A White Paper on

Performance, Cost Per Use, and Environmental Impact of Single-Use and Reusable Surgical Gowns & Drapes

McIlvaine Company

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EXECUTIVE SUMMARY

Findings presented in this White Paper include the following:

Performance: Performance is a strong suit for the single-use products. Performance includes such attributes as barrier effectiveness, consistency, linting, flammability, comfort, and safety.

Cost per Use: The Study has determined that the cost-per-use for single-use products *can be* competitive with reusable products. Key variables in cost-per-use are the quoted price for both product types, and the laundering cycles and laundering costs reported by the healthcare provider for reusable products. In recognition of these variables, this is reported as a *conditional finding*.

Environmental Burden: Environmental burden has been found by this Study to actually be *lower* for single-use products than for reusable products. Environmental burden takes into account inputs and outputs over the complete life cycle including the manufacture, utilization, and disposal phases for both product types. Laundering is a substantial environmental burden for reusable textiles that tips the balance in favor of single-use products.

Safety: Safety includes consideration of the increased exposure of healthcare workers and the public to contaminated reusable garments from the additional processing required for laundering. This is an area of potential advantage for single-use products.

Green Opportunities: The Study has determined that there are numerous long-term strategic opportunities in the area of Sustainability and Green Initiatives for both single-use and reusable products. These opportunities are in the following three areas:

- Waste-to-energy use of disposed garments as a high btu pelletized fuel for kilns, dryers, and coal-fired power plants
- Bio-based (non-petroleum) polymers to address green issues in the supply chain, and
- Carbon credits for offsetting the environmental impact (burden) for disposal of garments.

SCOPE

This Study was undertaken to establish a factual framework for the evaluation of single-use and reusable surgical gowns and drapes. The scope of this study addresses the following key aspects of single-use and reusable medical garments.

- Functional efficacy (safety, barrier qualities, infection prevention)
- Cost-per-use
- Eco-efficiency and sustainability
- Physiological (e.g. comfort) issues for doctors and nurses
- Legal and regulatory issues
- Other issues

BUSINESS ENVIRONMENT FOR MEDICAL TEXTILES

Nearly all aspects of the healthcare industry are being impacted by three major factors: performance standards; cost containment mandates; and environmental regulations. These factors will likely have considerable impact on the future of medical textiles including surgical gowns, drapes, and isolation gowns.

Performance Standards: The entire purpose for surgical gowns and drapes is to protect the healthcare provider and the patient from infection. This must necessarily remain the number one priority in surgical gown and drape selection.

Cost Containment: In the near term, it is likely that cost containment will be a powerful driver in the purchasing habits of major healthcare institutions. The most important element in cost containment is cost-per-use. Therefore, it is imperative that suppliers of medical garments position themselves favorably in terms of cost-per-use to remain viable suppliers to the market.

Environmental Concerns: Environmental concerns present a long-term driver in this market, and can be depended upon to tip the balance in favor of the supplier that can provide the demonstrably more eco-efficient product. There are growing opportunities for eco-friendly processes in the area of garment production, utilization, and disposal. Environmental legislation represents a powerful force in market dynamics because it can alter customer purchasing habits with the force of law.

PERFORMANCE ISSUES

Performance issues relating to single-use and reusable medical garments can be generally summarized within the following six groups: barrier performance; reliability and consistency; linting; flammability; comfort; and safety.

Barrier Performance

Reducing the risk of acquiring or transmitting infection is the primary reason for the use of protective medical garments in surgery and other provider/patient interactions. A key consideration in the protective function of the garment is barrier integrity. Barrier integrity describes the ability of the garment to prevent transmission of infectious material from the healthcare provider to the patient, or vice-versa.

Summary of Salient Points

- *Barrier performance for reusable medical textiles is a function of the number of laundering operations*
- *"For reusable products, one must consider not only the characteristics of the purchased items but also the characteristics of the laundered products." [A Review of Single-Use and Reusable Gowns and Drapes in Health Care]*

With the adoption of AAMI PB70:2003, critical zones in garments as well as quantitative tests were established for evaluating barrier effectiveness. The standard defines four levels of protection ranging from Level 1 which provides basic dust or debris protection but no significant moisture or liquid barrier, to Level 4 which provides an impervious barrier. The appropriate level of protection depends on the medical procedure being undertaken.

<u>Barrier Protection in Single-Use and Reusable Medical Textiles</u>

Single-use and reusable medical garments are rated for barrier performance in accordance with AAMI PB70 guidelines. Unlike single-use products, reusable medical textiles undergo multiple wash cycles that affect textile performance characteristics over time. The effect of laundering operations is

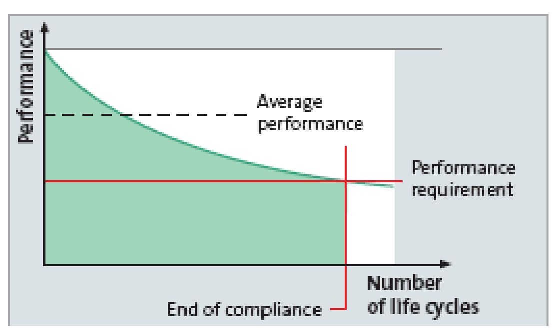


Figure 1. Performance vs. wash cycles for reusable garments. Source: European Textile White Paper "Mehr Wege fur die Zukunft"

illustrated in Figure 1. As shown, if the textile is laundered enough times, an end-of-compliance state is reached that requires retirement or disposal of the garment. The actual end-of-compliance state is not precisely definable in terms of wash cycles, and depends on such variables as the degree of soiling, the nature of the contaminants, the nature of the laundering operation (temperature of wash water, type of detergents and sterilizing agents) and whether rips or tears are present in the garment. In an article titled “A Review of Single-Use and Reusable Gowns and Drapes in Health Care” by William A. Ritala, PhD/MPH, and David J. Weber, MD/MPH it is stated that “For reusable products, one must consider not only the characteristics of the purchased items but also the characteristics of the laundered products. Maintaining manufacturers’ specifications is easier for single-use items compared with reusable products.”

In a separate article titled “Medical Fabrics Gain New Attention in Era of SARS” it is stated that “When you compare reusables and disposables, single-use comes out on top….it is well documented that the barrier properties of multiple-use product degrade with time. The data we have shows single-use products as having very effective barriers against not only fluids, but microbial transmission.”

A 2007 research dissertation authored by Wei Cao at the Florida State University College of Human Sciences contains the following quotation: “Leonas (1998) evaluated the barrier efficacy of five commercially available reusable surgical gowns and found that laundering reduced the ability of the fabric to prevent the transmission of bacteria through the fabrics. Smith and Nichols (1991) pointed out that reusable gowns eventually lose their barrier properties as a result of abrasion and damage during wearing and the breakdown of the fabric during laundering and sterilization.”

Reliability & Consistency

The reliability and consistency of medical garments used in healthcare is a prime concern. The rise in hospital-borne infections in the United States and throughout the world has heightened this concern. It has been estimated that 1 in 20 patients in the United States contract a hospital borne infection.

Summary of Salient Points

- *Reusable surgical gowns and drapes require inspection after each laundering operation to ensure continued fitness-for-purpose.*

The quality control of the textile manufacturer defines product consistency, and modern production techniques are in place to ensure extremely high first-use product quality for both single-use and reusable garments.

However, findings show that single-use garments have advantages relative to reusable garments in terms of consistency. Reusable garments are subject to a loss in barrier performance as a function of wash cycles, as described in the previous section of this Study. This has an effect on consistency, such that reusable garments must be inspected prior to each use to ensure that performance has not been materially compromised in laundering. Single-use products are not laundered and do not experience loss in barrier performance over time.

Linting

Linting has long been known as a potential contributor to the transmission of bacteria, or the cause of foreign-body reactions in open wounds. As such, efforts are continually being made to reduce lint generation in medical textiles, particularly in operating room environments.

Summary of Salient Points

- *"Particles including lint are a safety related concern in the OR and have been identified as the source of contamination that cause potential infections and pyrogenic affects." [University of California, Davis, Workshop, October 2007]*
- *"By using nonwovens to reduce the amount of lint produced in the operating room, and to block the passage of skin particles, the particle count is reduced by 90%." [Non-Wovens: A Single-Use Solution]*

In a workshop conducted at the University of California (Davis), it was noted that a "survey of the industry indicated that two characteristics of traditional surgical fabrics needed to be improved upon – linting and barrier performance.

1. Linting: Particles including lint are a safety related concern in the OR and have been identified as the source of contamination that cause potential infections and pyrogenic affects.

2. Barrier: Not only protection of the patient from infection was a concern but protection of the healthcare worker due to infectious diseases like AIDS also focus attention on the need for improved barrier properties for surgical fabrics."

Woven all-cotton textiles widely used before the development of synthetic fibers presented significant linting issues, and have now been largely replaced in the operating room by non-woven single use textiles, or by reusable woven blended fabrics with a smaller percentage of cotton or even 100% synthetics such as polyester.

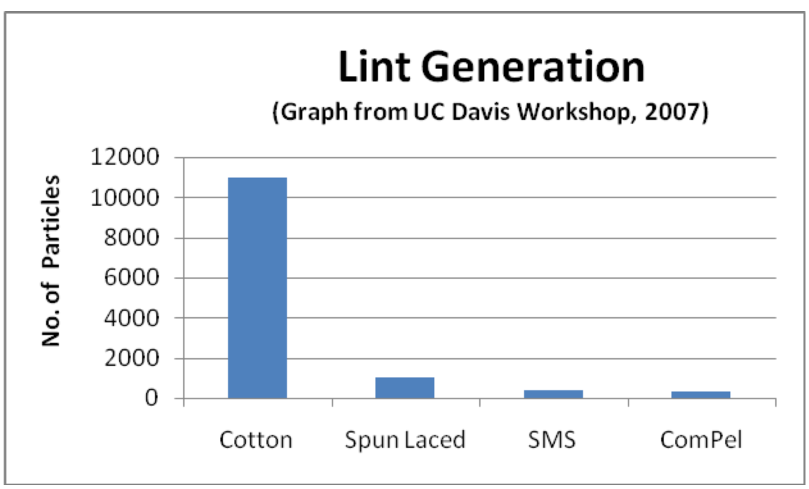


Figure 2. Comparative Lint Generation for various surgical garment textiles.

The Gelbo Lint Test is a commonly used procedure for measuring the number of lint particles removed from a fabric during repeated flexing. A low number is superior. Spunbond-meltblown-spunbond (SMS) composite non-woven fabrics exhibit superior linting characteristics (i.e., low lint generation), as illustrated in Figure 2.

In a March 2007 article titled “Nonwovens: A Single-Use Solution” it was stated that “…by using nonwovens to reduce the amount of lint produced in the operating room, and to block the passage of skin particles, the particle count is reduced by 90%.”

It should be noted that 100% continuous filament polyester fiber construction for woven textiles also provides low linting performance, and the superior performance of SMS construction is relative to blended fabrics with some percentage of cotton.

Flammability

According to the AORN 2004 Standards, Recommended Practices and Guidelines, "gowns and drapes should resist combustion. The O.R. environment contains the necessary fuel, heat source, and oxygen to cause a potential fire."

Oxygen-enriched OR environments, plus the use of electrosurgical and electrocautery tools, and laser surgical equipment may tend to heighten the likelihood of operating room fires. It has been estimated that there are between 50 to 100 operating room fires each year in the United States.

Summary of Salient Points

- *Polypropylene (the most commonly used feedstock material in non-woven gowns and drapes) has the highest ignition temperature in air relative to other textile materials including cotton and polyester.*
- *Polypropylene test swatches do not ignite in air under the influence of a surgical laser*
- *Polypropylene textiles tend to locally vaporize under the influence of a surgical laser and do not support further combustion*

Although many factors may be involved in the actual ignition of a surgical gown or drape in an operating room environment, different materials reflect different base ignition temperatures in air. Table 1, below, lists the ignition temperature in air for some common textile materials.

Table 1. Ignition temperatures of common textile materials in standard atmosphere

Textile Material	Ignition Temperature
Cotton	**≈ 250 º to 300º C / (482 - 572 º F)**
Polyester	**≈ 432º - 488º C/ (810 - 910 º F)**
Polypropylene	**≈ 570º C/ (1058 º F)**

As shown, 100% cotton exhibits the lowest ignition temperature of three common textile materials. Polypropylene exhibits the highest ignition temperature of the selected materials. Combinations of fibers, such as cotton/polyester blends may actually burn (once ignited) more intensely than a fabric comprised of one fiber alone. A University of California at Davis study found that some polyester-cotton-blend clothing can burn "up to 25 percent faster than clothing made either from pure synthetics such as polyester or from pure ‘cellulosic' fibers such as cotton or rayon”.

The following data table shows the approximate time to ignition (TTI), in seconds, for test swatches of materials that may be found in operating room environments. Three different environments are presented: standard atmospheric (21% O_2), enriched (50% O_2), and highly enriched (95% O_2). The ignition source was a 15W carbon-dioxide surgical laser.

Table 2. Time-to-ignition (TTI) for materials under varied conditions of oxygen concentration.
Ref: Laser Ignition of Surgical Drape Materials (Wolf, Gerald L. M.D.; Sidebotham, George W. Ph.D; Lasard, Jackson L.P. M.D.; Charchaflieh, Jean G. M.D.)

Material Tested	21% O_2		50% O_2		95% O_2	
	No. Ignited/ No. Tested	TTI, sec (Mean+/-SD)	No. Ignited/ No. Tested	TTI, sec (Mean+/-SD)	No. Ignited/ No. Tested	TTI, sec (Mean+/-SD)
Phenol polymer	0/10	Does not ignite	10/10	4.9+/- 0.88	10/10	0.68 +/- 1.3
Polypropylene	0/10	Does not ignite	9/10	0.14 +/- 0.13	10/10	0.18 +/- 0.17
Huck towel	8/10	11.9 +/- 5.0	10/10	2.3 +/- 1.0	10/10	<0.1 +/- 0.0
Cotton-polyester	10/10	4.0 +/- 0.94	10/10	1.1 +/- 0.32	10/10	0.65 +/- 0.24
Nonwoven cellulose-polyester	10/10	2.7 +/- 2.2	10/10	<0.1 +/- 0.0	10/10	<0.1 +/- 0.0

As shown, polypropylene and phenol polymer do not ignite in air under the influence of the laser. For polypropylene and phenol polymer, the laser instantly vaporized a hole, and therefore interaction between the laser and material ceased, not supporting further combustion.

Test methods for evaluating flammability of textiles are included in NFPA 702-1980 Standard Classification of the Flammability of Wearing Apparel, and CPSC Standard for the Flammability of Clothing Textiles.

Comfort

> ***Summary of Salient Points***
> - *Although comfort remains an important consideration in surgical gown selection, it no longer is the defining issue between woven and nonwoven textiles.*
> - *Proprietary material developments by leading suppliers of nonwoven textiles have virtually eliminated the breathability and temperature issues formerly associated with synthetic fabrics.*

Barrier effectiveness and comfort have been key selection criteria for surgical gowns for many years. Historically, it was believed by many clinicians that these two performance criteria were mutually exclusive. That is, as one moved higher on the comfort scale, it was believed that there was usually a dramatic trade-off in terms of protection. That kind of dramatic trade-off is no longer the case for a number of reasons.

First, not all medical procedures require an AAMI Level 4 impervious barrier, which means that intrinsically breathable gowns are appropriate for many procedures.

Secondly, industry standards such as AAMI PB70:2003 provide some definition of "critical zones" in gowns and drapes that may require Level 4 impervious barrier protection, with non-critical areas free to use more breathable fabric constructions without the impervious barrier.

And thirdly, advances in material technology have been made that provide breathable fabrics with outstanding barrier protection. As an example, spunbond-meltblown-spunbond (SMS) composite fabrics are available that offer AAMI Level 3 protection that are suitable for a majority of surgical procedures. For Level 4 protection, proprietary breathable film layers are available to provide Level 4 performance. These impervious fabrics feature a reactive membrane that allows water vapor to escape from inside the gown, while maintaining complete impervious protection. The result is a gown that is both comfortable for the wearer, and suitable for Level 4 surgical procedures.

The comfort vs. safety tradeoff has been largely eliminated by current fabric constructions, gown designs, and OR environmental controls. Both nonwoven and woven medical textiles address the key factors of comfort, including drapeability, air permeability, water vapor transmission rate (WVTR), and the ability to maintain the wearer's desired body temperature.

Overview of Performance Issues

The following table provides a summary of *performance issues* for single-use and reusable medical textiles. A simple rating method has been adopted that uses a "+1" for a positive implementation of a performance metric, and a number between "0" and "1" for a performance metric not equally addressed by single-use and reusable products. This numbering system allows for a quantifiable comparison of the two product types in terms of performance issues. It should be noted that no attempt has been made to provide a relative weighting of the importance of one performance metric relative to another metric. For the purposes of this study, each attribute is weighted equally.

Table 3. Overview of performance metrics for surgical gowns

Performance Metric	Single-Use Disposable	Multi-Use Reusable	Comments
Barrier Performance	**+1**	**+1**	**Both single-use and reusable products are available with AAMI PB70 level 4 ratings**
Comfort	**+1**	**+1**	**Material advancements in synthetic fabrics and gown constructions have addressed early comfort issues associated with synthetic gowns**
Linting	**+1**	**+1**	**Modern polypropylene nonwoven fabrics have lower linting based on Gelbo Lint Test than cotton or cotton blends. Woven 100% continuous filament polyester products also exhibit low linting performance**
Flammability	**+1**	**0.9**	**Flammability of 100% polypropylene fabric is lower than all-cotton or cotton-polyester blends based on ignition temperatures and time-to-ignition (TTI) tests**
Consistency	**+1**	**0.5**	**Consistency is more reliably assured for single-use products than for launderable reusable products over the life of the product**
Safety	**+1**	**0.5**	**Single-use products provide fewer exposure opportunities for personnel outside the operating room relative to laundered products**
Total Score	**+6**	**+4.9**	

COST-PER-USE

> ***Summary of Salient Points***
> - *Single-use surgical gowns and drapes can be price-competitive with reusable products depending on the particular details of the transaction and the specific laundering experience at the customer facility.*

Cost-per-use is a key factor in the buying decision that is in sharp focus at healthcare facilities engaged in cost reduction programs.

The cost-per-use for a single-use surgical gown is taken in this Study to be the purchase price, per gown. This cost will vary from hospital to hospital with quantity discounting, the type of gown and other aspects of the transaction.

The cost-per-use for a reusable gown is the purchase price per gown divided by the average number of launderings in the life-cycle of the gown, plus the laundering cost per gown, per use. Alternatively, if a rental service is retained the price per gown would be the "rental" price which includes the cost of laundering and sterilizing, plus the price of the gown amortized over the expected number of launderings, plus the rental service markup.

Table 4. Cost-Per-Use (Example)

Surgical Gown Type	Number of Launderings	Purchase Price Range	Purchase Price Range on Per-Use Basis (50 launderings for Reusables)	Laundry Cost, Ea,	Cost-Per-Use
Reusable (XL, AAMI 3)	**50**	**$60 to $140**	**$1.20 to $2.80**	**$0.90**	**$2.10 to $3.70**
Single-Use (XL, AAMI 3)	**n/a**	**$2.03 to $3.49**	**$2.03 to $3.49**	**n/a**	**$2.03 to $3.49**

NOTES

1. Reusable garments are assumed to be usable over a life of 50 launderings. Number of laundering cycles is from an article by Howard M. Zims "Environmental, Cost, and Product Issues Related to Reusable Healthcare Textiles (2006)".
2. Laundry cost of $0.90 per garment is from an article by Howard M. Zims "Environmental, Cost, and Product Issues Related to Reusable Healthcare Textiles (2006)". Total laundering cost is broken down to reflect $0.50 laundry cost and $0.40 packaging and sterilization cost.
3. $60 purchase price per reusable garment is from an article by Howard M. Zims "Environmental, Cost, and Product Issues Related to Reusable Healthcare Textiles (2006)".
4. $140 purchase price per reusable garment is for GORE garments with prices ranging from $112 to $140 based on internet research. One surgical laundry referenced a price of $86 per garment for a GORE gown.
5. Price range for single-use surgical gowns reflects actual transaction pricing.

Critical variables in the cost-per-use analysis of a reusable garment are the number of wash cycles actually realized before retirement of the garment, and the laundering cost per garment, per use. This data is generally obtainable from the Accounting Departments of most hospitals, regardless of whether on-site or contract laundering services are used.

Figure 3, below, illustrates the competitive price position of disposable surgical gowns relative to reusable gowns, assuming 50 wearings for reusables before retirement.

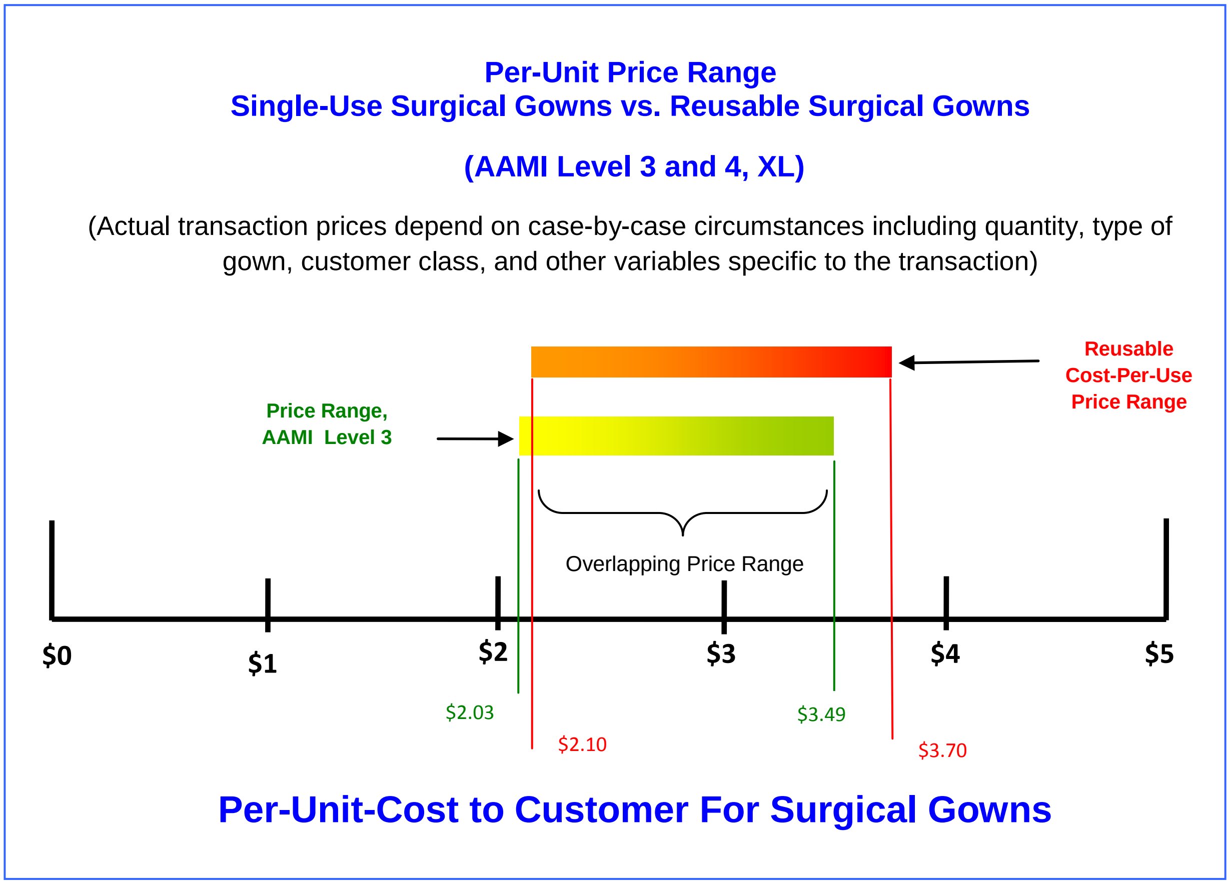


Figure 3. Competitive Price Positioning of Single-Use vs. Reusable Surgical Gowns

As shown, single-use gowns *can* compete over the entire range of prices for reusable gowns. Competitiveness in any given situation will depend upon individual circumstances reflecting the volume of the purchase, the type of gown, the customer class, and other transaction-specific details.

With regard to European markets, a research report conducted by Martec for markets in Germany, France and the UK concluded as follows: “Film-reinforced re-usable gowns can be competitive when repeat usage exceeds 50 times. However, these gowns are difficult to process internally, and it is likely that such high usage rates are seldom achieved. Below a usage rate of about 50 times, these gowns are not cost-competitive.

Single-use surgical drapes were also found to have a competitive cost position in France and Germany…..despite the ‘perceived’ high waste disposal costs of these items…”,

A Note on Disposal Costs

Disposal costs in the United States for Regulated Medical Waste (RMW) and non-regulated waste are a small percentage of garment price, and are summarized below.

<u>Regulated Medical Waste Disposal Cost</u>

Range: $350/ton to $1100/ton [$0.17/lb to $0.55/lb]

At 0.32 lbs per garment, the disposal cost would be $0.06 to $0.18 per single-use garment.

<u>Non-Regulated Waste Disposal Cost</u>

Range: $30/ton to $60/ton [$0.015/lb to $0.03/lb], or $0.005 to $0.01 per single-use garment.

ENVIRONMENTAL BURDEN (LIFE CYCLE ANALYSIS)

The environmental burden (CO_2, NOx, water pollutants, and solid waste) created in the manufacture, use, and disposal of either single-use or reusable medical garments is small. EPA estimates put medical landfill waste at less than 1% of the total municipal waste stream in the United States (see Appendix VI).

Summary of Salient Points

- *The total environmental burden created by surgical garments is small in the context of total environmental burden.*
- *The total environmental burden of surgical gowns can be offset with a purchase of carbon credits from a carbon exchange.*
- *The environmental burden of single-use surgical gowns is less than the environmental burden of reusable gowns, on a per-use basis.*
- *Reusable gowns are resource intensive in terms of water consumption in laundering operations.*

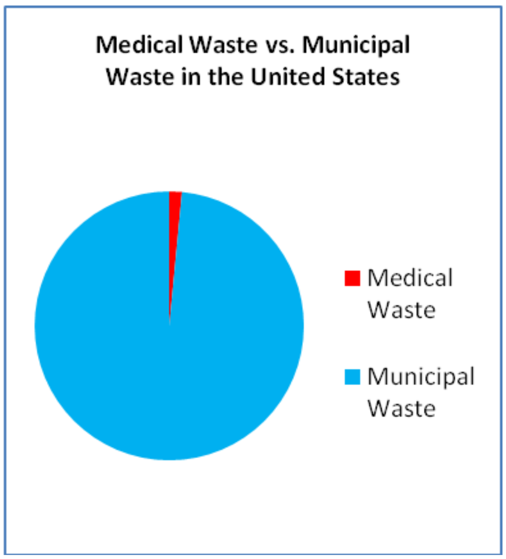


Figure 4. Medical vs. municipal waste

Burden Determination

Manufacturing, use, laundering and disposal are the steps in the product life cycle where burdens are generated. It has been determined that the CO_2 and NOx air emissions, and the chemical/biological oxygen demand (CBOD) and Total Suspended Solids (TSS) in laundry water are the biggest environmental burdens in the garment life cycle. Safety is also a potentially significant burden related to reusable garments. Refer to Appendix VIII and Appendix XII for development of safety burdens.

Discussion of Burden Components

Considerable analysis has been conducted to determine the various air, water, resource-depletion, and safety burdens associated with single-use and reusable gowns and drapes. This section of the Study summarizes the burdens associated with various phases of the life cycle, i.e., manufacturing, utilization, laundering, and disposal. Detailed derivations of burden values are presented in Appendix VIII of this Study.

Manufacturing Phase: The environmental burden created by garment manufacture is mostly determined by the energy source. If solar or wind power is used to generate electricity, there are no air burdens from manufacturing. If a coal plant supplies the power, there are some air burdens. Any calculation of manufacturing environmental burden has to take into account either the specific fuel mix at the plant where the garments are made or the average fuel mix for electricity in the U.S. or other country of manufacture. The U.S. is presently utilizing coal for 52 percent of electricity generation, and manufacturing burdens reflect this present average.

According to industry convention, approximately 50 single-use garments are required for every reusable garment. This accounts for the higher manufacturing burden for single-use products relative to reusable products shown in Figure 5.

Laundry Phase (reusable garments only): The laundry phase introduces significant burdens for the reusable products. Burdens are associated with the energy required to heat the laundry water, and then to dry and sterilize the gown or drape. There is also a burden associated with the consumption of the water resource, itself. This burden is variable, and will depend on the abundance or scarcity of water in the particular region. The values reflected in Figure 5 are representative, but subject to considerable adjustment. The number of wash cycles, the amount of water per garment, and other variables create a range of possibilities. The burden for the laundry process is included, but not for the lights and heat in the space. The energy for transportation to and from the laundry is also not included because much of the transportation burden is offset by a similar burden for delivery and disposal of single-use garments.

Disposal Phase: The ultimate disposal of the garments results in many variables. If disposed in a land fill, there would be no air emissions. The only burden would be landfill resource depletion. If garments were burned in a waste to energy plant, there would be minor emissions, which would largely be offset by the high btu value of the garments. Polypropylene and polyester materials are almost pure fuel with 50% more Btu/lb than coal, and would replace traditional fuels having higher environmental burdens (see Table 6 later in this Study). In either case (landfill disposal or burning), the net environmental burden is small for both product types.

The foregoing burden discussion is for garments and does not include the packaging, which is essentially equivalent for both single-use and reusable products.

As shown in Figure 5, single-use garments have a *lower* overall burden than reusable garments, largely because of the laundering burden for reusable garments. For a complete derivation of burden calculations, refer to Appendix VIII and Appendix XII in this Study.

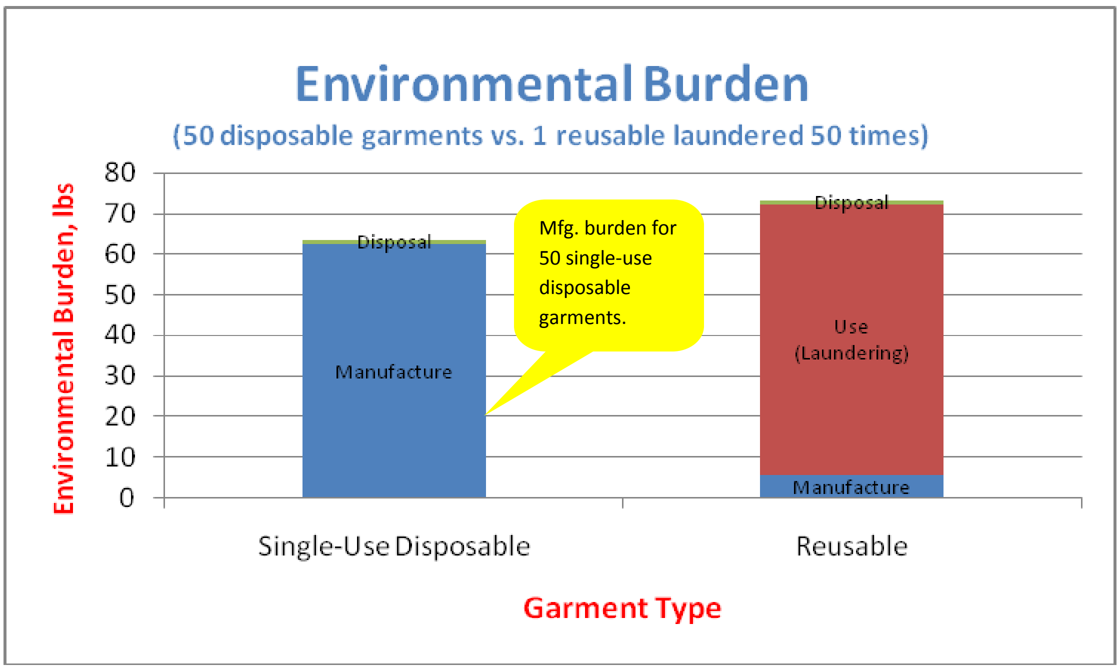


Figure 5. Environmental Burden Comparison, Single-Use Gowns vs. Reusable Gowns

Resource Depletion

An analysis of resource depletion shows that there are only two significantly impacted resources: oil and water. Water resource depletion (from laundering) is a minor consideration in an area of water surplus. However, it is significant in an area with periodic water shortages and water restrictions. It becomes an order of magnitude more important in regions of persistent drought. Water issues are primarily related to laundering operations for reusable medical textiles. Burden calculations for water resource depletion are provided in Appendix VIII.

Resource Utilization

Resource utilization is another important parameter. A total measure of resources used can be obtained by adding the weight of material used in the garments, the weight of equivalent coal to produce the energy to make the garments, and the water used in manufacturing and laundering. The dominant resource consumption for reusable garments is the water used in laundering. This is based on 2 gallons of water/lb of washed garments. The weight of energy producing material was based on coal with a conversion efficiency of 30%.

Table 5. Pounds of resources for 50 garment wearings

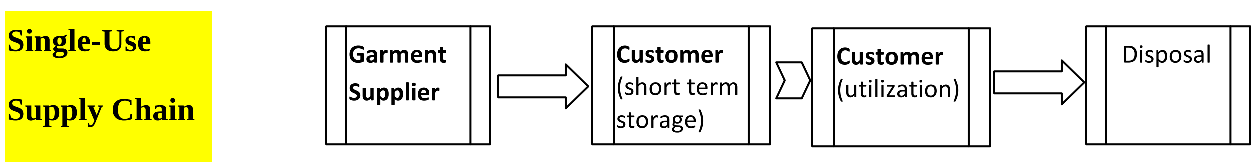
Category	Manufacturing		Laundering		Total	
	Reusable	Single-Use	Reusable	Single-Use	Reusable	Single- Use
Garment Material (lbs)	0.64	16	xx	xx	0.64	16
Water (lbs)	6.6	58	533	xx	539.6	58
Energy (lbs of coal equivalent)	5.3	52.5	22	xx	27.3	52.5
Total (lbs)	12.5	126.5	547	xx	567.5	126.5

Delivery and Storage for Single-Use Surgical Gowns and Drapes

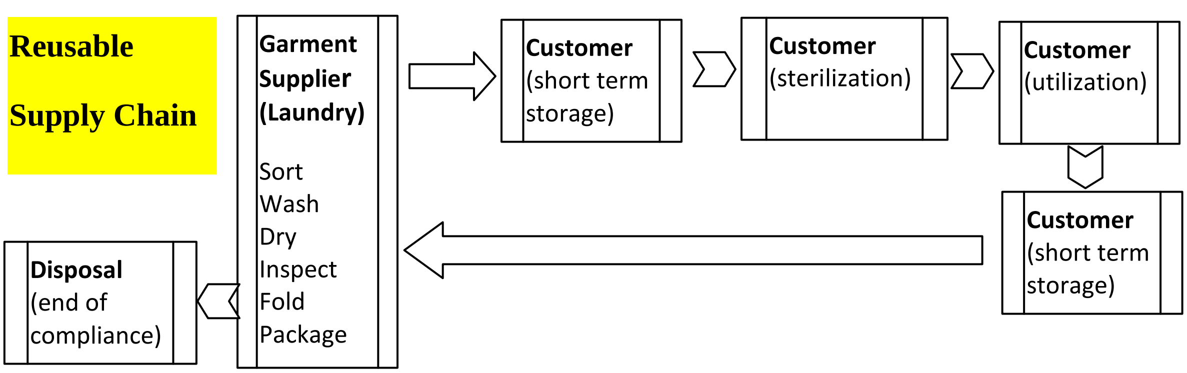
> ***Summary of Salient Points***
> - *Single-use sterile surgical gowns and drapes do not require an additional sterilization at the point of use (hospital).*
> - *Reusable products used in the OR often require sterilization at the hospital after return from the laundry.*

Most suppliers of gowns and drapes support deliveries to hospitals on a high-frequency basis, in many cases daily. This is done to ensure manageable inventory levels at the hospital, and high inventory turns to provide minimum carrying costs for the customer.

Operating room surgical supplies are provided for the customer, gamma or EO sterilized and packaged, and ready for use without further handling besides removal from packaging. Kitted supplies including gowns, drapes, towels, masks, gloves, basins, and other supplies are similarly sterilized and packaged. The supply chain is shown, below.



The supply chain for reusable surgical gowns and drapes is different than for single-use garments. In the case of laundered garments, the materials are subjected to a sterilization procedure at the hospital prior to use in surgery. The supply chain is pictured, below, with disposal at the end-of-compliance state after a determined number of launderings.



LAWS AND REGULATIONS

Garment Production: Raw Materials

Overview: As a general rule, reusable woven gowns and drapes are made of a cotton/polyester blend or 100% polyester, and single-use non-woven garments are made from materials such as polypropylene.

Natural fibers such as cotton are generally believed to be more environmentally favorable since they come from a renewable resource and are biodegradable. However, cotton requires pesticides and herbicides to ensure quality, healthy growth and efficient harvesting. Man-made fibers require energy and deplete natural resources because they come from oil. Studies have generally concluded that natural and man-made fabrics impose similar environmental burdens. *Designing for Cleaner Textiles*, http://www.co-design.co.uk/jhealey.htm

Environmental damage caused by cotton production has led to a number of alternatives such as unbleached cotton, 'green' cotton and natural dyes. Organic cotton is grown in relatively small quantities and the costs of production can be double that of standard cotton. Synthetic fibers can be made from recycled PET plastic bottles, although not necessarily for medical uses.

Regulations for Cotton Production:

- Pesticides and herbicides are regulated by EPA under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).
- Storm water run off is regulated under the Clean Water Act.
- Water used for irrigation may be regulated under state laws.

Regulations for Polypropylene: Petroleum production and the processing of oil into chemicals such as polypropylene are regulated by the full panoply of environmental laws at the state and federal levels.

Garment Production: Textile Manufacturing

Clean Air Act

- *National Ambient Air Quality Standards for Ozone*

During the finishing stages, fabrics may be coated with lubricating oils, plasticizers and water repellent chemicals, primarily hydrocarbon-based compounds such as oils, waxes or solvents. After the coatings are applied, the coated fabrics are cured by heating in ovens or dryers. A frequent result is the vaporization of organic compounds into high molecular weight volatile organic compounds (VOCs).

VOCs react with sunlight and contribute to ground level ozone. The Clean Air Act establishes National Ambient Air Quality Standards (NAAQS) for ozone. Consequently, a textile mill has to have an air permit and install Best Achievable Control Technology (BACT) to control VOC emissions. BACT technologies include electrostatic precipitators, scrubbers and fabric filters.

- *Opacity*

VOCs can also contribute to visible smoke. Smoke is basically made up of particles less than one micron in size, suspended in the gaseous discharge. A textile mill's air permit may have opacity limits.

- *New Source Performance Standards*

EPA established NSPSs for Synthetic Fiber Production Facilities (40 CFR Part 60 Subpart HHH) which limit VOC emissions to 20lb/ton of solvent feed. EPA has not established NSPSs for any other subcategory of textile manufacturing.

- *Hazardous Air Pollutants*

National Emission Standards for Hazardous Air Pollutants (NESHAPS) have been established for one subcategory of textile manufacturing: Fabric Coating, Printing and Dying (40 CFR Part 60 Subpart OOOO). This regulation controls emissions of hazardous air pollutants (generally VOCs) such as toluene, xylene and ethylbenzene. The rule requires a thermal or catalytic oxidizer to achieve 98% removal or an emission limit of 20 ppmv. See: *Air Pollution Control in the Textile Industry: A Technology for the 21st Century,*
www.croll.com/_website/ca/casetextl1.asp

Clean Water Act

Overview: High volumes of wastewater are produced in textile manufacturing operations such as sizing, dyeing, rinsing, printing, bleaching, finishing and cleaning. Wastewater may contain:

- Chlorine, from bleaching
- Heavy metals (such as lead and mercury), ammonia, alkali salts or pigments, from dyes
- Chromium, from mordants used to fix the dyes

- *Effluent Standards*

In 1982, EPA promulgated effluent guidelines for textile manufacturers. 40 CFR Part 410. The rule is divided into nine subcategories including wool scouring and finishing, woven fabrics, nonwoven fabrics and carpets. Each subpart contains effluent limitations, new source performance standards and pretreatment standards. Effluent limitations represent the degree of effluent reduction attainable by using either best practicable control technologies (BPT) or best available technologies (BAT). Limits are established for:

- Biological oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Total suspended solids (TSS)
- Sulfides
- Phenol
- Total chromium
- pH

A textile mill must obtain either:

- an NPDES (National Pollution Discharge Elimination System) permit for a wastewater discharge into a waterway; or
- a pretreatment permit for discharge into a municipal sewer (Publicly Owned Treatment Works or POTW).

See: *EPA Office of Compliance Sector Notebook Project: Profile of the Textile Industry, September 1997,* http://www.p2pays.org/ref/01/00506.pdf

Resource Conservation and Recovery Act (RCRA)

- *Solid Waste*

Fabric waste and other scraps left over at the end of production and some packaging materials may be sent to a municipal landfill along with general trash.

- *Hazardous Waste*

Certain dyes, solvents, bleaches and finishing agents used in textile manufacturing may result in the generation of hazardous wastes in the form of spent solvents or wastewater treatment sludges. Hazardous waste must be disposed of in a permitted hazardous waste disposal facility.

See: *Environmental Hazards of the Textile Industry, June 2006*, http://www.hsrc-ssw.org/update24.pdf

Hospital Use

- *OSHA's Bloodborne Pathogen Rule*

OSHA imposes certain responsibilities on employers to protect the health and safety of their workers. OSHA's bloodborne pathogen rule requires hospitals to protect their workers from risks associated with infectious materials in blood. In particular, hospitals must provide personal protective equipment (PPE) such as gloves, gowns, and masks, and must clean or replace the equipment as needed. With respect to surgical gowns, this means a hospital must ensure that the gown provides a barrier to protect the worker from bloodborne pathogens.

This rule tips the balance in favor of single-use garments, since a hospital can provide sufficient barrier protection with more certainty. Reusable gowns may lose some of their barrier protection after repeated washings, increasing the risk that the worker is not adequately protected.

Reusable Garments: Laundering

- *OSHA's Bloodborne Pathogen Rule*

OSHA imposes certain responsibilities on employers to protect the health and safety of their workers. OSHA's bloodborne pathogen rule requires laundries to protect their workers from risks associated with infectious materials in blood. In particular, laundries must provide personal protective equipment (PPE) such as gloves and work garments and must clean or replace them as needed. Laundries must also follow specific procedures for collecting and handling soiled hospital garments.

- *Wastewater Effluent Standards*

Generally, laundries discharge wastewater to the municipal sewer and must obtain a pretreatment permit from the local POTW (Publically Owned Treatment Works). Organics and metals may be in the wastewater due to chemicals and detergents used in the laundering process. Pretreatment permits generally set standards for the following:

  - Biological oxygen demand (BOD)
  - Chemical oxygen demand (COD)
  - Total suspended solids (TSS)
  - Sulfides
  - Phenol
  - Total chromium
  - pH

Treatment prior to discharge could include equalization, coagulation/flocculation, dissolved air flotation, oil/water separation or clarification.

- *Water Use*

Laundries use a large amount of water and many have looked into recycling and reuse processes to save on the use of fresh water. Some state or local regulations may also limit fresh water use. See *Industrial Laundry Wastewater Treatment*, http://www.vsep.com/pdf/IndustrialLaundry.pdf

Garment Disposal

Waste Classification: Hospital wastes may fall into one of three categories:

1. Hazardous waste, such as mercury and radioactive wastes, which is regulated by the federal EPA.
2. Regulated Medical Waste, also referred to as infectious waste, biohazardous waste or "red bag" waste, which is regulated by state environmental or health agencies. Blood soaked surgical gowns and drapes generally fall into this category.
3. Solid wastes or general trash such as packaging and discarded surgical gowns (which are not considered infectious or "red bag" wastes) which can be disposed of in a municipal landfill.

The OSHA Bloodborne Pathogen rule defines regulated medical waste to include gowns or drapes "that would release blood or other potentially infectious materials in a liquid or semi-liquid state if compressed" or squeezed. 29 CFR 1910.1030(b). In other words, garments that are soaked or saturated with blood are Regulated Medical Wastes, whereas stained or tainted garments are not. The OSHA standard was designed to protect healthcare workers from the risks of exposure and does not deal with waste disposal *per se*. However, the definition has been used by states in establishing waste classification policies. www.practicegreenhealth.org/private/library_resource/142 *Specific d*efinitions and disposal or treatment requirements differ from state to state. http://cms.h2e-online.org/ee/rmw/rmw-regulations/state-rmw-regulations/

See also: www.epa.gov/osw/nonhaz/industrial/medical/mwfaqs.htm

- *Solid Waste: Reusable Garments*

Reusable surgical gowns and drapes that have reached the end of their useful life are considered solid wastes (unless classified as regulated medical wastes because they are saturated with blood) and may be disposed of in a municipal landfill. Cotton and other natural materials are biodegradable.

- *Solid Waste: Single Use Garments*

Single use surgical gowns and drapes are considered solid wastes (unless classified as regulated medical wastes because they are saturated with blood) and may be disposed of in a municipal landfill. Polypropylene does not react with water, so does not contribute to landfill leachate, and is stable so avoids settling problems. However, it does not biodegrade.

- *Regulated Medical Waste: Reusable or Single Use Garments*

Either reusable or single use surgical gowns and drapes will be considered regulated medical wastes if they are saturated or soaked with blood. The garments must then be either 1) incinerated or 2) disinfected prior to being landfilled.

Disinfect and landfill: Garments must be treated or "disinfected" to destroy or kill infectious microorganisms prior to landfilling. Disinfecting technologies include:

  - Thermal treatment, such as microwaving
  - Steam sterilization, such as autoclaving
  - Electropyrolysis
  - Chemical treatment, using chlorine based products (common bleach) or alkali products (sodium hydroxide or lye)

Of these, the federal EPA regulates only chemical treatment technologies. Products which claim to reduce the infectiousness of waste by use of a chemical must be registered with the EPA Office of Pesticides, Antimicrobial Division, under FIFRA.

Medical waste treatment processes may be regulated under state law and may need to be certified, licensed or permitted.

Disinfected medical wastes may generally be disposed of in a municipal landfill along with other general trash. However, many states consider disinfected medical wastes to be "special wastes" requiring disposal at special landfills authorized to accept such wastes.

Incinerate:

- *Clean Air Act*

EPA originally issued performance standards for medical waste incinerators in 1997. The performance standards set emission limits for dioxins and furans, toxics (such as lead, mercury and cadmium), acid gases (hydrogen chloride and SO_2), CO and NOx.

The rule was challenged in court by the Sierra Club. As part of the settlement agreement, EPA has until September 2009 to issue a new final rule. On December 1, 2008, EPA issued a proposed rule pursuant to that mandate, proposing much stricter emissions standards. 73 FR 72961.

As a result of the 1997 rule, incinerators had to install air pollution control devices such as scrubbers. There were roughly 2,400 hospital and medical waste incinerators in operation at that time. EPA estimates that there are 57 today. Many of those would close under the newest proposal. In particular, EPA expects hospitals to close on-site incinerators and use regional incinerators, or opt to disinfect their regulated medical wastes prior to landfilling.

It is important to note, that incinerator operators value the high energy content of polypropylene in single use garments since it helps with the combustion of wet wastes. (See Kimberly Clark flyer promoting polypropylene garments in Australia, http://www.kca.com.au/healthcare/docs/balanced-view-hospital-wastes.pdf)

- *Transportation*

The Department of Transportation defines regulated medical wastes as "hazardous materials" which have specific packaging, labeling and handling requirements. 49 CFR 173.197.

Since there are very few on-site incinerators now, and will be even fewer in the future, transportation becomes a bigger issue. Saturated surgical gowns and drapes being transported to an incinerator for disposal would have to meet the DOT requirements

- *Hazardous Waste*

Ash remaining at the bottom of an incinerator after burndown often contains heavy metals than may leach out. Dioxins and furans may also be found in the ash. Often the ash is considered a hazardous waste pursuant to EPAs toxicity characteristic leachate procedure (TCLP).

Waste Minimization:

Disposing of regulated medical waste is much more expensive than disposing of solid waste and normal trash. Minimizing the amount of regulated medical waste is, therefore, very important. Whether dealing with discarded reusable garments or single use garments, regulated medical wastes should be segregated at the point of generation and kept isolated from other wastes.

Single use items are often falsely implicated for certain costs of waste disposal. Improper waste segregation, rather than use of single use gowns and drapes, is usually the cause of increased amounts of regulated medical wastes.

Even so, waste minimization concepts favor reusable surgical gowns and drapes.

See, *Non-Incineration Medical Waste Treatment Technologies: A Resource for Hospital Administrators, Facility managers, Health Care Professionals, Environmental Advocates and Community Members, August 2001,* http://www.noharm.org/library/docs/Non-Incineration_Medical_Waste_Treatment_Te_2.pdf

SUSTAINABILITY

A number of Sustainability Index services are available for companies pursuing Sustainability Programs. Two such services are the Dow Jones Sustainability Index that has been in operation since 1999, and the Global Reporting Initiative (GRI). GRI provides sustainability reporting guidelines for Corporations covering their economic, environmental, and social performance. These indexes are discussed in further detail in Appendix X of this Study.

<u>Shortcomings of Traditional Sustainability Guidelines</u>

A potential weakness in traditional sustainability guidelines is a limited focus that does not include consideration of factors such as human health and safety, and resource depletion.

Human health and safety, and resource depletion are significant factors in a comprehensive burden analysis, particularly in the healthcare industry. The importance of these factors is highlighted by their inclusion in sustainability software used by the National Institute on Standards and Technology (NIST). NIST is the most important "standards" group in the United States. The NIST software which reflects consideration of human health and safety is called "BEES" which is an acronym for "Building for Environmental and Economic Sustainability".

Any comprehensive burden analysis should include consideration of health, safety, and resource depletion, which are particularly relevant since human health and safety are integral parts of the healthcare business. It is particularly appropriate for purposes of comparing reusable and single-use operating room garments from the perspective of hospital purchasers, and even investors.

One of the biggest opportunities resulting from this Study will be to open the door to consideration of higher performance garments that contribute even more to human health and safety. The impact of lives saved, hospital days eliminated, and quality enhanced life days (QELD) is large compared to other burdens. At the present EPA-determined value for a human life ($7M), hospitals could justify paying an additional $1 for a high-performance garment if the result were just one life saved….which would help arrest the slide to commodity pricing that is characterizing the current market.

GREEN OPPORTUNITIES

There are Green Opportunities for manufacturers, suppliers, and customers in initiatives that include waste-to-energy, bio-based polymers, bio-degradable polymers, carbon credits, and others. This section of the Study elaborates on the most promising of those opportunities.

Carbon-Offset Credits

As discussed earlier in this Study, a low-cost and socially-responsible means to completely offset the minimal environmental burden represented by surgical gowns and drapes is to purchase carbon offsets at an existing climate exchange, such as the Chicago Climate Exchange. This action can be taken in the larger context of a Sustainability Program.

Waste-to-Energy: Single-Use Garments as a High Priced Green Fuel

Kimberly Clark has a video entitled "Trash to Treasure" which establishes the value of single-use garments as a high btu fuel for incinerators and waste-to- energy plants. Manufacturers have the opportunity to open up a more attractive opportunity which is the use of *pelletized* garment waste as a replacement for coal in power plants and other combustion applications.

Power plants in Europe are paying up to $100/ton for low quality biomass fuels. They are importing wood pellets from the U.S. and palm leaves from Asia. The waste-utilization of 5,000 tons of garments could have a value of $500,000 as a fuel if similarly priced. Arguably, the price could be even higher since the average fuel value is 3 to 4 times higher than typical biomass.

In any case, the replacement of coal with plastic waste results in a direct reduction of CO_2 for every pound of garments so disposed. There would also be reductions in SO_2, mercury, and HCL by the coal substitution since polypropylene is a much cleaner fuel than coal. Additionally, since modern coal-fired plants have very good air pollution control systems any NOx created by the garment combustion will be greatly reduced. Net reductions in mercury and other pollutants by the substitution are also enhanced.

Why synthetic surgical garments are an ideal fuel

The high fuel value of synthetic surgical garments makes them an ideal fuel. The following table is a comparison of the btu value of polypropylene vs. other wastes and fuels. As can be seen, the btu value of polypropylene is higher than even gasoline. Polypropylene is the major constituent of non-woven single-use garments.

Table 6. Btu value of various fuels

Material	Btu / lb.
Fuel oil	20,900
Polyethylene plastic (pots, mulch)	19,900
Polypropylene plastic (twine, lids)	19,850
Gasoline	19,200
Polystyrene plastic (inserts, Styrofoam)	17,800
PA Kittanning coal	13,900
Wyoming coal	9,000
Newspaper	8,000
Textiles	6,900
Wood	6,700
Avg. Municipal waste	6,500
Yard waste	3,000
Food waste	2,600

How can single-use garments be converted to fuel

Already substantial amounts of hospital red-bag waste are autoclaved or otherwise decontaminated and used in waste-to-energy plants. In these plants, such wastes replace natural gas because of the higher fuel value. If this material is pelletized it can be used in a much larger number of applications.

There are many pelletizing processes to make wastes suitable for use along with coal and other fuels in power, cement, metal working, and pulp plants. There are a number of initiatives to improve upon conventional pelletizing. Here is one example.

Plastofuel™ is a densification process for converting dirty plastics into a clean burning fuel. The process accepts both rigid and film plastics and forces them through a heated die, melting the outer layer of plastic which locks in dirt, debris and small pieces of plastic. By only melting the outer one to two millimeters of plastic, energy is conserved, especially when compared with the standard pelletizing process which requires the entire mass of plastic to be melted. The extruded material, called extrudate, is then cut to any length desired with a hot knife, sealing the ends to make the nugget durable. The fuel nuggets can be blended with coal in coal-fired boilers, or used as a fuel in kilns and driers

This concept has been developed by Pennsylvania State University which has an entire program on Plasticulture. http://plasticulture.cas.psu.edu/plastofuel.html

Program to promote the use of garments as supplemental fuel

Much hospital waste is now autoclaved or otherwise decontaminated. The pelletizing step as described with "Plastofuel" above may be able to be fine tuned to provide the 250 F temperature for 30 minutes required for an autoclaving procedure and thereby eliminate an autoclave step. In any case waste must be first treated and pelletized. This is all existing technology but there may be some potential for improvement.

Ameren, a large utility serving middle and southern Illinois is already using waste plastic. There will be no problem working with the utility industry to provide a market for the pelletized product. The advantage of coal fired boilers and kilns, as opposed to waste-to-energy plants is the proximity. There are 900 coal fired power plants spread across the country, and hundreds of cement and lime kilns. So transportation from the hospital to the combustor will be minimal.

All that is necessary to develop the demand is to alert the key players. This would be the utility companies. Also DOE and EPA have interests and research funds.

Bio-Polymers (a supply-side solution)

The single-use medical garment industry is currently dealing with ongoing concerns regarding the disposal of surgical gowns and drapes, and other textiles used in health care. Although waste-industry data demonstrate minimal environmental impact of single-use products in terms of annual tonnage, there is continued research of eco-friendly opportunities *on the supply side* in the area of new feedstock materials, i.e, bio-based polymers.

Bio-polymers, sometimes also referred to as "green polymers" or "renewable polymers", represent a class of polymer produced by living organisms. This class of polymer is in contrast with traditional "petro-polymers" derived from essentially non-renewable petroleum products such as crude oil. Petro-polymers are today the basis of most plastics, including polyethylene and polypropylene. Biopolymers are being researched that may, in certain applications, one day replace petro-based polyethylene and polypropylene.

Biopolymers can be derived from numerous plant sources. Sugar cane, switch grass, and other plants may be used for the source biomass. Drivers for the development of biopolymers include:

- sustainability,
- domestic sourcing, and
- lower greenhouse gas emissions

Biopolymers are renewable, sustainable, and can be carbon neutral. Some biopolymers are biodegradable, and may be compostable with a 90% breakdown into constituent components within 6 months. Cost of biopolymers is currently an issue, and an area of continuing investigation. Refer to Appendix XI for additional information on bio-polymers.

Bacterial decomposition of petro-plastics (a disposal side solution)

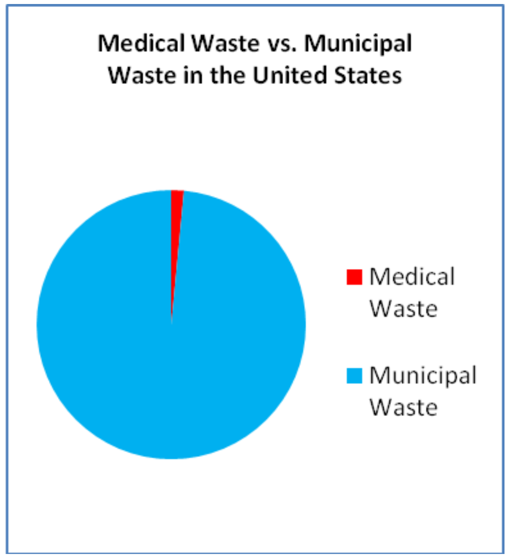
Conventional petro-based plastics are stable molecular structures with generally long life cycles in landfills lasting hundreds of years or longer. This is a positive factor in terms of reduced leachate, but contributes to the total long-term volume of the landfill.

Recent research in bacteria-based bio-degradation of traditional petro-plastics has focused on two strains of naturally occurring bacteria called Sphingomonas and Pseudomonas. When presented with a suitable fermenter including a medium, the bacteria microbes, and plastic material, decomposition of the plastic into water and CO_2 proceeds in a period of 6 to 12 weeks. A heated fermenter assists the decomposition, but most of the heat is supplied by the process so minimal additional energy is required.

Although this process does release CO_2 back to the atmosphere, that drawback may be in part offset by the reduction in landfill mass. Additional research is required to determine process efficacy on a range of plastics. Some research has been conducted on polypropylene. It is important to note that this process relates to traditional petro-plastics and is not restricted to starch-based bio-plastics.

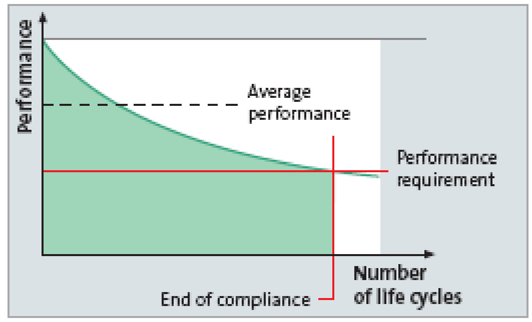
CONCLUSIONS & RECOMMENDATIONS

SITUATION ANALYSIS



- EPA estimates have shown that the percentage of medical waste in the United States as a percentage of total municipal waste is relatively small…on the order of just one half of one percent. Regulated Medical Waste (RMW) is less than 30% of total medical waste. Therefore, any discussion of the environmental impact of medical waste must be in the context of the complete waste-stream.
- The public image of the single-use medical garment industry has to some degree been formed by "green" campaigns promoted by the reusable textile industry. This Study has shown that the environmental burden for single-use textiles is slightly less than for reusables when laundering operations are included.

PERFORMANCE



- Performance and reliability are strong suits for single-use surgical gowns and drapes. Single-use gowns and drapes can be shown to provide superior performance relative to reusable gowns and drapes in terms of consistency, flammability, and other performance metrics. Moreover, reusable gowns have end-of-compliance issues which may present potential liability issues.

Performance Metric	Single-Use Disposable	Multi-Use Reusable	Comments
Barrier Performance	+1	+1	**Both single-use and reusable products are available with AAMI PB70 level 4 ratings**
Comfort	+1	+1	**Material advancements in synthetic fibers and gown constructions have addressed early comfort issues associated with synthetic gowns**
Linting	+1	+1	**Modern SMS fabrics have lower linting based on Gelbo Lint Test than cotton or cotton blends. Woven 100% continuous filament polyester textiles also provide low linting.**
Flammability	+1	0.9	**Flammability of 100% polypropylene fabric is lower than all-cotton or cotton-polyester blends based on ignition temperatures and time-to-ignition (TTI) tests**
Consistency	+1	0.5	**Consistency is more reliably assured for single-use products than for launderable reusable products over the life of the product.**
Safety	+1	0.5	**Single-use products provide fewer exposure opportunities for personnel outside the operating room relative to laundered products**
Total Score	+6	+4.9	

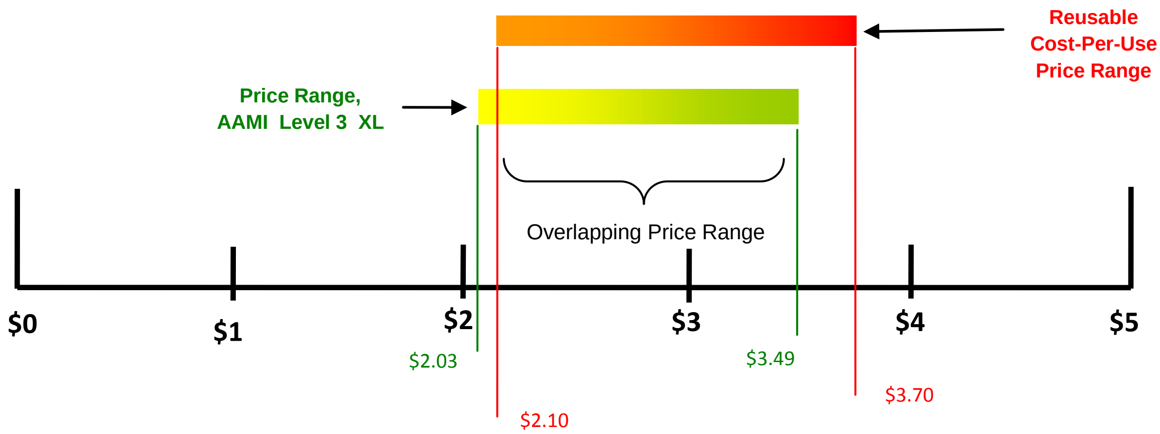
COST-PER-USE

- Based on available evidence, the cost-per-use for single-use gowns *can be* competitive with the cost-per-use for reusable gowns and drapes. The cost differential is not absolute, however, and can be reduced or even reversed one way or the other with changes in net pricing or changes in the assumed number of launderings before retirement of reusable gowns or drapes. As such, this is a *conditional* conclusion.

Per-Unit Price Range
Single-Use Surgical Gowns vs. Reusable Surgical Gowns

(AAMI Level 3, XL)

(Actual transaction prices depend on case-by-case circumstances including quantity, type of gown, customer class, and other variables specific to the transaction)



Per-Unit-Cost to Customer For Surgical Gowns

RESOURCE USAGE

- Reusable garments consume approximately 4.5 times as many resources as single-use garments, primarily in terms of water usage in laundering. The table below shows the resources consumed (in lbs) for single-use and reusable garments. In a water scarce environment, water usage may become a critical factor in the purchasing decision.

Category	Manufacturing		Laundering		Total	
	Reusable	Single-Use	Reusable	Single-Use	Reusable	Single-Use
Garment Material (lbs)	**0.64**	**16**	**xx**	**xx**	**0.64**	**16**
Water (lbs)	**6.6**	**58**	**533**	**xx**	**539.6**	**58**
Energy (lbs of coal equivalent)	**5.3**	**52.5**	**22**	**xx**	**27.3**	**52.5**
Total	**12.5**	**126.5**	**547**	**xx**	**567.5**	**126.5**

TOTAL ENVIRONMENTAL BURDEN

- The overall impact of the medical textiles on the environment is small in terms of burden, for both single-use products and reusable products.
- The environmental burden of single-use medical textiles has been found to be actually *less than* for reusable garments, largely due to the impact of laundering required for reusable garments.

APPENDIX

I. List of Key Assumptions

1. The weight of a reusable garment was assumed to be twice the weight of a single-use garment based on an analysis conducted by Kimberly Clark of single-use and reusable gowns. Calculations in this report used a weight of 0.32 lbs for a single-use garment, and 0.64 lbs for a reusable garment. These numbers are conservative based on weights recorded in the Study of 0.24 lbs (single use) and 0.93 lbs (reusable).
2. A life-cycle of 50 launderings was assumed for reusable garments.
3. Single-use gowns were assumed to be of all polypropylene nonwoven material.
4. Reusable gowns were assumed to be of all polyester woven material.
5. Two-gallons of water per pound of laundry was assumed in all laundry calculations, based on information available on the internet.
6. The combustion BTU content of polypropylene and polyester was assumed to be 19,000 BTU per pound, based on information available on the internet.
7. The combustion BTU content of bituminous coal was assumed to be 12,000 BTU per pound based on information available on the internet.
8. The key resources consumed in the product life-cycle were assumed to be water and oil.
9. The key emissions in the product life-cycle were assumed to be NOx, CO_2, and water.
10. CO_2 was established as the normalized base for the Environmental Burden calculations, with a Normalized Weighting Factor of 1.0, and a cost of $20 per ton.
11. The value of a human life was taken to be $7,000,000 per a government report, with an equivalent value in CO_2 units of 350,000 tons of CO_2.

II. List of factors not included in the Study

1. The cost of fuel in the transportation of single-use and reusable garments was considered to be approximately similar, and was not factored into this Study.
2. The warehousing cost of single-use and reusable garments was considered to be approximately similar, and was not factored into this Study.
3. The cost and environmental impact of packaging for single-use and reusable garments was considered to be approximately similar, and was not factored into this Study.

III. Sensitivity of results to key variables

1. The environmental burden for reusable garments is strongly influenced by water availability. In a water-restricted area, the environmental burden posed by reusable garments is an order of magnitude higher based on the increased value of the water.
2. The cost-per-use evaluation for reusable garments is sensitive to the assumed number of launderings to the end-of-compliance state, and to the quoted price for the single-use garment.
3. Safety of garments adds an environmental burden equal to the total environmental burden of the garments for reusable products. There is documentation supporting a higher level of safety for single-use disposable garments relative to reusable garments, when breakdown in barrier efficacy is considered for laundered products, as well as the increased exposure to hazards in the laundering process.

IV. Nonwoven Suppliers

The Top 40 suppliers of nonwoven roll goods along with annual sales are listed in the Table, below [Ref: Nonwovens Industry, September 2008 issue].

Ranking	**Company Name**	**2007 Global Nonwovens Sales**
1	Freudenberg	$1.45 billion
2	DuPont	$1.35 billion
3	Kimberly-Clark	$1.3 billion
4	Ahlstrom	$1.28 billion
5	PGI	$1.06 billion
6	Fiberweb	$948 million
7	Johns Manville	$670 million
8	Fibertex	$294 million
9	Buckeye	$260 million
10	First Quality	$250 million
11	Avgol	$237 million
12	Companhia Providencia	$225 million
13	Hollingsworth & Vose	$225 million
14	Concert Industries	$212 million
15	TWE Group	$211 million
16	Propex	$210 million
17	Colbond	$195 million
18	Japan Vilene	$194 million
19	Vita Nonwovens	$190 million
20	Sandler	$171 million
21	Asahi Kasei	$170 million
22	Pegas	$167 million
23	Jacob Holm	$160 million
24	Georgia Pacific	$150 million
25	Toyobo	$143 million
26	Mitsui	$136 million
27	Lydall	$135 milllion
28	Union	$133 million
29	Andrew Industries	$130 million
30	Western Nonwovens	$125 million
31	Toray Saehan	$123 million
32	Foss Manufacturing	$108 million
33	Suominen	$104 million
34	Fitesa	$103 million
35	Royal Tencate	$102 million
36	Albis	$100 million
37	Textilgruppe Hof	$98 million
38	Unitika	$88 million
39	PCC	$87 million
40	Rexcell	$86 million

V. List of Medical Laundry Operations in the US

1. Cintas Corporation
2. Healthcare Services Group Inc
3. Alsco Inc
4. G&K Services, Inc
5. Angelica Corporation
6. Ameripride Services, Inc
7. National Service Industries, Inc
8. Mission Linen Supply
9. Mission Of Nevada, Inc
10. Summit Services Group, Inc
11. Domestic Linen Supply And Laundry Company
12. Admiral Linen Service Inc
13. Palace Laundry, Inc
14. Sri/Surgical Express, Inc
15. Hospital Central Services Cooperative, Inc
16. A & P Coat Apron & Linen Supply Inc
17. Ameritex
18. Sodexho
19. Alsco

VI. Municipal and Medical Waste Data

Municipal and Medical Waste Data

1990 Data: In a comprehensive 1990 report entitled "Finding the Rx for Managing Medical Wastes," EPA estimated that from 0.3% to 2.0% of municipal solid wastes were medical wastes. Of that amount, about 15% is regulated medical waste.

http://www.epa.gov/waste/nonhaz/industrial/medical/mwpdfs/rx/toc.pdf

In 1990, Americans generated about 205.2 million tons of municipal waste.

http://www.epa.gov/osw/nonhaz/municipal/pubs/msw07-fs.pdf

Based on 1990 data, then, corresponding waste amounts would be as follows:

Total Municipal Solid Waste:	205.2 million tons per year
Total Medical Wastes:	615,000 to 4.0 million tons per year
Regulated Medical Wastes:	92,000 to 205,000 tons per year

2000 Data: A report published in 2000 suggested that total medical wastes were 600,000 to 1 million tons per year and regulated medical wastes were 90,000 to 150,000 tons per year.

http://www.memagazine.org/backissues/membersonly/sept00/features/rx/rx.html

In 2000, about 239.1 million tons of municipal waste was generated.
http://www.epa.gov/osw/nonhaz/municipal/pubs/msw07-fs.pdf

Therefore, total medical waste was 0.3% to 0.4% of municipal solid waste in 2000.

2007 Data: In 2007, Americans generated about 254 million tons of municipal waste.

http://www.epa.gov/osw/nonhaz/municipal/pubs/msw07-fs.pdf

EPA's medical waste data and estimates have not been updated since the 1990 report. However, 2007 medical waste data can be extrapolated as follows. All numbers are in tons per year:

Year	**Municipal Solid Waste**	**Total Medical Waste (tons)**	**Regulated Medical Waste (tons)**
1990	205.2 M	615,000 to 4.0 M (0.3 – 2.0%)	92,000 to 205,000
2000	239.1 M	600,000 to 1.0M (0.3 – 0.4%)	90,000 to 150,000
2007	254.0 M	1.0 M (0.4%)	150,000

Pie chart percentages:

Total Municipal Waste: 254.0 million tons per year

Total Medical Waste: 1.0 million tons per year or 0.4%

Total Medical Waste:

Non-Regulated 850,000 tons per year or 0.34%

Regulated 150,000 tons per year or 0.06%

VII. Carbon Credit Overview

Carbon credits are a key component of national and international emissions trading schemes that have been implemented to mitigate global climate change. They provide a way to reduce greenhouse gas emissions by capping total annual emissions and letting the market assign a monetary value to any shortfall through trading ("cap and trade").

Europe has had an active carbon market since 2005 through the European Union Emissions Trading Scheme (EU-ETS). In the US, there are currently two operating carbon markets: the Regional Greenhouse Gas Initiative (RGGI) and the Chicago Climate Exchange (CCX).

RGGI: RGGI is a regional "cap and trade" system established by ten states in the eastern US to limit greenhouse gas emissions from electric power plants. The states establish a regional emissions cap, then each state allocates its share of the cap among facilities within the state. RGGI administers an emissions auction once each quarter beginning in March 2009. Two preliminary auctions were conducted in 2008 with allowances selling for just over $3.00 per carbon credit (or ton of carbon dioxide equivalent emission).

The auctions are open to third parties such as environmental groups (who would purchase a credit and hold it, thereby reducing emissions) or investors (who would purchase a credit, expecting the price to increase). In order to participate in an auction, an entity needs to qualify by completing an application form and posting financial security in the form of cash, bond or letter of credit to cover the anticipated bid amount. http://www.rggi.org/co2-auctions

Chicago Climate Exchange: CCX is a private corporation, not a government initiative, which created a cap and trade system in 2003. A company (such as an electric utility) can agree to voluntarily participate in the Exchange by making a legally binding commitment to reduce greenhouse gas emissions. Participants are assigned annual emission allowances based on the CCX Emission Reduction Schedule. Those who reduce below the targets have surplus allowances to sell or bank; those who emit above the targets comply by purchasing CCX Carbon Financial Instrument (CFI) contracts. Trading by third parties on CCX is most likely to occur through qualified traders or a brokerage firm. CCX allowances have been selling for around $2.15 per carbon credit. http://www.chicagoclimatex.com/

VIII. Environmental Burden Calculation Worksheet

The following table provides burden estimates for the manufacturing, use, laundering, and disposal of single-use and reusable surgical gowns and drapes. A research presentation entitled "Life Cycle Assessment of Healthcare Garments" co-sponsored by NC State University and University of California at Davis and presented by Celia Steward Ponder and Dr. Michael Overcash in 2007 provides data for manufacturing burdens presented in this table.

Universal Environmental Burden Index: Reusable/Single-Use Gowns for 50 Wearings, Pounds

Segment	Pollutant	Factor	Reusable Quantity	Reusable Burden	Single-Use Quantity	Single-Use Burden
Waste to Energy	CO_2	1	2.88	2.88	72	72
Waste to Energy	NOx	100	0.0019	0.19	.0037	4.75
W/E Energy Total				3.07		76.75
Fuel Sub. Credit				-3.07		-76.75
Net Disposal				0		0
Garment Mfr	CO_2	1	5.3	5.3	59	59
Garment Mfr	NOx	100	0.0037	0.37	0.035	3.5
Garment Mfr Total				5.67		62.5
Laundry	CO_2	1	48.6	48.6	xx	xx
Laundry	NOx	100	0.03	3.00	xx	xx
Laundry	TSS/CBOD	100	0.15	15	xx	xx
Laundry Total				66.6	xx	xx
Subtotal				72.27		62.5
Garment Use and Laundry	Life	700 Million	500 Million	70	xx	xx
Grand Total				142.27		62.5
*CO2 Offsets	CO_2	1			-62.5	-62.5
Offset New Total				142.27		0.00

*These calculations are based on 50 launderings per reusable garment. The calculations are in pounds of burden. In the case of CO_2, it is actual lbs. In the case of other pollutants, it is the actual lbs x 100 to create the equivalent burden (some burdens such as NOx and mercury are rated by the EPA as more environmentally hazardous than CO_2). In the case of safety, the value of one life ($7,000,000) is equivalent to 700 million lbs (350,000 tons). Refer to Appendix XII for additional details.

Waste Disposal (Combustion Energy and CO_2 and NOx Emissions)

Bituminous coal creates 4931 lbs of CO_2/short ton, and 240 lbs of CO_2/ Million-Btu.

http://www.eia.doe.gov/oiaf/1605/coefficients.html

Generation of CO_2 per lb is a function of the Btu value. Surgical drapes and gowns have a high Btu value (approximately 19,000 Btu/lb compared to 12,000 Btu/lb for bituminous coal) and would generate 4-5 lbs of CO_2 per lb of garments.
[240 lbs (CO_2)/MBtu]X[0.019MBtu/lb of garment] = 4.5 lbs of CO_2 per lb of garments

http://www.kchealthcare.com/docs/KL-950-1%20Incineration%20of%20KC%20Single-use%20HC%20Products.pdf

Polypropylene generates 19,000 Btu per lb. In waste to energy plants, this provides more electricity than coal. Even in incinerators without energy recovery, this high fuel value product would reduce the requirement for natural gas to combust the low fuel value components in the waste mix.

Combustion of 53 lbs of polypropylene yields 1-million Btu. [1MBtu/19,000 Btu/lb = 53 lbs of polypropylene/Million-Btu]

NOx Emissions

NO_x emissions are typically 0.15 lbs/Million-Btu. Therefore,
NO_x = [.15lbs/MBtu]X[MBtu/53 lbs of garments] = 0.0028 = 0.003 lbs of NO_x/lb of garment.

At 0.32 lbs/garment, the NO_x would be 0.32 x 0.003 = 0.00096 lbs of NO_x per disposable garment. Reusable garments are taken to be twice as heavy and would generate 0.64 x 0.003 = .00192 lbs of NO_x/garment.

CO_2 Emissions

CO_2 emissions are 240 lbs/Million-Btu. Therefore,
CO_2 = [240 lbs/MBtu]X[MBtu/53 lbs of garment] = 4.52 lbs of CO_2 /lb of garment.
The CO_2 per garment would be 0.32 x 4.52 = 1.44 lbs of CO_2 per garment (disposable).
Reusable garments would generate 2 x 1.44 = 2.88 lbs of CO_2 per garment.

Waste-to-Energy Burden (NOx and CO_2 Emissions)

Pollutants From Waste Combustion	Quantity (lbs/garment)	Number of Garments	Total Quantity (lbs)	Burden Factor	Total Burden (equiv. lbs)
Single-Use Garments (NO_x)	.00095	50	.0475	100	4.75
Single-Use Garments (CO_2)	1.44	50	72	1	72
Reusable Garments (NO_x)	.0019	1	.0019	100	0.19
Reusable Garments (CO_2)	2.88	1	2.88	1	2.88

Garment Manufacture (NOx and CO_2 Emissions)

Energy required is 5162 MJ for 1000 single-use garments and 27380 MJ for 1000 reusable garments, as reported in the North Carolina State University analysis. One megajoule is 948 Btu.

Hence, it takes [948Btu/MJ]X[5.162MJ/garment] = 4893 Btu/garment. At 0.15 lbs/MBtu for NO_x, NO_x per garment = [0.15lbs/MBtu]X[0.004893MBtu/garment] = 0.0007 lbs per garment.
NOx for reusable garments: [948 Btu/MJ]X[27.380MJ/garment] = 0.0259MBtu/garment
[0.0259MBtu/garment]X[0.15 lbs/MBtu] = 0.0038 lbs of NOx per reusable garments.

At 240 lbs of CO_2/Million-Btu, the CO_2 per single-use garment is as follows:
[0.004893MBtu/garment]X[240lbs CO_2/MBtu] = 1.17 lbs CO_2 .
Reusables are as follows: [0.0259MBtu/garment]X[240 lbs CO_2/MBtu] = 6.2 lbs CO_2

Pollutant	Quantity (lbs/garment)	Number of Garments	Total Quantity (lbs)	Burden Factor	Total Burden (equiv. lbs)
Single-Use Garment (NO_x)	.0007	50	.035	100	3.5
Single-Use Garment (CO_2)	1.17	50	59	1	59
Reusable Garment (NO_x)	.0038	1	.0038	100	.38
Reusable Garment (CO_2)	6.2	1	6.2	1	6.2

Laundry Burden Calculations

Energy consumption varies with water per garment and the number of cycles.

http://www.weidel-nemeth.hu/WEBSET_DOWNLOADS/378/CleanTech_EN.pdf

1.4 kWh/kg (WECO pilot survey though says only 0.35)

293 kWh /Million-Btu

1 kWh = 3413 Btu, but coal is 30 % efficient so 1 kWh = 10,000 Btu

Therefore, one kg of laundered product requires 14,000 Btu

One garment requires 290grams x 1kg/1000 grams x 14,000 Btu/kg = 4060 Btu

NO_x would be .15 lbs/mm Btu x 4060 Btu = .0006 lbs /garment

CO_2 would be 240 lbs/ mm Btu x 4060 Btu = .974 lbs/garment

Water pollutants from laundering would be based on water usage

2 gallons per lb x 50 garments x. 0.64 lbs = 64 gallons for 50 garments

10 mg /ltr for TSS x 64 gal x 3.78 ltrs/ gal x lbs/ 453592mg= .005 lbs x 100= 0.5 lbs of burden

Nitrogen and CBOD are the same. So the total for water pollutants is only 1.5 lbs. However, if the laundry is discharging the water untreated the burden could be 10 x or 15x as much.

Pollutant	Quantity (lbs/garment)	Number of Garments	Total Quantity (lbs)	Burden Factor	Total Burden (equiv. lbs)
NO_x	**.0006**	**50**	**.03**	**100**	**3**
CO_2	**.974**	**50**	**48.7**	**1**	**48.7**
TSS/Nitrogen/CBOD	**0.003**	**50**	**.15**	**100**	**15**

Safety Burden:

As shown on the Universal Environmental burden chart, one life is worth $7 million. With CO_2 @ 20/ton, one life is worth 350,000 tons or 700 million lbs. The burden chart is based on 50 wearings. If there were one death saved per 500 million single-use garments sold, the burden reduction would be 700 million/500 million = 1.4/garment wearings x 50 = 70 lbs burden reduction for 50 wearings.

Assuming $200/lost day for illness, each day is the equivalent of 10 tons of burden (CO_2 @ $20/ton) or 20,000 lbs.

20,000 lbs/lost day x l lost day/14285 garment wearings = 1.4 lbs /garment wearing x 50 = 70 lbs of burden reduction for 50 wearings.

Resource Depletion

Sustainability requires inclusion of the potential depletion of resources. There is a 40-year supply of oil, so potential depletion of this resource is significant. There is a 200-year supply of coal so the depletion impact of l pound is an order of magnitude less than oil.

Only a fraction of 1% of the world's water is both uncontaminated and available. However there is a big difference in availability between cities such as Phoenix which suffers a large water deficit and Minneapolis which has a water surplus. Where there is a surplus of water, depletion would be similar to coal. But where there is a water deficit the loss would be similar to oil. There are temporary situations where the water deficit turns into a drought.

Water Resource Depletion

The resource depletion for water used in laundries for reusable gowns is shown below.

Item	Water surplus burden	Water deficit burden	Water Drought burden
Reusable Garment Weight (lbs)	0.64		
Water usage	2 gal/lb		
Water Usage (gal/garment)	1.3 gal		
Water Usage (lbs/garment)	10.8		
Lbs/50 wearings	540		
Water Surplus burden of 0.001	1		
Deficit at 0.01		10	
Drought at 0.l			100

Category	Environmental Burden	Safety	Water Resource Depletion Factor	Total Environmental Burden
Single-Use Garments	**62.5**	**0**	**0.16**	**62.66**
Reusable Garments (water surplus)	**72.27**	**70**	**1**	**143.27**
Reusable Garments (water deficit)	**72.27**	**70**	**10**	**152.27**
Reusable Garments (drought)	**72.27**	**70**	**100**	**242.27**

In a normal area of water surplus, the burden added by water resource depletion is only a small amount and would not impact the choice between reusable garments and single-use garments. In a water deficit region it would be a significant factor. In a drought condition, the burden would be larger than any other.

Oil Resource Depletion

The garments are made almost entirely of oil as the raw product. So the resource depletion is simply the weight for 50 wearings multiplied by the burden factor.

Burden from resource depletion of oil for 50 wearings

Category	Lbs/garment	Number of Garments	Total lbs for 50 Wearings	Burden (.01)
Reusable Garments	0.64	1	0.64	0.0064
Single-Use Garments	0.32	50	16	0.16

Oil and Water Resource Depletion

The oil used in the manufacturing and the water used in the laundering are the two resources that are significantly depleted. So the total resource depletion is the aggregate of these two.

Category	Oil	Water	Total
Single-Use Garments	0.16	0	0.16
Reusable Garments (water surplus)	0.0064	1	1.0064
Reusable Garments (water deficit)	0.0064	10	10.0064
Reusable Garments (drought)	0.0064	100	100.0064

It is therefore apparent that water resource depletion becomes an important burden in regions where there is a water deficit and the most important burden in areas of drought.

<u>Waste Disposal Landfill Resource Depletion</u>

The basis for the main comparison was based on waste-to-energy or incineration. Either one would result in a net 0 burden due to the high fuel value. An alternative is disposal in a normal or hazardous waste landfill.

The environmental burden of a normal landfill would be similar to the depletion of a common resource such as coal. We will run out of land fill space about the same time we run out of coal (200 years). So an equivalent burden of 0.001 is appropriate. Hazardous waste landfills are associated with a higher burden due to risk and availability. Therefore a burden of 0.01 is appropriate.

If red bags are not decontaminated they would have to be disposed in hazardous waste landfills. But there are many ways to de-contaminate the waste so that it would be disposed in normal waste landfills. In either case the environmental impact for 50 wearings is less than 0.2 for single-use garments. Therefore waste disposal is a non-issue. More than 254 million tons of waste is generated in the U.S. The 18,600 tons generated by 30 million garments is insignificant and thus the low numerical environmental burden.

Environmental Burden (lbs) due to garment disposal and based on 50 wearings.

Category	Lbs/garment	Number of garments	Total lbs for 50 wearings	Burden for hazardous waste at 0.01	Burden for normal waste @ .00l
Reusable Garments	**0.64**	**1**	**0.64**	**0.0064**	**0.00064**
Single-Use Garments	**0.32**	**50**	**16**	**0.16**	**0.016**

<u>Resource Usage Calculations</u>

Resource utilization is another important parameter. A quantitative total can be obtained by adding the weight of material used in the garments, the weight of equivalent coal to produce the energy to make the garments, and the water used both in manufacture and in laundering.

<u>Laundering</u>

One reusable garment requires water at the rate of 2 gallons per pound of material laundered.

2 gal/lb x .64 lbs/garment x 50 = 64 gallons for 50 garments.

So reusables use 64 gallons x 8.33 lbs/gal or 533 lbs for 50 reusable garments.

Laundering requires 2030 btu/garment. So the total lbs of equivalent coal would be 1 lb of coal /14,000 btu/lb x 2030 btu/garment wearing x 3 inefficiency x 50 garments = 22

<u>Manufacturing</u>

The quantity of material in 50 wearings of garment for reusables is

.64 lbs/garment x l garment = 0.64 lbs

The single-use garment weight is .32 lbs/ garment x 50 = 16

Coal is 1lb/ 14,000 btu x 4930 /btu/garment x 3 inefficiency= 1.05 lbs x 50 garments = 52.5 lbs if it were all coal at very low efficiency

Reusables would be 27380/ 5162 x 1.05= 5.30 for 50 wearings

Water used in manufacture disposal is 531 kg/1000 garments for disposable. So 531kg x 2.2 /1000 x 50 = 58 lbs for 50 wearings

For reusable it is 3000 kg/ 1000 garments x 2.2 x1=6.6 lbs for one garment to be worn 50 times

The following chart shows the resource totals for the two alternatives

Lbs of resources for 50 wearings of garments

Category	Manufacturing		Laundering		Total	
	Reusable	Single-Use	Reusable	Single-Use	Reusable	Single-Use
Garment material (lbs)	0.64	16			0.64	16
Water (lbs)	6.6	58	533		539.6	58
Energy (lbs of coal equivalent)	5.3	52.5	22		27.3	52.5
Total	12.53	126.5	547		567.5	126.5

The reusable garments require 567/126 or 4.5 times the weight of resources consumed by single-use garments.

IX. Waste Handling References

BioMedical Technology Solutions, Inc

http://www.bmtscorp.com/index.htm

The Demolizer® II

The system for low to medium volume medical waste generators, is approved, or meets regulatory requirements in 47 states, for treatment and disposal of both sharps and red bag waste. About the size of a desktop printer, the Demolizer® II ensures complete disposal of medical waste, automatically documents state-required records, and eliminates the generator's cradle-to-grave liability. The patented treatment process, using dry heat technology, renders waste sterile and sharps unrecognizable. The treated waste is properly labeled and simply thrown away as common trash.

ECodas

ECODAS has developed a closed, and fully automated system that sterilizes Regulated Medical Waste (RMW), reduces its volume by 80 %, and renders its components unrecognizable.

The process combines shredding and direct pressurized heated steam all in one enclosed system achieving complete sterilization of infectious materials. The final treated waste is harmless, unrecognizable, and safe for disposal, just like ordinary municipal waste.

The solution consists first of shredding, which permits steam penetration and ensures that all waste is in direct contact with the sterilizing steam. Then superheated steam (138°C/280°F) under high pressure (3.8 bars/55 psi) destroys all forms of microbial life. This is a simple, efficient and cost effective operation to convert contaminated medical materials into harmless municipal waste.

The ECODAS SYSTEMS were designed to handle a large variety of regulated medical waste, including hospital and laboratory waste, liquid and solid medical waste, human and animal blood specimens, sharps and pathological waste, cultures and stocks, as well as any other waste listed in local, state and federal regulations as medical waste.

The French Ministries of Health and the Environment have approved several non-incineration processes to treat potentially infectious wastes, including a steam system developed by Ecodas, headquartered in Roubaix. According to Oliva, this company is the leading provider of alternative biomedical waste treatments.

Ecodas drew upon its 20 years of experience manufacturing steam pressure autoclaves for the textile industry to design a medical waste treatment system. "The innovation lies in combining a high-strength grinder with a particularly powerful sterilizer," said Jaafar Squali, managing director of Ecodas.

The first stage of the Ecodas treatment involves loading contaminated waste into a hermetically sealed chamber that feeds a grinder with 20 rotating blades. These blades are fashioned from an alloy strong enough to shred stainless steel surgical instruments that are sometimes mistakenly disposed of with other clinical wastes. The grinder reverses its rotation at regular intervals to prevent jamming.

Loads of waste are emptied into a loading chamber that feeds the autoclave. Inside the autoclave, the waste is subjected to steam heated to 280[degrees]F and pressurized to 55 pounds per square inch for 10 minutes, which sterilizes the waste. A temperature probe in the center of the autoclave embedded in the waste sends signals to the computer control system to regulate temperature.

When disinfection is complete, operators open the lower lid of the autoclave to release the processed waste into a container. The entire process takes about one hour to treat a single load.

Ecodas designed three different versions of its waste treatment machines to accommodate a range of waste volumes and space available for installation. The TDS 300 is 10 feet tall and treats 35 to 55 pounds of waste per hour; the TDS 1000 treats 110 pounds per hour, and the TDS 2000 treats up to 132 pounds per hour.

In France, public hospitals in Ajaccio, Aurillac, Nevers, and Roubaix disinfect their wastes with Ecodas autoclaves. So do hospitals in Odense, Denmark; Majorca, Spain, and Budapest, Hungary. Among the waste processing companies that use the Ecodas system are Cosmolys and Tecmed in France, Tecsan in Argentina, Matmed in Brazil, and Tremesa in Mexico.

Honua Technologies (Advanced Biowaste Solutions)

http://www.honuatech.com/index.html

The waste stream that the Pyrolytic Destructor™ is specifically designed to destroy includes pathological wastes from surgery and autopsy (e.g., body parts, human and animal tissue samples and cultures, placentas, whole blood and blood products); chemotherapy wastes (e.g., all materials that come into contact with chemotherapy agents, including polyvinyl chloride ("PVC") plastics); laboratory wastes (e.g., blood cultures, serums, blood samples); and pharmaceutical wastes (e.g., expired drugs, confiscated narcotics, and related drug paraphernalia).

Honua also employs autoclaving, a time-tested high heat medical waste treatment technology, to efficiently and cost-effectively render large volumes of medical "red bag" waste (e.g., contaminated bandages, dressings, cotton, gauze, paper, gowns, bedding, latex gloves, masks, suction canisters and sponges) and "sharps" (e.g. contaminated needles, syringes, syringes containing fluids, scalpels, and glass test tubes, pipettes and petri dishes) non-infectious and safe for disposal.

Honua also uses its proprietary heat recovery systems, heat recovery boilers and thermal energy cogeneration control equipment to ensure that medical waste treatment facilities utilizing the Pyrolytic Destructor and autoclave systems together can effectively treat 100% of the components of the medical waste stream with only the energy used in and produced from treating 20% of that same waste stream.

Finally, Honua employs proprietary sharps containment and washing systems to enable medical waste facilities and hospitals to safely handle and reuse its reusable sharps containers, which amounts to a dramatic cost savings when compared to conventional disposable sharps containers.

Pyrolysis is the endothermic (heat absorbing reaction) gasification of waste using external energy (heat) in the absence of oxygen. In practice, it involves the controlled breakdown of the waste's molecular structures by elevating their temperatures in the absence of oxygen. High heat must be applied from an external source. Because the flame never touches the waste, and no outside air is added to the chamber, pyrolysis does not allow the waste to combust (an exothermic or heat releasing reaction) within the pyrolysis chamber as it would in a traditional, starved air, rotary kiln, or plasma arc incinerator. There is no turbulence or flame in the pyrolysis chamber to cause currents that carry away air emissions and particulate.

There are no visible particulate emissions from a properly operated Pyrolytic Destructor and it easily meets the most stringent emissions laws in the world - the United States Environmental Protection Agency's regulations pertaining to regulated medical waste incinerators.

The United States Environmental Protection Agency (U.S. EPA) has excluded equipment achieving true pyrolysis from the hospital and medical waste incinerator regulations because pyrolysis is not considered incineration. The U.S. EPA has even provided a specific exemption for pyrolysis in its most current air pollution regulations (40 CFR 60.50.c(f)). The U.S. EPA has set very rigid standards for pyrolysis. In order to qualify, Honua submitted detailed test results to the U.S. EPA, which have been accepted. Honua' claims that its Pyrolytic Destructors are the only such units that meet the U.S. EPA exemption.

Honua's proprietary Pyrolytic Destructor systems have sealed pyrolysis chambers with small ducts to allow the transfer of volatile organic compounds ("VOCs" or hydrocarbons). No external air (oxygen) can enter the chamber once it has been sealed. As the pyrolysis cycle begins, heat is transferred through the pyrolytic chamber hearth (floor) from the hot gases produced by a standard industrial burner. Temperature in the pyrolysis chamber is gradually increased until the chamber reaches operating temperature.

As the temperature in the pyrolysis chamber increases, air trapped in the chamber expands and is transferred through the small venting duct. Pyrolysis begins at approximately 232°C (450°F), when the more volatile components of the waste begin to gasify. Heat continues to be applied at a controlled rate until the internal temperature of the pyrolysis chamber has reached the set point of 760°C (1,400°F). Heat transfer is controlled to maintain the set temperature for a sufficient period of time, in order to completely gasify all organic components of the waste. When gasified in the absence of oxygen, the VOCs are not combusted as they would be in an incinerator - where the violence and agitation of the combustion process yields particulate and chemical air pollution. Instead, they are gently transferred in their gaseous state to the oxidization chambers, where the controlled application of heat and air completely oxidizes them - virtually eliminating any toxic or hazardous by-products.

After contributing significant energy content to the continuous heating of the pyrolysis chambers, hot gases from the oxidation chambers are then discharged through the exhaust ducts or captured by the heat recovery system for use in heating the Heat Recovery Boiler. All that is left of the waste is a totally inert, non-toxic carbon residue that is virtually undisturbed.

Honua offers three (3) Models of Pyrolytic Destructors as the optimum technology for destruction of pathological and chemotherapy waste stream components. They are the Model 550 (500 kg per day), Model 1200 (1000 kg per day) and Model 2500 (2000 kg per day). Honua's Pyrolytic Destructors will literally serve as the heart of a centralized medical waste treatment facility.

Autoclaving (steam sterilization), heats medical waste to approximately 135°C (275°F) until the waste is rendered non-infectious. The treated waste can then be shredded and compacted for safe and efficient handling to a landfill site. In a typical Honua installation, autoclaves will be used to treat approximately 80% of the waste (the muscle) using supplemental energy from the Pyrolytic Destructor (the heart).

Honua specifies industrial autoclaves for use in centralized medical waste facilities because of their low acquisition cost, ease of use, reliability, and low maintenance requirements. Honua's autoclave manufacturer has been in the autoclave and pressure vessel manufacturing business for over thirty years. They have a full staff of engineers and produce autoclaves and other pressure vessels for many different applications and industries. All of Honua's autoclaves are manufactured in strict accordance with the exacting ASME Boiler and Pressure Vessel Code standards and regulations. Honua's autoclave products are custom built to meet the individual needs of each project and will be supplied as a part of Honua's total system to work in seamlessly with the Pyrolytic Destructor and matched heat recovery and auxiliary fired boiler systems.

Honua specified autoclaves have completely automated control systems allowing for unattended operation. After pushing the "Cycle Start" pushbutton, the sterilizer will proceed through a purge cycle, that is, both the steam inlet and vent valves will be open, allowing the steam to completely fill the chamber and force all air out. This ensures better penetration and sterilization effectiveness. An adjustable timer controls the purge cycle. At the completion of the purge time, the exhaust valve will close and allow pressurization of the unit. An alarm switch starts the main cycle timer, which begins only upon reaching sterilization temperature. At the completion of the timed period an exhaust vent valve will open to de-pressurize the sterilizer. A safety relief valve is provided to prevent over-pressurization of the sterilizer vessel. The controls include an "Emergency Stop" button should there be requirements for an emergency shutdown.

Autoclaves require high temperature stainless steel carts. An autoclave may be operated with as few as five (5) carts, however, Honua recommends ten (10) carts to ensure that the facility operates in an efficient manner between autoclave cycles. While the autoclaves are cycling, a second and third load can be prepared for loading. Once the autoclaves have cycled, they can quickly be discharged, unloaded and reloaded in a short time to allow for the maximum number of autoclave cycles per day.

Sanitec

The entire Sanitec disinfection system is enclosed in a all-weather steel housing, and is connected to the hospital's electrical and water systems. Hospital workers bring collected waste in carts to the automated lift and load system, which raises the cart and empties it into the in-feed hopper. The hopper is sealed and the shredder is activated. Shredding reduces the waste's volume by 80 percent and, just as important, creates a more even waste stream that can be effectively treated at lower temperatures, minimizing the system's overall energy consumption as well as the potential for releasing potentially harmful air emissions.

The Shredding Challenge

Designing a shredding mechanism for medical waste is more challenging than a mechanism that shreds tires or tree stumps, because medical waste is, by definition, a heterogeneous mixture. "The Sanitec system has to shred soft fabric drapes, gowns and bandages, brittle glass, plastic syringes, and hard steel needles, knives, and clamps. "A proprietary shredder consists of two rotating shafts with teeth that grind all types of regulated hospital wastes to the proper size, so that it falls through a close tolerance screen to the next stage."

A fan draws air from the in feed hopper through a series of filters. A high-efficiency particulate air, or HEPA, filter and a carbon filter control odors and prevent harmful emissions from escaping during processing.

A stainless steel screw conveyor moves the shredded waste through the output of an electric steam generator that uses about 8 gallons of water per hour to add moisture to the waste. The moistened waste then passes through a series of a half-dozen 1,400-watt microwave units made by Alter of Reggio Emilia, Italy. The microwaves excite the water molecules on the waste particles, creating friction and raising the temperature of the waste to 205 to 212[degrees]F for 25 minutes.

The combination of high temperature and residence time is sufficient to ensure the destruction of pathogens, a process that is validated by regular spot checks.

A secondary screw conveyor removes the treated waste from the Sanitec unit to a standard waste compactor or dumpster prior to its final disposal into a municipal solid waste program. An optional granulator enables the hospital to further reduce waste volume.

The entire Sanitec process is overseen by an Allen Bradley microprocessor equipped with a computer program that monitors the residence time and temperature parameters to ensure that disinfection is complete before the waste is discharged.

A group of four hospitals in Madison, Wis.--the University of Wisconsin Hospital and Clinics, Meriter Hospital, Methodist Hospital, and St. Mary's Medical Center--joined forces in 1986 to create a shared medical waste processing facility to reduce costs. The hospitals formed a nonprofit corporation called Madison Energy Recovery Inc., or MERI, to operate the plant, which was originally equipped with a state-of-the art incinerator.

By 1994, tighter environmental regulations meant that the incinerator would have to be retrofitted with new pollution control equipment at a cost likely to exceed $500,000. After reviewing options, the MERI board selected the Sanitec disinfection system.

"We find the Sanitec system to be quiet, clean, and very efficient in disinfecting waste," said John Crha, general manager of MERI. Many health care facilities agree, and today the MERI

Sanitec system processes more than 1.5 million pounds of regulated medical waste per year generated from 12 additional hospitals and clinics throughout the state, including Mercy Health Systems in Janesville and St. Agnes Hospital in Fond du Lac.

Each day, a specially designated MERI truck picks up plastic carts filled with waste packaged in red bag or plastic sharps containers from 250 locations. After the carts are emptied into the Sanitec system, they are washed, cleaned, and disinfected before being trucked back to their hospitals. Each cart is tracked by signed manifests, which are also used to bill the participating hospitals. Treated wastes are sent to municipal solid waste landfills.

Mobile Microwave disinfection

Rather than transporting waste to a disinfection site, SafeWaste Inc. of Charlotte, N.C., brings the Sanitec process to hospitals in its home state and Virginia on four truck-mounted, mobile units. SafeWaste's Sanitec trucks pick up the waste from almost 40 hospitals, including Carolina Medical Center in Charlotte, and Fairfax Hospital in Fairfax, Va., and treat it on-site, using each hospital's water and power connections. The company uses smaller vans to treat waste from more than 400 smaller medical facilities, including doctor's offices, rural clinics, laboratories, and veterinary establishments. In all, SafeWaste processes nearly 10 million pounds of potentially hazardous material annually.

Sanitec has set its sights beyond its traditional practice of selling its microwave disinfection systems to hospitals and waste treatment companies. "We are now concentrating on creating our own service companies by forming joint ventures such as Sanitec of Kentucky, in Florence, Ky., and Sanitec of Hawaii in Honolulu," Taitz said. "We supply the equipment to the joint venture and participate in the revenues, thus making our sterilization equipment more accessible to the end user. Hopefully, we can eventually create a nationwide treatment for all medical waste generators."

Taitz sees bright prospects for the Sanitec system outside the United States as well. "Our biggest sales growth is in offshore markets, including Brazil, Japan, Korea, Saudi Arabia, the United Kingdom, the Philippines, and Kuwait," Taitz noted.

The problem of treating hospital waste knows no borders. Some 3,400 French hospitals and clinics generate 700,000 metric tons of medical waste each year, according to Didier Gabarda Oliva, an engineer in charge of the medical waste department at the French Agency for the Environment and Energy Control based in Valbonne.

Approximately 140,000 metric tons of contaminated hospital waste in France is incinerated and, as in the United States, there are environmental concerns that the heavy metal particles this generates are a health hazard in their own right. Incinerating biomedical waste is further complicated at French hospitals because incineration facilities are often remote. In the entire country, only about 50 hospitals operate incineration plants on-site, and an additional 24 off-site facilities are authorized to burn potentially infectious medical waste. Entire regions such as Burgundy, Franche-Comte, Picardy, and Poitou-Charentes have to ship their waste a considerable distance to be burned.

For these reasons, French companies are developing specific, non-incineration techniques for treating biomedical wastes. "It is a question of reducing the microbial contamination of waste, and also of changing its appearance for psychological reasons and safety aspects," Oliva explained. The treated waste is disposed of in existing landfills and incineration systems that treat household waste.

KC Medwaste

One of the newest clinical waste treatment technologies uses hot air to disinfect shredded hospital waste streams. This technology was developed and is being marketed by KC MediWaste of Dallas. The first MediWaste system was installed at Sisters of Mercy Health System in Laredo, Texas, last summer. KC MediWaste combines a dry sterilization process invented by the company's president, Keith Cox, with licensed fluidized bed technology from Torftech Ltd. of Reading, U.K.

The Mercy Health System installation was one of several advanced, electricity-based technologies built into the Laredo hospital as part of a joint project sponsored by the local utility, Central and South West Services; its subsidiary, Central Power & Light, and the Healthcare Initiative of Electric Power Research Institute in Palo Alto, Calif. These technologies are designed to help hospitals cut costs, improve operating efficiency, and enhance patient services.

"The greatest challenge in designing the first MediWaste system was making waste hot enough to sterilize it, but cool enough to prevent volatile organic compounds from being released from the plastic waste," said Sue Herbert, a mechanical engineer and project engineer for the Laredo installation. "We collected samples of everything that ends up in a hospital waste stream, and worked with plastic companies to study the flash points of the different plastic compounds in order to find the optimum heating temperature."

Mercy Health System workers use covered carts to deliver their waste materials to the MediWaste unit. A hydraulic lifting system empties each cart into the system's feed hopper. Internal exhaust fans create negative pressure within the MediWaste system to control odors.

Inside the unit is a shredder consisting of four shafts covered with closely interlocking teeth, made of a heat-treated stainless steel. The shredder grinds the waste before it is sent to a processor. Air heated to about 320[degrees]F by electrical resistance heaters is injected into the processor at high velocity through a fixed blade ring. The blades are angled to direct the air in a manner that optimizes turbulence within the processor. As the ground waste enters the processor, the turbulent air creates a fluidized bed that provides cyclonic mixing action, and high rates of heat and mass transfer.

The waste remains in the fluidized bed for five minutes before a dump door opens so that the material is propelled into a compactor unit that reduces its volume by 80 percent. The Laredo hospital sends its treated waste to a conventional municipal waste landfill.

The processed air that exits the MediWaste system passes through three stages of filtration before entering the atmosphere. First, two fabric prefilters remove gross particulates before the high-efficiency particulate air filter--a membrane contained in a metal frame--removes smaller particulates. Charcoal filters eliminate odors from the airstream.

The MediWaste system at Laredo is designed to treat up to 200 pounds of material per hour, which is more than sufficient to treat the 700 to 800 pounds of waste generated per day. "We are currently developing a unit capable of disinfecting up to 1,000 pounds of material per hour," said Herbert.

Crawford Equipment and Engineering

Although incineration alternatives appear to be gaining popularity, combustion is still used to disinfect and reduce much clinical waste. Crawford Equipment and Engineering Co. of Orlando, Fla., designs and markets a range of medical incinerators that can process from 20 to 3,000 pounds of bio-hazardous waste per hour. These units are designed for connection to scrubbers that enable them to meet the provisions of the Clean Air Act.

The Crawford Equipment incinerators are typically natural gas fired, but can also burn propane or fuel oil if they are more readily available or economical. Each incinerator contains a primary and secondary chamber, both refractory--lined to withstand the intense heat of combustion. Hospital workers load waste either manually or hydraulically in red bag or plastic sharps containers through the primary chamber door. They close the door and activate the incineration process.

First, the burners in the secondary chamber, located in a series or below the primary chamber, ignite. Heat then irradiates through the refractory material in order to raise the temperature of the primary chamber, thus making it increasingly energy efficient. When the primary chamber achieves the minimum temperature of 1,800[degrees]F, a sensor will activate the primary chamber's burners to incinerate the waste.

"The 1,800[degrees] temperature kills pathogens, and oxidizes all the organic wastes, converting them into carbon dioxide and water," said Luis Llorens, a chemical engineer and director of solid and liquid waste disposal systems at Crawford Equipment. "All the smoke and odors generated by combustion are vented into the secondary chamber, and remain there for one or two seconds so the 1,800[degrees] heat will destroy them."

Air from the secondary chamber is routed through a customized breech to a standard pollution control system that will remove acids and heavy metals, such as lead, cadmium, and mercury. The system uses wet scrubbers that spray a mist of water and reagent, such as caustic solution, in order to react with the flue gases and remove acid gas emissions.

In addition to reducing the volume of medical waste by more than 90 percent of its original bulk, the Crawford incinerators reduce its weight by 95 to 97 percent, something that microwave and steam autoclave systems cannot do, noted Llorens.

The incineration chambers' walls consist of brick, insulation, a steel shell, and a second steel outer shell. "We run air through the sidewalls by fan to keep the outer wall of the incinerator cool to prevent injuries," said Llorens. In addition, Crawford mounted a fan to induce a draft into the incinerators' refractory-lined stack. This helps the incinerator run cleaner, and keeps the gases in the secondary chamber at a lower flow, increasing their retention times to ensure that they will burn.

"There are other good medical waste treatment technologies, such as microwave, but incineration is still the best option under the right conditions," Llorens said. "Hospitals' choice depends on their communities and their needs."

For example, the Department of Veterans Affairs' Medical Center in West Palm Beach, Fla., has been using a Crawford incinerator since 1995 to process its wastes, as well as occasional loads of illicit drugs and weapons seized by local and federal law enforcers.

"We selected the Crawford incinerator because it quietly and efficiently destroys all materials, producing an ash that weighs 5 to 10 percent of the pretreated waste, and can be landfilled," said Wally Thompson, a mechanical engineer and chief of facilities management at the V.A. Medical Center in West Palm Beach.

The key to the success of the Crawford unit hinges on its scrubber. V.A. representatives in West Palm Beach worked with Emcotek of Visalia, Calif., to design a scrubber for the incinerator that processes 500 pounds of waste per hour. Hot gases, leaving the incinerator at 1,900 to 2,100[degrees]F, enter the Emcotek scrubber's primary quench tank. Spray nozzles apply water and sodium hydroxide to cool the gases to approximately 200[degrees]F and neutralize the hydrochloric acid generated during incineration. The gas then enters a secondary quench tank where the spray process is repeated, cooling the gases to 120 to 140[degrees]F and buffering acids with more sodium hydroxide.

The piping system contains pH probes connected to a programmable logic controller. The PLC controls two positive displacement pumps that inject the amount of sodium hydroxide needed to neutralize the acid waste.

The quenched gases enter a rotary atomizer chamber where a gearbox pumps water into the center of a rotating disc that creates a radial curtain of water. This curtain provides a high-energy wet scrubbing action that reduces particulates to approximately 0.015 gram per dry standard cubic foot of air or better.

A bank of demister filters removes excess water droplets, which can carry various heavy metals and particulate matter, before the gas stream is exhausted through the stack. The Emcotek scrubber removes 95 to 99 percent of acids, heavy metals, dioxin, and various organic compounds from the gas stream. The scrubber's performance is monitored by various sampling probes installed in the discharge stack.

Because of the emissions standards for Palm Beach County, the V.A. requested that Emcotek add a titanium heat exchanger to lower the temperature of the water that feeds the rotary atomizer to 80 or 85[degrees]F to optimize the removal of heavy metals.

As is the case with many incinerators that meet environmental specifications, the West Palm Beach facility gave consideration to aesthetics. "We also had Emcotek add a titanium steam coil in the scrubber stack to reheat the cool gas stream, which is saturated, to remove an unsightly, but otherwise harmless, plume cloud," Thompson said.

AUTOCLAVING

Several years ago, Maine hospitals found themselves subject to rising prices as the sole medical waste vendor in the state switched from charging customers by the pound to charging them by the container. This transition meant hospitals in the state went from paying anywhere from $0.24-0.26 cents per lb to upwards of $0.40 to $0.50 cents per lb. In addition, there was concern on the part of hospitals and the community that waste treated by the vendor was disinfected and then incinerated in a waste-to-energy plant which contributed to both mercury and dioxin emissions.

The Maine Hospital Association (MHA), in collaboration with its members, the Maine Department of Environmental Protection and Synernet, a local consulting company, began looking for an alternative way of handling medical waste in the state. MHA, through its subsidiary, Associated Health Resources, decided upon purchasing and siting a 'hydroclave' unit, in Pittsfield, ME. The hydroclave is similar to an autoclave and works by steam sterilizing medical waste in an internal chamber which has internal paddle-like devices that both break down and move the waste around for maximum disinfection. Waste is then shredded and landfilled. The MHA contracted with Hydroclave to build the unit and Hydroclave subcontracts with Sterilogic to manage the day-to day operations of the plant. Only pathological and trace chemotherapy waste are still incinerated, and only because state law still requires it. Thirty-two of Maine's 39 hospitals have currently switched to the new technology, as of 2005 and MHA expects all 39 to be on board in the next few years as former contracts expire. In addition, the Maine program is rolling out the use of reusable medical waste toters that are washed and disinfected, back-hauled to the hospitals and reused—potentially eliminating anywhere from 40-60,000 cardboard containers per year. Reusable sharps container program is under discussion as well.

An article in the Maine Telegram discusses the program in its early stages:

www.noharm.org/details.cfm?type=news&ID=51.

X. Sustainability Indexes

The environmental burden associated with the manufacture, utilization, and disposal of medical textiles has been shown to have negligible impact on the environment for reasons of scale.

Nevertheless, it is becoming increasingly important for corporations to demonstrate sustainable practices to government agencies, to the public, and to shareholders to maintain good corporate citizenship and equal standing with peer companies in their business sector.

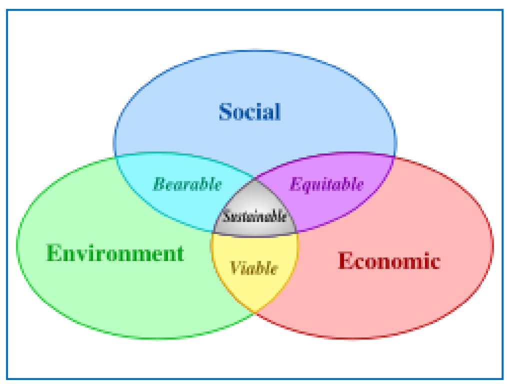
There are companies that develop and audit sustainability guidelines for clients. A major supplier to the healthcare industry (Ahlstrom Corporation) has adopted and endorsed the sustainability guidelines developed by the Global Reporting Initiative (GRI). Another company that audits sustainability programs, worldwide, is the Dow Jones Company, with a program that has been in place since 1999. Information on the Dow Jones program is provided in this report under "References/Sustainability Indexes".

For informational purposes, the following text is quoted from the Wikipedia definition for sustainability found on the Internet.

"Sustainability, in a broad sense, is the capacity of maintaining a certain process or state. It is now most frequently used in connection with biological and human systems. In an ecological context, sustainability can be defined as the ability of an ecosystem to maintain ecological processes, functions, biodiversity and productivity into the future…...

For humans to live sustainably, the Earth's resources must be used at a rate at which they can be replenished. However, there is now clear scientific evidence that humanity is living unsustainably, and that an unprecedented collective effort is needed to return human use of natural resources to within sustainable limits.

Since the 1980s, the idea of human sustainability has become increasingly associated with the integration of economic, social and environmental spheres. In 1989, the Brundtland Commission articulated what has now become a widely accepted definition of sustainability: "[to meet] the needs of the present without compromising the ability of future generations to meet their own needs" . For more information, refer to the complete Wikipedia discussion found on the Internet in a word search under "sustainability".



The following graphics and text are exerpted from the Dow Jones Sustainability Index Website.

OVERVIEW

Launched in 1999, the Dow Jones Sustainability Indexes track the financial performance of the leading sustainability-driven companies worldwide. Based on the cooperation of Dow Jones Indexes, STOXX Limited and SAM Group the indexes provide asset managers with reliable and objective benchmarks to manage sustainability portfolios. The DJSI family currently comprises global, European, Eurozone, North American and US benchmarks.

Dow Jones Sustainability World Index
The Dow Jones Sustainability World Index (DJSI World) covers the top 10% of the biggest 2,500 companies in the Dow Jones World Index in terms of economic, environmental and social criteria. This index was first published on 8 September, 1999.

Dow Jones STOXX Sustainability Index and Dow Jones EURO STOXX Sustainability Index
As a benchmark for European sustainability investments, the Dow Jones STOXX Sustainability Index (DJSI STOXX) covers the leading 20% in terms of sustainability of the companies in the Dow Jones STOXX SM 600 Index. The Dow Jones EURO STOXX Sustainability Index (DJSI EURO STOXX) is the Eurozone subset of the DJSI STOXX and, thus, tracks the financial performance of sustainability leaders in this particular region. This set of indexes was launched on 15 October, 2001.

Dow Jones Sustainability North America Index and Dow Jones Sustainability United States Index
The Dow Jones Sustainability North America Index (DJSI North America) cover the leading 20% in terms of sustainability of the 600 biggest North American companies in the Dow Jones World Index. The Dow Jones Sustainability United States Index (DJSI United States) is the US subset of the DJSI North America. This set of indexes was introduced on 23 September, 2005.

Customized Indexes
In addition, the DJSI methodology facilitates the design, development and delivery of customized sustainability indexes; e.g. indexes covering different regions, indexes covering different segments of the leading sustainability companies, indexes covering additional exclusion criteria and indexes denominated in different currencies.

The following graphics and text are exerpted from the Dow Jones Sustainability Index Website.

Dow Jones Sustainability Indexes

CORPORATE SUSTAINABILITY

Corporate Sustainability is a business approach that creates long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments. Corporate sustainability leaders achieve long-term shareholder value by gearing their strategies and management to harness the market's potential for sustainability products and services while at the same time successfully reducing and avoiding sustainability costs and risks.

The quality of a company's strategy and management and its performance in dealing with opportunities and risks deriving from economic, environmental and social developments can be quantified and used to identify and select leading companies for investment purposes.

Leading sustainability companies display high levels of competence in addressing global and industry challenges in a variety of areas:

Strategy: Integrating long-term economic, environmental and social aspects in their business strategies while maintaining global competitiveness and brand reputation.

Financial: Meeting shareholders' demands for sound financial returns, long-term economic growth, open communication and transparent financial accounting.

Customer & Product: Fostering loyalty by investing in customer relationship management and product and service innovation that focuses on technologies and systems, which use financial, natural and social resources in an efficient, effective and economic manner over the long-term.

Governance and Stakeholder: Setting the highest standards of corporate governance and stakeholder engagement, including corporate codes of conduct and public reporting.

Human: Managing human resources to maintain workforce capabilities and employee satisfaction through best-in-class organizational learning and knowledge management practices and remuneration and benefit programs.

Corporate sustainability performance is an investable concept. This is crucial in driving interest and investments in sustainability to the mutual benefit of companies and investors. As this benefit circle strengthens, it will have a positive effect on the societies and economies of both the developed and developing world.

The following graphics and text are exerpted from the Dow Jones Sustainability Index Website.

Dow Jones Sustainability Indexes

CRITERIA AND WEIGHTINGS

Corporate Sustainability Assessment Criteria

Dimension	Criteria	Weighting (%)
Economic	Codes of Conduct / Compliance / Corruption & Bribery	5.5
	Corporate Governance	6.0
	Risk & Crisis Management	6.0
	Industry Specific Criteria	Depends on Industry
Environment	Environmental Performance (Eco-Efficiency)	7.0
	Environmental Reporting*	3.0
	Industry Specific Criteria	Depends on Industry
Social	Corporate Citizenship/ Philanthropy	3.5
	Labor Practice Indicators	5.0
	Human Capital Development	5.5
	Social Reporting*	3.0
	Talent Attraction & Retention	5.5
	Industry Specific Criteria	Depends on Industry

*Criteria assessed based on publicly available information only

For more details about each individual criteria, please have a look at the SAM Questionnaire.

XI. Bio-Polymers

Following is a Press Release by Cereplast, Inc, a manufacturer of bio-based sustainable plastics.

“Cereplast, Inc., manufacturer of proprietary bio-based, sustainable plastics, today announced that it has received confirmation of the low carbon footprint of its bioplastics-based Biopropylene(R) resin. In conjunction with Ramani Narayan University Distinguished Professor of Michigan State University, and after several months of research by an independent testing laboratory, it is demonstrated that the intrinsic carbon dioxide emissions reduction in using Biopropylene(R) in place off regular polypropylene is 42%.

The study found that approximately 1.82 kilograms of carbon dioxide are produced for each kilogram of Biopropylene(R) used, compared to 3.14 kilograms of carbon dioxide emitted for the same amount of polypropylene.

"By using Biopropylene(R) instead of polypropylene, converters generate 1.32 kilos less carbon dioxide for each kilo of product they manufacture," said Frederic Scheer, Cereplast's Chairman and CEO. "This is a very significant reduction in carbon dioxide emissions, especially when considering that worldwide market for polypropylene is about 45 billion kilograms, or approximately 100 billion pounds."

"This recent development offered by Cereplast is quite interesting. I see this family of resins providing an intrinsic reduced carbon footprint value," said Professor Narayan.

"Besides dramatically reducing carbon dioxide emissions during conversion, Biopropylene(R) also delivers the environmental advantage of replacing up to one-half of the petroleum content in traditional plastic with renewable, bio-based materials," continued Scheer. "Furthermore, Biopropylene(R) can be used in a variety of applications which so far were satisfied only with traditional polypropylene."

Biopropylene(R) is a patented compound manufactured by Cereplast using traditional polypropylene and up to 50% starch content, making it the first real "hybrid" bioplastic. Since its introduction at the end of 2007, Biopropylene(R) has been tested by more than 90 major corporations, with particular attention from companies in the automotive, consumer products and cosmetics industries. While the drivers vary by industry, significant interest in Biopropylene(R) has been motivated by some of the new properties that it offers, such as better printability, softer touch, and other attributes.”

The following additional quotation is from a Press Release by DSM Venturing, a company involved with Novomer, Inc. in producing bio-polymers from CO_2 and CO.

"DSM Invests in 'green' Polymers from CO2

DSM Venturing, the corporate venturing unit of Royal DSM N.V., announced that it has made an investment in Novomer Inc. The companies also plan to sign a cooperation agreement. Financial details of the investment will not be disclosed.

Novomer is developing a technology platform to use carbon dioxide and other renewable materials to produce performance polymers, plastics and other chemicals. The company's products combine environmental benefits with improved materials performance and can be used in a range of applications, from injection molded parts for electronics to paper coatings and medical implants…..

DSM Venturing joins Flagship Ventures and Physic Ventures in this financing round. In addition to the investment DSM and Novomer also intend to sign a cooperation agreement. Both the investment and cooperation agreement will support DSM's ambitions to develop bio-based performance polymers to meet customers' growing needs for improved materials performance and environmental benefits at competitive costs…..

Novomer's catalyst technology enables the production of polymeric materials from renewable feedstocks with decreased reliance on fossil fuels. Their use of feedstocks such as carbon dioxide and carbon monoxide combined with the precision and reliability of synthetic manufacturing processes is expected to enable the cost-effective manufacture of bio-based building blocks, polymers, compounds and formulations…..

This press release contains forward-looking statements. These statements are based on current expectations, estimates and projections of DSM management and information currently available to the company. The statements involve certain risks and uncertainties that are difficult to predict and therefore DSM does not guarantee that its expectations will be realized. Furthermore, DSM has no obligation to update the statements contained in this press release."

XII. THE UNIVERSAL ENVIRONMENTAL BURDEN INDEX

Since many choices involve varying quantities of pollution from several sources it is necessary to create a common metric. If reusable garments result in water pollution while single use garment manufacture results in air pollution it is necessary to make a decision on which is worse.

For the last 20 years Mcilvaine has been developing metrics to make this type of comparison. The original metric was called a harm index. With the concern about greenhouse gases, the concept was expanded and the Universal Environmental Burden Index was created. This is based on equivalent tons of CO_2.

This metric is very useful but it is second order logic. There is a first order logic that rates the life quality enhancement or reduction. Mcilvaine has created a metric "Quality Enhanced Life Days" (QELD) to measure the impacts of not only environmental but political and social decisions as well.

Quality Enhanced life Days (QELD) can be used to measure the impact of any environmental burden. Some burdens directly impact health and life span. Others affect the quality of life. All can be converted to QELD. There are already a number of indices determining the relative burden of specific pollutants. By determining QELD for one pollutant we can quickly ascertain the QELD for the others.

Air Pollutants

McIlvaine began working on an index to rank toxic air pollutants soon after the 1990 Clean Air Act mandated the reduction of hazardous air pollutants. The regulations identified hundreds of air toxics and mandated the reduction of these toxics based on their health impacts. Congress told EPA that even with the least toxic on the list that any source emitting 10 tons per year or 25 tons of a combination of toxics should be subject to installing best available control technology (BACT). Some substances are thousands of times more toxic than others. Therefore EPA prepared a lesser quantity emission rate (LQER) for 47 pollutants. These have been integrated with priority pollutants into the following abbreviated index.

Chemical	LQER
2,3,7,8 TCDD Dioxin	**0.0001**
Mercury	**0.001**
Chromium Compounds	**0.01**
Lead Compounds	**0.01**
Arsenic	**0.01**
Nickel Compounds	**0.10**
Selenium Compounds	**0.10**
Barium Compounds	**1.00**

Zinc Compounds	**1.00**
Vanadium Compounds	**1.00**
Hydrochloric Acid	**10.00**
Sulfuric Acid	**10.00**
Hydrogen Fluoride	**10.00**
Ammonia	**10.00**
$PM_{2.5}$	**10.00**
SO_2	**100.00**
NO_x	**100.00**

While the threshold to trigger BACT would be on 10 tons of HCl the threshold for chromium would be 0.0l tons.

The LQER was drafted by EPA but became politically sensitive and never incorporated into standards. However it is a good base for determining the environmental burden. However, it is necessary to add values for other pollutants. Since NO_x and SO_x emitters are considered major emitters when their emissions exceed 100 tons/year it is logical to assess an environmental burden which is 10 times that of the most benign toxic pollutant.

$PM_{2.5}$ is identified as the cause of 50,000 premature deaths in the U.S. each year. So setting an index factor equal to the most benign toxic is justifiable.

VOCs can be air toxics and qualify for high numerical rating (e.g. dioxins). Non-toxic VOCs react with NO_x to form ozone. So setting a numerical equivalent to NO_x is logical.

Greenhouse Gases

Some greenhouse gases are more potent factors in global warming than others.

CO_2 can be indexed based on potential trading values. NO_x trades for $2000/ton in some areas of the United States. CO_2 is trading for $3/ton in the North East U.S. There is talk of generating an allowance system based on trading values of $20/ton. At this value a ton of CO_2 would be worth one percent of the value of a ton of NO_x. If a ton of CO_2 is indexed at one, NO_x would be indexed at 100.

Life Values

In order to determine the cost benefit of environmental regulations, the U.S. EPA has calculated the value of a human life. It is now $6.9 million, down from $7.8 million some years ago. A value of $7 million/life has been incorporated into the environmental burden index. If CO_2 is

valued at \$20/ton then a human life is valued at 350,000 tons of CO_2. There are 35,000 days (QELD) in an average enhanced life (QELY). So 1 QELD= 0.1 tons of CO_2.
The following Environmental Burden Index table displays both the relative burden and the QELD value.

Wastewater Burdens
U.S. municipal wastewater plants experienced CBOD5 loadings of 11 million tons per year in 2004 while discharges were 1.3 million tons. This compares to SO_2 in air where 20 million tons were generated by power plants, but emissions were 9 million tons. There is a program to reduce this to 2 million tons, so the two would be comparable objectives.

As of 2004 EPA estimates the capital cost needed for wastewater plants is \$70 billion. At an average of \$500/kW it would take \$140 billion for U.S. coal-fired power plants to install best available control technology. Since half the control technology is in place, the power plant air needs are close to the \$70 billion required for municipal wastewater plants.

Total suspended solids fit the same parameters.

Ammonia is an order of magnitude more strictly limited. The environmental burden for a ton of ammonia released to the air is the same as one released to the water. This makes sense in that one can convert to the other. The same is true of toxic metals such as mercury, arsenic, etc. In fact, the main concern about airborne mercury is its entry into water and eventually into fish.

Chlorine is pegged at 10,000 in water vs. 1,000 for hydrochloric acid in air. But in terms of weight of chlorine the burden is more equal.

Environmental Burden Index
(relative)

	Tons of CO2 equivalent	**QELD** (lost per ton generated)
2,3,7,8 TCDD Dioxin	**100,000,000**	**10,000,000**
Mercury (air or water)	**10,000,000**	**1,000,000**
Chromium Compounds	**1,000,000**	**100,000**
Lead Compounds	**1,000,000**	**100,000**
Arsenic	**1,000,000**	**100,000**

One life lost	**350,000**	**35,000**
Nickel Compounds	**100,000**	**10,000**
Selenium Compounds	**100,000**	**10,000**
Barium Compounds	**10,000**	**1,000**
Zinc Compounds	**10,000**	**1,000**
Vanadium Compounds	**10,000**	**1,000**
Chlorine (water)	**10,000**	**1,000**
Hydrochloric Acid (air)	**1,000**	**100**
Sulfuric Acid	**1,000**	**100**
Hydrogen Fluoride	**1,000**	**100**
Ammonia (air)	**1,000**	**100**
Ammonia (water)	**1,000**	**100**
$PM_{2.5}$ (air)	**1,000**	**100**
SO_2	**100**	**10**
CBOD5 (water)	**100**	**10**
TSS (water)	**100**	**10**
Nitrogen (water)	**100**	**10**
VOC	**100**	**10**
NO_x	**100**	**10**
Methane	**23**	**2.3**
CO_2	**1**	**0.1**
Water resource depletion (drought area)	**0.1**	**0.01**
Water resource depletion (deficit area)	**0.01**	**0.001**

Oil resource depletion	**0.01**	**0.001**
Landfill depletion (Europe)	**0.01**	**0.001**
Coal resource depletion	**0.001**	**0.0001**
Water resource depletion (surplus area)	**0.001**	**0.0001**
Landfill depletion (U.S.)	**0.001**	**0.0001**

The first column represents the relative burden with CO_2 at 1. The second column represents the QELD in terms of equivalent quality enhanced days lost per ton generated. These values could change. If the burden of CO_2 were to change the value of methane would also change but it would not affect the burden of toxic air pollutants. This is because the basis of burden is greenhouse gases for both CO_2 and methane but it is health for toxic air pollutants.

Sustainability and specifically life quality enhancement requires inclusion of the potential depletion of resources. There is a 40 year supply of oil and so potential depletion of this resource is significant. There is a 200 year supply of coal so the depletion impact of one ton is an order of magnitude less than oil.

Only a fraction of one percent of the world's water is both uncontaminated and available. However there is a big difference in availability between cities such as Phoenix, which suffers a big water deficit, and Minneapolis, which has a water surplus. Where there is a surplus of water depletion would be similar to coal. But where there is a water deficit the loss would be similar to oil. There are temporary situations where the water deficit turns into a drought.

The following QELD burden factors have been assigned for water resource depletion.

Water Surplus Location	0.0001
Water Deficit Location	0.001
Water Drought Location	0.01

Landfill depletion is another factor. No one wants to live next to a garbage dump. On the other hand, how objectionable is a land fill which is 30 miles away? In the U.S. there is space for landfills to be farther from communities than in Europe. Likewise, there is a lot more land to fill in the U.S. Europe prohibits combustible material from being land-filled and insists that this material be utilized in waste to energy plants. The U.S. has taken the opposite position but is slowly changing.

The McIlvaine offices are only a 3 minute drive from a renovated landfill. It is now a golf course. The restaurant which is adjacent is the favorite choice for company parties. Hence, the lost QELD can differ greatly depending on the condition and location of a specific landfill.

There is no shortage of landfill space in the U.S. therefore the deposit of one ton of waste in a landfill will generate losses of only 0.0001 QELD. In Europe the loss would be 10x greater or 0.001 QELD.

QELD Measurement

There are two challenges. One is to measure the QELD value an individual attaches to an activity. The other is to aggregate this information for a group or nation of people.

Individual QELD Measurement

Measurement of individual QELD is not straight forward. There will be no precise measurement. But with iteration of three different approaches a good approximation can be made initially. Over time a body of work will make the task more simple and routine. There at least three approaches to measuring individual QELD. They are “willingness to sacrifice uneventful life days”, “monetary value”, and “comparable options”.

Willingness to sacrifice uneventful life days

Individuals are applying the QELD principle continuously but without labeling it. Driving on a 2.4 hour round trip to work rather than work close to home demonstrates a willingness to sacrifice 10 percent of an uneventful day (QALD) for a quality enhanced day (QELD). Since statistically every hour spent driving reduces statistical life by an hour, a 2.4 hour trip divided by 24 hours results in a reduction in life of 0.1 days. In fact the gamble in the mind of the worker is probably not even. He anticipates something more than a 1.1 QELD if he is sacrificing 0.1 QALD.

In general people live 80 years by taking risks rather than live non active lives for 96 years. Hence, there is a 20 percent life enhancement factor inherent in normal life choices. This is an average. There are many life enhancement activities which involve little or no risk to life. There are other activities such as sky diving, extreme skiing, battle, rescue, and care giving for contagious relatives where the statistical life reduction is more than 0.2 days per day engaged in that activity.

The most valuable QELD determination is the number of QALD one would sacrifice for a QELD in the activity under evaluation. The question to be posed is: Instead of living 95 years and 356 days, how many days would your trade in order to e.g. see the finals of the NCAA basketball tournament, see your daughter graduate from college, own an expensive sports car, prevent the elimination of the snail darter species, keep your house at the ideal comfort temperature year round, normalize relations with Cuba.

If people are presented with their present patterns and choices, they will have the perspective to answer the QELD questions.

Monetary value

QELD is the principle goal of individuals. Money is a major factor in determining the ability to achieve some of these goals. Since individual resources are limited the individual is rating the value of his enhancement options based on how much he is willing to pay for them. How much would he pay for the expensive sports car or the trip to the NCAA finals as opposed to visiting an art museum or walking in the park?

Since EPA evaluates a human life at $7 million, a QELD can be valued at $200. Therefore any payment activity or willingness to pay can be measured in QELD. The problem with this approach is that the income of the individual becomes a large variable. A wealthy person would be generally willing to pay much more than a poor person for the same enhancement. Nevertheless questions framed in monetary terms are very useful as alternate way to determine the QELD enhancement factor. How much would an individual be willing to donate to save the snail darter or the polar bear or a parasitic mosquito species? How much would an individual pay to eliminate a view of a distant wind turbine in Cape Cod?

Comparable options

Another way to determine the enhancement for a specific activity is to compare it to others. How many regular season basketball games would an individual trade for a seat at the NCAA finals? How many Florida vacation days would an individual trade for a ride in the space shuttle? How many Florida vacation days would an individual sacrifice to save the snail darter? How many Florida vacation days would an individual sacrifice to save 100 people from starvation in Sudan? Much of the enhancement of daily life is emotional rather than physical. The feeling of making a positive contribution to preventing starvation in Sudan may be more of an enhancement than the physical experience of sun and ocean in a warm climate.

The comparable option approach is only useful if QELD enhancement is already established by one or a combination of the other two methods. On the other hand the “comparable option” approach is a basis for the monetary approach and can help the individual better determine what sacrifice in life quantity he would be willing to make for quality.

All of this analysis is based on the assumption of rational choice. However, many QELD decisions are based on inadequate information or lack of a means to make a rational decision. Education is a key to making the QELD approach most valuable.

Assessment of Group QELD

The quality assessment for a group depends first on defining or limiting the group. This is because of the “tribal factor” which is discussed separately. If the group is the nation then the enhancement factor for foreign aid is different than if the group is defined as the world. But within the group there are three ways to determine the aggregated individual enhancement factors.

Academic assessment

The employment of QELD in decision making is on one hand just an organized approach to assessments we are already making. But to the extent that we can improve these assessments we need insights from every segment of academia. Philosophy, science, sociology, politics, economics and religion are all significant in proper assessment of enhancement factors.

Peter Singer of Princeton University makes a persuasive argument that we will have to ration healthcare because the potential cost exceeds the funding ability. His observation has caused much consternation. Deep rooted religious and political beliefs are confronted with reality. The application of the QELD concept to this issue would be a valuable academic pursuit.

Analysis of life style patterns of groups

Since QELD is just quantifying life style decisions already being made it is highly desirable to analyze these in general ways. How far are people traveling to achieve various enhancements? They may travel only one hour to attend a high school basketball game but 16 hours to attend an NCAA final.

There are certain bellwether decisions. The increase of the speed limit from 55 mph to 65 mph has resulted in thousands of increased deaths. However, the majority of Americans are willing to take this increased risk and are strong advocates of the higher speed limit.

High risk sports are another indicator. How many people participate in each? How many are fully aware of the risks? Substantial insights can be gained from study of this subject. Obesity, smoking, and nearly every other activity can be analyzed from the QELD perspective.
These analyses supported by “Important Event Odds” and “Personal Risk Odds”.

Polling

Proactive polling would make a considerable contribution to the enhancement ratings people employ. The results of this polling would be of considerable value to politicians who hope to be re-elected to agencies providing health care and to businesses which need to understand purchasing motivations.

Interactive electronic communication

New interactive tools such as Twitter and blogs can be a very economic way to ascertain the group enhancement ratings. The instant polls conducted by CNN and other television networks are another example of effective ways to ascertain the views of the individuals and aggregate them. Questions can be posed in such ways as to elicit thoughtful responses.