE for an elaboration of findings.

when laundering is taken into account along with manufacturing, energy consumption for the weighted average of home and commercially laundered reusable diapers is approximately 80 percent that of single-use diapers.<sup>5</sup>

3. From the standpoint of total water requirements (gross water use), single-use diapers use 37 percent more water than home laundered or diaper service laundered reusables. When in-plant water recycling is taken into account (net water use), reusables laundered by a diaper service use approximately 40 percent less water than single-use diapers when fecal disposal to the toilet is included. Reusable diapers laundered at home use approximately 77 percent more water than single-use diapers.
4. Diaper laundry services have lower resource and environmental impacts than home laundering due to economies of scale. Home laundered reusable diapers use over 2.5 times as much net water per diaper change and nearly 2 times as much energy as commercially laundered reusable diapers.
5. Waste water from growing cotton and manufacturing cloth is relatively high volume and low impact compared to waste water generated from single-use diaper components and product manufacturing. Waste water from the plastic and the pulp and paper industries contains priority pollutants and compounds which are considered hazardous, including dioxins, furans and chlorophenols. Significant environmental degradation has resulted from release of effluents from these industries leading to proposed regulatory actions.

While water usage and consumption data, and therefore effluent quality data, are difficult to compare for the two diapering modes, the following generalizations can be made:

- Waste water created by laundering reusable diapers is high in chemical oxygen demand (COD), biological oxygen demand (BOD) and total dissolved solids (TDS), and is similar to other domestic waste waters. Laundry waste water contains little or no hazardous constituents, but can contain high levels of nitrogen and phosphorous.

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<sup>5</sup> These calculations are based on a weighted average between commercially and home laundered reusables. Included in calculating energy consumption in the manufacturing process (for single-use and reusable diapers) is the energy value of the feedstock, e.g., hydrocarbons used as feedstock in plastic for single-use diapers and fertilizer used to grow cotton for reusables.



- Waste water created and recycled in industrial processes included in single-use diaper manufacturing is either discharged with minimal treatment, adding to environmental burdens, or treated on site, creating industrial sludge which requires careful management. Little data was found on the characteristics of industrial sludge.
  - Waste water created in reusable diaper manufacturing contains high amounts of suspended solids but relatively low COD. Plastics, pulp and paper waste waters are lower volume, but contain high COD and numerous potentially toxic organic and inorganic residues.
6. Air emissions are comparable for both single-use and reusable diapering modes. Because of lower energy use commercial diaper services produce fewer air emissions on an equivalent change basis than home laundered diapers.
  7. Reusable products conserve resources and energy through multiple use, resulting in less resource and energy consumption per use compared to the high energy and resource allocations for single-use products. Because disposable diapers are a single-use product, the material and energy inputs are higher, resulting in immediate and significant solid waste generation. Large quantities of natural resources are consumed in the production of both types of diaper. Obtaining those natural resources results in land degradation, process solid waste generation, air and water pollution, soil erosion, and habitat loss, as well as contributing to the greenhouse effect.
  8. Single-use diapers require more out-of-pocket expense per diaper change than reusable diapers. Costs of commercial diaper service laundering lie between home washed reusables and single-use disposables.
    - Out-of-pocket expenses for single-use diapers are approximately 50 percent higher than for reusable diapers laundered commercially, and 66 percent higher than for reusable diapers laundered at home.
    - Allowing for a value for household services of \$6.00 per hour for home laundering raises the cost of home laundered reusable diapers above the cost of commercially laundered reusable diapers. However, both are still well below the unit costs of single-use diapers, especially when solid waste collection costs are taken into account.



9. Recent pilot programs aimed at recycling single-use diapers have yet to demonstrate economic viability and are not likely to be feasible without continued subsidies from single-use diaper manufacturers. Recycling single-use diapers may not significantly improve their environmental impact compared to reusable diapers, and would likely increase the cost, energy, and water requirements.
  
10. The waste water treatment system, contrasted with the solid waste disposal system, is more appropriate for handling diaper waste, since it was specifically designed to handle all human sewage and septage. It also appears to provide a more efficient, sanitary disposal pathway with greater opportunity for beneficial reuse of concentrated and processed sludge.
  - If all diaper consumers relied on reusable diapers, the waste water load from diapers would be less than 0.5 percent of total municipal waste water, compared to 3 percent loading of the solid waste stream if all consumers relied on single-use diapers. From a relative resource impact perspective reusable diapers have a lower environmental impact than single-use disposables.

## E. Recommendations

1. Reusable diapers are, and should be promoted as, a more environmentally sound approach to diapering in comparison to single-use diapers. The clear advantages of reusables in reducing solid waste, conserving natural resources, and reducing the generation and release of potentially toxic pollutants should be emphasized.
2. Diapers should be included as part of an integrated solid waste management program that emphasizes waste reduction as the preferred option. Use of reusable diapers instead of single-use diapers is an overlooked source reduction option, that should be encouraged as part of a broader waste reduction strategy to minimize landfilling of solid waste.
3. Although reusable diapers are gaining in popularity, single-use diapers remain the most frequently used diaper. Increased education on the environmental and economic benefits of reusables, particularly in institutional settings and day-care facilities, is necessary.
4. Discussions of which diapering mode is superior from an environmental perspective should include the question of the most appropriate waste path for diaper waste. The waste water treatment system is preferable to the solid waste disposal system because it provides for more efficient and less expensive transportation to processing facilities, and because of reduced risks of exposure to disease-causing organisms.

## II. OVERVIEW OF ENVIRONMENTAL AND ECONOMIC ASSESSMENTS OF DIAPERS

### A. Introduction: The Controversy Revisited

The environmental impacts of using diapers were virtually ignored by the public until 1989, when Carl Lehrburger published Diapers In The Waste Stream: A Review Of Waste Management and Public Policy Issues<sup>6</sup>, a report to the National Association of Diaper Services (NADS). That study, which addressed the solid waste impacts of single-use diapers, concluded that reusable diapers were the clear and obvious solution to the solid waste problem created by single-use diapers, and encouraged closer scrutiny of the overlooked environmental impacts they created.

During 1989 and 1990, the media and policy makers focused intently on the diaper issue as solid waste problems escalated. This new attention to diapers coincided with two emerging perspectives: 1) "green marketing," whereby manufacturers of products began to emphasize and promote the environmental benefits of their products; and 2) a growing consensus that "cradle-to-grave" evaluations or lifecycle studies are essential to understanding the overall impact of a product.

In response to the growing public debate over diapers, the Procter and Gamble Company (P & G), the largest manufacturer of single-use diapers, sponsored in 1990 an environmental and economic comparison of diapers. This study<sup>7</sup> acknowledged the solid waste differences between reusable and single-use diapers highlighted in Diapers In The Waste Stream, but concluded that reusables consume more energy and water and create greater amounts of air and water pollution than single-use diapers. Among the study's conclusions is the declaration that neither reusable nor single-use diapers "are clearly superior in the resource and environmental impact categories considered...", and that disposables have clear health, environmental and economic advantages that "appear to outweigh the more limited advantages of reusable diapering materials..."

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<sup>6</sup> Carl Lehrburger, "Diapers in the Waste Stream: A Review of Waste Management and Public Policy Issues," (December 1988).

<sup>7</sup> Arthur D. Little, Inc., "Disposable Versus Reusable Diapers: Health, Environmental and Economic Comparisons," (Cambridge, MA: Arthur D. Little, Inc., 1990). Hereafter ADL2.



This P & G-sponsored study received attention not only for its content and conclusions, but also as a model for how product lifecycle assessments should or should not be performed. The authors of the present study benefitted from access to this and other diaper studies, and from participating in industry forums seeking to refine the process by which studies of this nature are undertaken.<sup>8</sup>

The authors' present study was initiated in early 1990 to provide an independent diaper lifecycle analysis that encompassed resource impacts not previously considered in Diapers in the Waste Stream. The conclusions are at odds with the P & G-sponsored study, particularly regarding water and energy use comparisons between reusable and single-use diapers. The present study concludes that reusable diapers are superior from an environmental perspective. A more detailed comparison of the assumptions used in this and the P & G-sponsored study are examined in section IIF, "A Review of Other Diaper Assessments".

It is evident that different studies of the same subject may arrive at contradictory conclusions as a result of varying assumptions and depending on the boundaries of the lifecycle assessment, and no one study should be used solely as a basis for evaluations. Public debate must transcend media oversimplification and include review of methodology and assumptions as well as conclusions. However, the authors' believe that this report provides a more comprehensive comparison between reusables and single-use diapers than the P & G-sponsored study as a result of: 1) the expanded boundaries of the present study; 2) a more refined distinction between home and commercially laundered diapers; and 3) more recent information not available to the authors of the P & G-sponsored study.

The diaper debate has moved to the forefront of the emerging field of lifecycle product assessments. As more companies seek to promote the environmental worthiness of their products, additional studies will be completed. More demands will be placed on industry and regulatory agencies to participate in these studies and make environmental data available to the public. Consumers, public-policy makers, and manufacturers of products will benefit from the growing inventory of information useful for making purchasing decisions, improving regulations, and formulating new products.

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<sup>8</sup> Product Lifecycle Assessment Workshop, August 1990, sponsored by the Society for Environmental Toxicology and Chemistry (SETAC).



## B. Description of a Product Lifecycle Analysis

Product Lifecycle Analysis (PLA) is generally defined as a cradle-to-grave analysis of a product that includes manufacturing, transportation, processing, consumer use and disposal. It is designed to assess those effects and costs that are not obvious to the consumer when he or she buys or uses a product.

An environmental assessment is only one of several tools used to evaluate the effects of an activity on the environment. A thorough Product Lifecycle Analysis consists of three components: (1) an inventory, (2) an impact assessment, and (3) an impact reduction assessment, or mitigation plan. One of the objectives of such a study is to determine and reduce the environmental burdens associated with an activity or process.

The inventory is an objective quantitative cataloging of the energy, water, and raw material requirements, air emissions, water effluent and solid wastes generated during all phases of the lifecycle of the product or process defined for study. An impact assessment is a characterization and evaluation of effects associated with energy, water, and materials use, and contaminant releases over the lifecycle of the product. And finally, the impact reduction assessment is a systematic evaluation of needs and opportunities to reduce the environmental burdens associated with energy, water, and materials use, and contaminant releases over the defined lifecycle of the product.

A PLA, consisting of all three components, is a powerful tool for generating information on the potential for reduction of environmental impacts associated with diapers. This study attempts to quantify the materials and energy inputs, and the emissions and release outputs for single-use and reusable diaper manufacturing, use and disposal. Results of the inventory and environmental assessment are documented in the report. Recommendations on how to minimize the environmental impacts associated with the use of diapers are limited to the conclusion that reusable diapers in general, and commercially laundered diapers in particular, create fewer environmental burdens than single-use diapers. This study does not attempt, however, to provide a quantitative risk assessment, and relative impacts are instead discussed qualitatively.

Too often, maintaining the status quo is easier than change, regardless of environmental and resource impact analyses. The most significant potential contribution of a PLA is to make intelligible the impacts of processes or products so that decisions can be made toward reducing the overall environmental loading. There is no such thing as a zero risk or zero impact activity. However, careful analysis and decision making can substantially reduce the impacts.

Environmental assessments and PLAs are useful tools for regulators, public policy makers and consumers in determining the relative importance of different resource categories and impacts.

## **C. Defining System Boundaries**

This diaper lifecycle assessment addresses the manufacturing processes involved in the production of single-use and reusable diapers, including: electrical energy generation; water use, treatment and discharge; raw materials refining; primary and secondary product manufacture; process and post-consumer waste management and disposal; and phases of waste and emissions generation including air, water and solid wastes.

Not included in this assessment are: capital equipment in primary and secondary product transformation; energy consumed in space heating and cooling; air pollution generation impacts of direct combustion of fossil fuels on manufacturing sites; impacts of detergent and pesticide manufacturing; or transportation impacts (transportation issues are discussed in section V F of the complete report). Heat and noise emissions are difficult to quantify because of a lack of available data and are not addressed in this study.

The base year for most of the data is 1988, unless otherwise indicated; 1988 is the most recent year for which the quantity and quality of data necessary to perform this magnitude of assessment are available. Figures 3 and 4 in this section define the systems and their boundaries for single-use and reusable diapers respectively, for the purposes of this study.

Energy from renewable sources has been omitted from energy consumption analyses in earlier lifecycle assessments, leading to a skewed assessment of secondary energy generation and consumption impacts. This study does not differentiate between renewable and nonrenewable energy sources on a quantitative basis, but will discuss the issue on a qualitative level when comparing the impacts and benefits of each type of diaper.

Manufacturing operations produce wastes in the form of heat, noise, waterborne, airborne, and solid wastes. These wastes eventually end up in an environmental sink: air, water, or soil, with uptake into plants, animals and humans as a temporary detour along the Earth's cycle of the elements.

Pollution control technologies commonly used today generally serve only to change the phase of the waste, and rarely are wastes completely destroyed. For example, waste water treatment converts waterborne wastes to a solid sludge through the processes of settling and clarification. Incineration of sludge converts the material into ash, a solid waste, and airborne emissions. Since all processes produce wastes, the characteristics of the wastes and their impacts on the environment must be one of the bases for comparison of alternative products and processes.

Two products with complex manufacturing processes are being compared in this study: disposable or single-use diapers, and cotton or reusable diapers. The criteria for their comparison are energy consumption, raw materials and water consumption, waste and emission generation, and waste toxicity or hazard.

The following components of diaper use and manufacturing processes are considered:

1. reusables

- a. raw materials acquisition,
- b. intermediate impacts,
- c. cotton growth and harvest,
- d. cotton refining,
- e. petrochemical refining,
- f. cloth manufacturing,
- g. conversion to cloth diaper,
- h. laundering processes,
- i. disposal.

2. single-use

- a. petrochemical refining,
- b. raw material acquisition,
- c. petrochemical manufacture,
  - (1) low density polyethylene
  - (2) polypropylene
  - (3) polyacrylic gels
  - (4) adhesives
- d. pulp and tissue manufacture,
- e. conversion to diaper,
- f. disposal.

3. processes common to both operations

- a. electrical energy production.

In order to address the question of which diapering system is less burdensome to the environment, this study undertook analysis of the relative resource impacts of each diapering mode on six categories, which are solid waste, energy use, water usage, water quality, air pollution, and resource use. The scope of the study is indicated in the following figures.



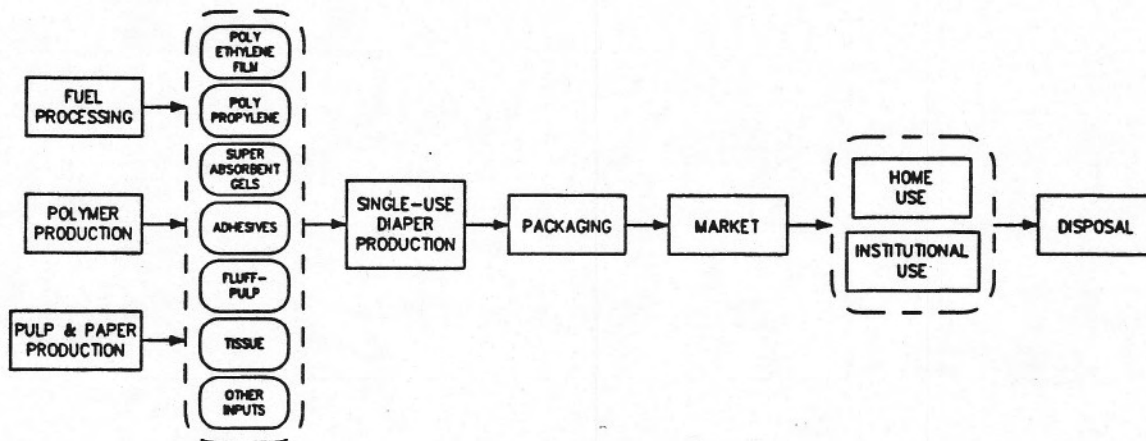


Figure 3. Single-use diaper process overview

### Manufacturing Process: Single-use Diapers

The analysis of single-use diapers contained in this report is based on the use of a super absorbent diaper such as the Procter and Gamble Ultra Pampers brand. While this type of diaper was only recently introduced, it represents a significant (21.5 percent) share of the single-use diaper market, and a considerable amount of data is available for analysis. Use trends indicate that super absorbent diapers will continue to capture a significant single-use diaper market share, eventually replacing bulkier, less absorbent single-use diapers.

Single-use diapers are made predominantly of fluff pulp and tissue, with smaller components of plastics such as low density polyethylene and polypropylene. These materials require the ancillary production activities of timber growth and harvest; pulp and fluff pulp manufacturing; chlorine, sulfuric acid and caustic raw material acquisition and intermediate product manufacturing; tissue paper manufacturing; ethylene manufacturing including the refining of crude oil and natural gas; low density polyethylene (LDPE) resin and film manufacturing; propylene resin and polypropylene nonwoven film manufacturing; polyacrylic gel manufacturing including ammonia production; and finally, the conversion to the diaper end product. Natural rubber and hot melt adhesives each represent less than 3 percent of the single-use diaper by weight, and are therefore not addressed in this study.



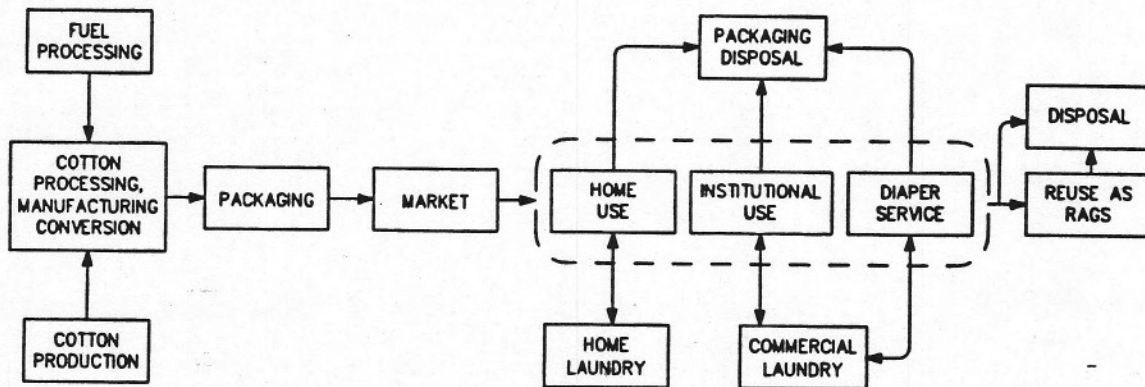


Figure 4. Reusable diaper process overview

#### Manufacturing Process: Reusable Diapers

Cotton diapers are manufactured from cotton fibers using standard textile processing weaving and manufacturing operations. Analysis of cotton diaper production begins with the initial operations of cotton growth and harvest. Fertilizer manufacture and fertilizer and pesticide application are included in the analysis of cotton growth where data is available, as is the consumption of energy and water. Harvesting, ginning, carding, drawing, spinning, weaving and finishing are secondary operations also included in the analysis, as are the primary operations of conversion of cotton cloth to the finished diaper product. Finally, the laundering operations associated with reuse are analyzed for both the home and commercial wash scenarios. In this analysis, all reusable diapers are assumed to enter the solid waste stream, and are accounted for in the solid waste calculations.

## D. Key Assumptions

The key assumptions used in this study are as follows.

1. Number of diapers:
  - A. Single-use diapers: 17 billion infant diaper equivalent units for 1989. Single-use diaper sales are reported at 16 billion units for infants and 440 million adult incontinence products. This study estimates a total of 17 billion diapers for 1989 by increasing the number of adult diapers to 1 billion based on: 1) the belief that the adult incontinence market is underestimated, and 2) adult incontinence products are larger than infant diapers and heavier when disposed compared to average infant single-use diapers.
  - B. Reusable diapers: estimated at 3.512 billion changes per year. This is derived from an estimate of 16 billion infant single-use diapers used per year with a market share of 82 percent. Therefore, 100 percent of the infant baby diaper market equals 19,512,195,120 infant diaper changes (16,000,000,000 /0.82). Since reusables are estimated to have an 18 percent market share, this equals 3,512,195,122 reusable diaper changes (0.18 X 19,512,195,120). The market share for adult reusable diapers is considered inconsequential and is not included.
2. Market share by diapers changed<sup>9</sup>:
  - A. Single-use diapers: 82 percent of infant diaper market.
  - B. Reusable diapers: 18 percent of infant diaper market.
3. Market share for reusable diapers<sup>10</sup>:
  - A. Home laundered: 87 percent of reusable diapers used.
  - B. Commercial diaper services: 13 percent of reusable diapers used.
4. Number of diapers per diaper change:
  - A. Single-use diaper: 1 diaper per diaper change.
  - B. Commercially laundered reusable diapers: 1.2 diapers per diaper change. A survey of 569 diaper service customers distributed by 21 diaper service operators across the U.S. determined that on average, 1.12 diapers are used

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<sup>9</sup> Smith and Sheeran (1990).

<sup>10</sup> Smith and Sheeran (1990).