The Energy and Environmental Benefits of Office Furniture Remanufacturing

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May 2005

Executive Summary

A number of studies have documented the energy and environmental benefits of remanufacturing. Davies Office Refurbishing, Inc., in Albany, New York, commissioned the National Center for Remanufacturing and Resource Recovery (NC3R) at the Rochester Institute of Technology to analyze and quantify the energy savings, avoided pollution and waste generation associated with the remanufacturing of office furniture.

The study, presented here, was designed to provide snapshots of the energy and environmental benefits associated with the remanufacturing of a single category of office furniture. Davies remanufactures a range of products including office panels, desk pedestals containing file drawers, lateral files, and chairs. A single design of the Steelcase Avenir® office panel, i.e., cubicle partition, was selected as the focus of this study. Office panels constitute a significant percentage of the material content of the typical office. Commonly, an office cubicle will consist of five individual panels. Panels are the highest volume product remanufactured by Davies. The Steelcase Avenir® is Davies' highest volume panel.

Remanufacturing is the process of recovering used, worn-out products (often referred to as "cores") that would otherwise become part of the waste-stream, and restoring them to a "like-new" condition. The remanufacturing process at Davies has a number of steps. Incoming cores are inspected; severely damaged units are recycled. Fabric and unusable backing materials are collected for recycling while steel components are cleaned, inspected and prepared for surface refinishing. New fabric is mounted on the refinished frames and the panels are assembled, inspected, and packaged for shipment.

Highlights of Key Findings

<u>Process Benefits of Remanufacturing Office Panels</u>

- At Davies, typically, only the fabric coverings are replaced and the exterior frames and panels refinished, resulting in the **reuse of over 98% of each panel, by weight.**

- Compared to the new manufacturing process, **Davies uses an estimated 111 fewer manufacturing steps** to produce an office panel.

Energy Benefits of Remanufacturing Office Panels at Davies

- **The energy savings from remanufacturing <u>1 office workstation</u> (5 panels) could power 10 average American households for <u>one whole day</u>.**
- **Remanufacturing <u>100 workstations</u> could power <u>3 households</u> for <u>one year</u>.**

<u>Each year</u>, remanufacturing office panels at Davies results in *energy savings* that could power <u>342</u> average U.S. households for <u>one year</u>.

Environmental Benefits of Remanufacturing Office Panels at Davies

One year of office panel remanufacturing at Davies conserves approximately 8.5 million pounds of *raw materials*

One year of office panel remanufacturing at Davies avoids the release of more than 6.9 million pounds of CO_2 into the environment

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A. Introduction

A number of studies have documented the energy and environmental benefits of remanufacturing. Davies Office Refurbishing, Inc., in Albany, New York, commissioned the National Center for Remanufacturing and Resource Recovery (NC3R) at the Rochester Institute of Technology to analyze and quantify the energy savings, avoided pollution and waste generation associated with the remanufacturing of office furniture.

The study, presented here, was designed to provide snapshots of the energy and environmental benefits associated with the remanufacturing of a single category of office furniture. Davies remanufactures a range of products including office panels, desk pedestals containing file drawers, lateral files, and chairs. A single design of the Steelcase Avenir® office panel, i.e., cubicle partition, was selected as the focus of this study. Office panels constitute a significant percentage of the material content of the typical office. Commonly, an office cubicle will consist of five individual panels. Panels are the highest volume product remanufactured by Davies. The Steelcase Avenir® is Davies' highest volume panel design.

B. Background

1. Sustainability and Sustainable Buildings

The U.S. economy consumes natural resources and generates waste at a staggering rate. In the year 2003, the U.S., with only 5% of the world's population, consumed about 98 quadrillion Btu's, or over 25% of the world's annual energy output. Industrial operations are responsible for about one-quarter of the nation's energy consumption.[1]

"*Sustainable Development*," that is "development that meets the needs of the present generation without compromising the needs of future generations"[2] is seen by many as the right framework for restructuring our system of product and energy production and consumption. A new approach to decision making on product development, manufacturing, and purchasing — *The Triple Bottom Line* — is emerging as an alternative to a purely economic bottom line philosophy. This new approach considers environmental and social impacts as well as financial costs and benefits and has been adopted by a number of forward thinking companies.

[1] U.S. Department of Energy, Energy Information Administration (DOE/EIA) (2004). "Annual Energy Outlook 2004 with Projections to 2025," Report #DOE/EIA-0383.

[2] UN 'Brundtland' Commission (1987). Our Common Future, Report of the World Commission on Environment and Development. Oxford, Oxford University Press.

An emerging field within the sustainability realm is *Green Building Design and Construction*, which aims to minimize negative impacts of buildings on the environment and the occupants within them. The U.S. Green Building Council (USGBC) developed the LEED (Leadership in Energy and Environmental Design) Certification program to promote the design and construction of “green buildings.” Certification is based on a point system that rewards “green” design elements, as defined by the USGBC. The guidelines reward the inclusion of material elements that are “salvaged, refurbished or reused material, products and furnishings,” i.e., this certification system rewards the use of remanufactured office furniture.

2. General Overview of Remanufacturing and its Benefits

Remanufacturing is the process of recovering used, worn-out products (often referred to as “cores”) that would otherwise become part of the waste-stream, and restoring them to a “like-new” condition. The restoration process is not simply a “dusting-off,” but a high quality process through which products are systematically disassembled, cleaned, and inspected for wear. Damaged components are repaired and refinished, feature upgrades can be incorporated which were either not needed or available at the time of original manufacture, and the product is reassembled. Finally, reliability testing is performed to ensure that the product performs like new. In many cases, the product can be remanufactured multiple times. Reuse is a process through which a component is removed from one system and installed in another, to provide its original function.

In a typical product life-cycle, a product will begin as a collection of raw materials. These materials are processed, and refined. The materials are then fashioned into the final product through a series of manufacturing and assembly stages. Once the product reaches the end of its life-cycle in this linear model, it would be disposed of either in a landfill or incinerator.

This linear model of a product’s life-cycle is outdated, and a transition to sustainability requires a more efficient and closed-loop model. By “closing-the-loop,” reuse, remanufacturing and recycling are able to extend the useful life of products already in existence, saving disposal costs and landfill space by keeping durable goods out of the waste stream. When a product can be remanufactured or reused, it eliminates the need to manufacture an original product. Figure 1 illustrates a closed loop product life-cycle. Environmentally, it has been shown that the remanufacturing process is generally much less energy and material intensive than original manufacturing. It has been found that remanufacturing auto parts, for example, conserves 60-85% of the energy that went into the original manufacturing.

The breadth of the remanufacturing sector ranges across a diverse set of industries including but not limited to, automobile engines, construction equipment, weapons systems and military equipment, office furniture, single-use cameras and toner cartridges.

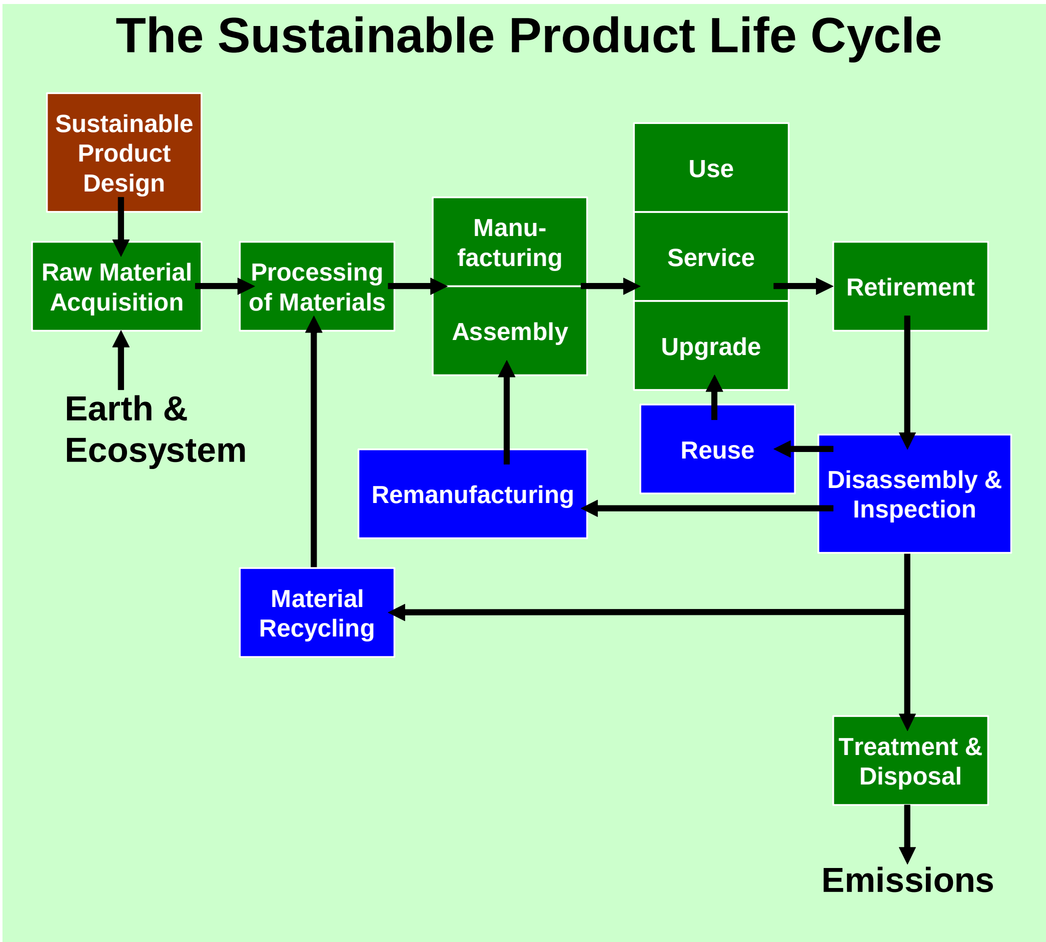

Figure 1. Sustainable Product Life Cycle

C. Office Furniture Remanufacturing at Davies

Office panels are highly engineered office products designed to withstand daily office use, suspend shelving, create landscape environments, reduce noise, and carry various types of wiring. The panel can transform a large open area into a multi-section, productive, and noise controlled office environment. The average office utilizes five panels, varying in size, based on the desired configuration and customer requirements. Generally, the panel is constructed of a steel frame, a fiber interior mat and a fabric cover. Figure 1 contains a diagram of the Avenir® Panel that was the subject of this study. A more detailed BOM, with part weights, can be found in Table 1. Pictures of the exterior and interior of the panel can be found in the Appendix.

Steel Frame

1. Hollow Tube Frame (1.5in x 1.5 in)
2. (2) Side Support Brackets
3. Top Bracket
4. (2) Top Cap Clips
5. Top Cap
6. (2) End Caps w/ bottom sliders
7. (2) Leg Brackets
8. Galvanized Channel
9. (2) Kick Panel Clips
10. (2) Kick Plates
11. Bottom Bracket

Steel Not Pictured

(2) Snap-on Steel Frames (front & back)
(2) Retainer Clips (bottom)
(2) Screws (bottom)
(2) Screws (top)
(4) Locator Screws (bottom)
(5) Adjustable legs

Non-Steel Components

Inner Core
- Fiber mat
- Cardboard
- Aluminum Staples

Panel
- Tack-board
- Fabric Cover
- Glue

Foam side seal (Threaded through Frame Side support)

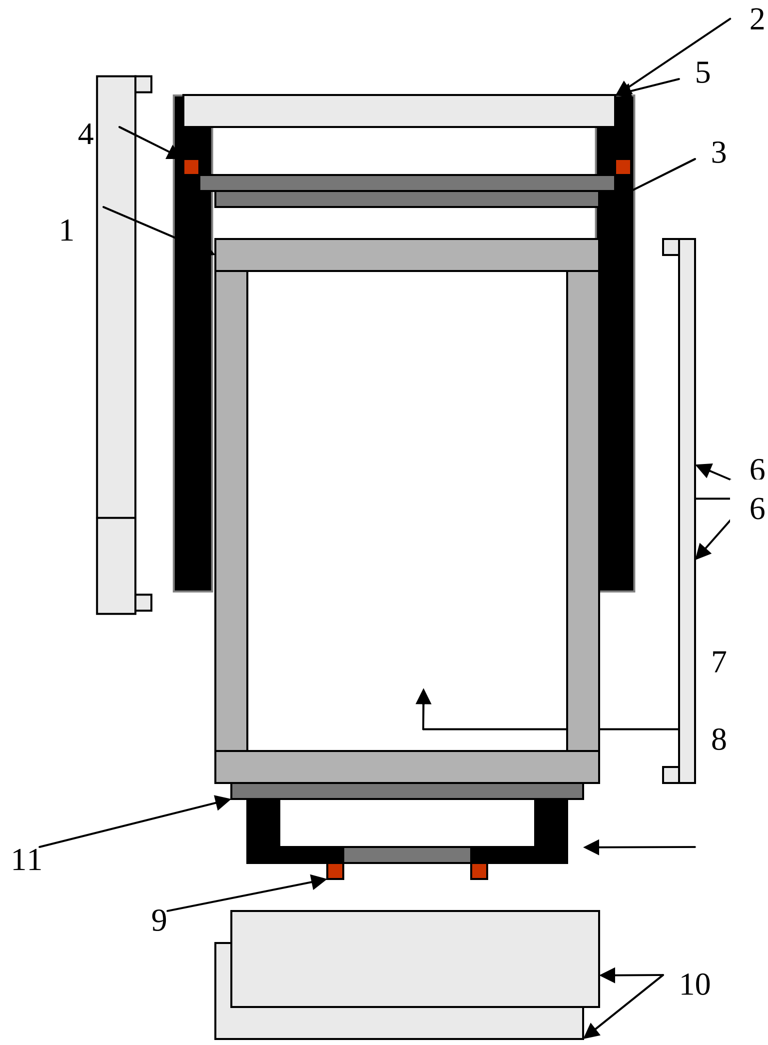

Figure 2. The Anatomy of an Office Panel

Table 1. Bill of Materials for a 45 inch Office Panel (1)

Component	Quantity	Composition	Weight (lbs)(2)
Hollow Tube Frame (1.5in x 1.5 in)	1	16 gage steel tubing	28.0
Side Support Brackets	2	steel	**
Top Bracket	1	steel	0.8
Top Cap Clips	2	steel	**
Top Cap	1	steel	1.6
End Caps w/ bottom sliders	2	steel	4.2
Leg Brackets	2	steel	**
Galvanized Channel	1	Galvanized steel	**
Kick Panel Clips	2	steel	**
Kick Plates	2	steel	3.1
Bottom Bracket	1	steel	**
Snap-on Steel Frames	2	steel	11.0
Retainer Clips	2	steel	**
Screws	2	steel	N/W
Screws	2	steel	N/W
Locator Screws	4	steel	**
Adjustable Legs	5	steel	**
Fiber mat	2	Fiberglass	2.9
Cardboard	1	cardboard	
Aluminum Staples	4	aluminum	
Tack-board	2	N/A	3.1
Fabric Cover	2	Fabric	0.5
Glue	N/A	Glue	N/W
Foam side seal	2	Foam	N/W

**Components are attached and included in the weight of the Hollow Tube Frame

1. Measurements taken on a 24 inch Avenir panel and adjusted.
2. N/A - not available, N/W not weighed

Total Weight =	55.2
Total Steel Weight =	48.6
% Steel by Weight =	88.15%

1. The Making of an Office Panel

There are significant differences in the processes utilized to produce an office panel via OEM and remanufacturing processes. Following a brief overview of the remanufacturing process, a comparison of OEM and remanufacturing is provided.

a. Remanufacturing Office Panels at Davies

The remanufacturing process at Davies begins when panels are received and inspected. Severely damaged units are set aside for component salvage and material recycling. The remaining units are disassembled to their basic components. Fabric and unusable backing material are collected for recycling while the steel components are cleaned and inspected. These components are then prepared for surface refinishing. The finish is selected based on customer orders. New fabric is mounted on the refinished frames and the panels are assembled, inspected, and packaged for shipment. In some cases panels are resized to meet specific customer orders. In most cases customer orders are filled using cores (remanufacturable components) already in stock. Therefore, customers do not have to wait for their specific components to be remanufactured.

Usually, only the fabric coverings are replaced and the exterior frames and panels refinished. Typically, over 98% of each panel, by weight, is reused. Figure 3 presents a schematic of the life cycle of a remanufactured office panel.

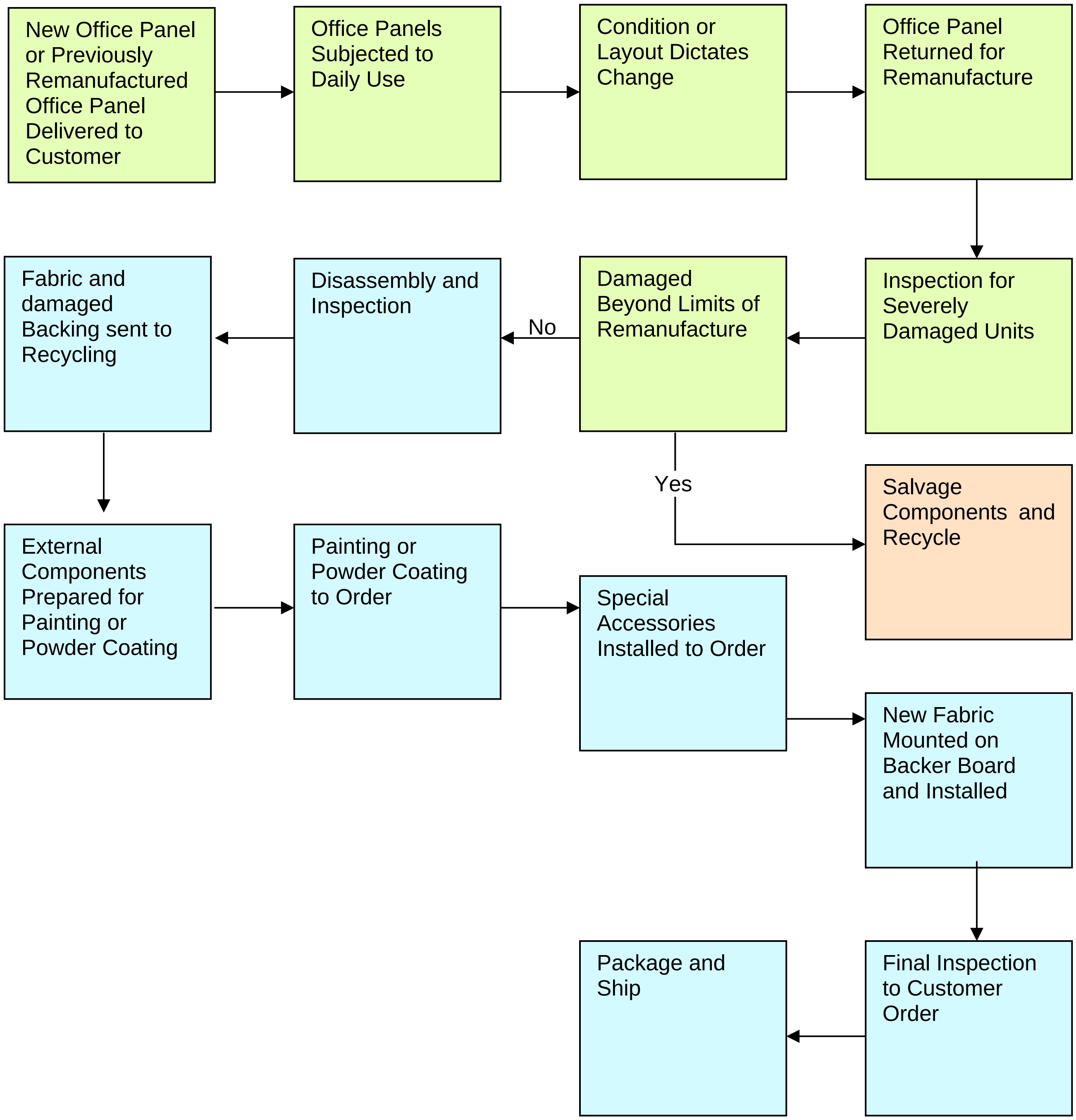

Figure 3. Life Cycle of a Remanufactured Office Panel

The office panel OEM manufacturing and remanufacturing processes are compared in Table 2 below.

Table 2. General Comparison of the OEM and Remanufacturing Processes for Office Panels

OEM	Davies Remanufacturing
Raw Material Acquisition	
All of the steel, fabric, rubber, fiber must be produced from raw materials and transported to the factory where it can be processed and assembled.	Once used office panels are consolidated and transported to the factory, virtually all of the materials are reused. Typically, only fabric and a small number of damaged parts need to be replaced.
Material processing	
Materials, such as steel, plastic, fibermat, tackboard, and fabric are cut, shaped and finished into components that are ready-to-assemble. Many of these processes are typically carried out by suppliers and are transported to the OEM for assembly.	New fabric is cut to size.
Disassembly	
N/A	Panels are disassembled to enable refinishing of metal parts and replacement of fabric.
Cleaning and Pre-Treating	
An extensive cleaning process is conducted as a pre-treatment before powder-coating exterior parts. Raw steel panels go through a five stage wash to remove oils and other contaminants that are residual from the various steel production and preparation processes. The five stage wash consists of a wash/degreasing step, an etching step (for surface preparation), a rinse, a phosphating step (for rust prevention), and a final rinse.	Metal components are washed to remove dirt and grease accumulated during service. Davies cleaning process entails a light scrub (for surface preparation), a mild detergent wash, and a rinse. Exterior metal parts that will be powder coated (i.e., 5 out of 17 metal parts) are sanded first.
Surface Finishing	
Surface finishing of metal parts is done with a powder coating process consisting of an electrostatic application of a powder coating and curing in an oven. In OEM production, 17 parts are powder coated.	Davies applies a light powder coat to 5 metal exterior parts.
Fabric Mounting, Assembly/Reassembly	
Fabric is mounted to the frame with adhesive and the panel is fully assembled.	Fabric is mounted to the frame with adhesive and the panel is fully reassembled.

Table A-1 in the Appendix provides a step-by-step process comparison for the OEM and remanufactured panels. The process steps for Davies were determined through on-site investigation and data collection. For the OEM, process steps were determined by the use of a technique called "feature-based analysis," a method that uses close inspection of a product and detailed knowledge of industrial manufacturing processes to determine how the product was manufactured. The panel was completely dismantled and all physical features, on every part, were documented. Weld lengths were measured to determine actual welding time. Stamped components were identified and the number of bends were counted. Drilled and tapped holes found in stamped or machined components were also documented. Manufacturing processes used to fabricate the panel were identified through in-house expertise and additional research. The result is an empirical analysis of the manufacturing processes used to create a sample panel that had never been remanufactured.

Compared to the OEM, Davies uses an estimated 111 fewer steps to produce an office panel compared to the OEM process. Figure 3 is a graphical representation of these results.

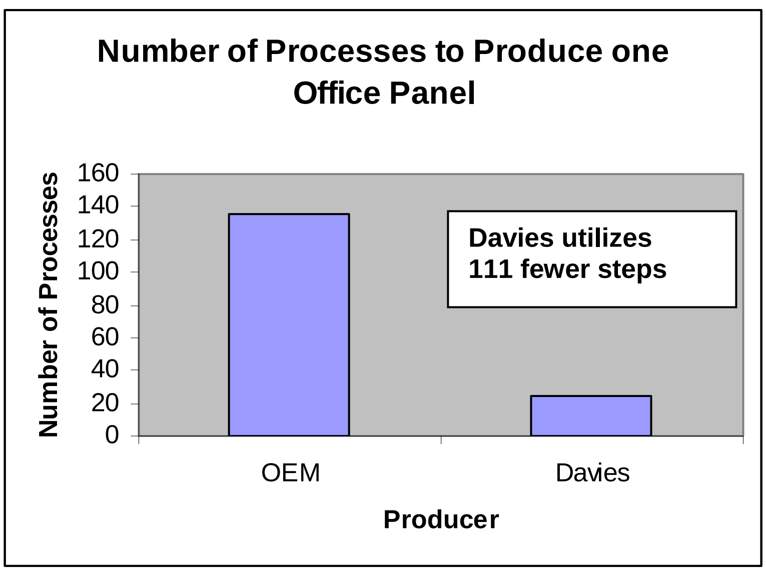

Figure 4. Comparison of Total Processing Steps for OEM and Davies Remanufacturing of Office Panels

D. Energy Analysis of Davies' Remanufacturing Process for Office Panel

The process comparison shows that significantly fewer process steps are needed to produce a remanufactured office panel, as compared to an OEM panel. In this section, we focus on, and quantify, the energy savings realized by reusing the steel portion of the panel in the remanufacturing process. While this is just one aspect of the energy savings derived from remanufacturing, it is a significant one since the Avenir® panel is approximately 88% steel, by weight, and because steelmaking is an energy-intensive process.

The energy intensity of manufacturing the steel components for an OEM office panel can be determined by examining energy consumption in the major processes utilized to produce steel. The OEM panel is constructed from steel with a 25-30% recycled content,[3] indicating that the steel was manufactured using an integrated steel making process, consisting of cokemaking and ironmaking, followed by steelmaking in a basic oxygen furnace (BOF), casting, forming and finishing. The major stages of the product life cycle — from raw material extraction through product manufacturing — are described below along with estimates of energy consumed at each stage. Energy consumption is given in British thermal units (Btu) per ton of steel.[4] A conversion factor of 10,500 Btu/kWh was used to convert electricity values, given in kWh, to Btu's.[5]

1. Mining

The primary raw material ingredients for steelmaking are iron ore, "metallurgical-grade" coal, and limestone. These materials are extracted from the ground. The energy requirements for mining and processing of these materials are shown in Table 3.

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[3] Obtained from Steelcase website, http://www.steelcase.com/na/

[4] The use of British thermal unit (Btu) as a measure of energy is standard practice in life cycle and other energy analyses since it enables the aggregation of all forms of energy (e.g., kWh of electricity, therms of natural gas) and input materials containing "energy value" (e.g., coal).

[5] This value, recommended by The U.S. Department of Energy's Energy Information Administration for studies of this kind, is used to estimate the Btu value of primary energy, i.e., the content of the energy inputs used to produce electricity, taking into account losses in electricity production (www.eia.doe.gov).

Table 3. Energy Requirements for Mining Raw Materials for Steelmaking

	Energy Used in Mining (1) (MMBtu/ton material produced)	Material Use (tons material/ton Steel)	Energy Use (MMBtu/ton Steel)
Material Input			
Coal (2)	0.4195	0.4919	0.2064
Iron Ore (3)	0.0944	1.32	0.1246
Limestone (4)	0.032	1.485	0.0475
		Total MMBtu/ton Steel	**0.3785**

1. Includes extraction and processing. Based on 0.825 tons iron for 1 ton steel (balance is scrap metal).
2. Based on avg. 1.325 tons of coal needed to product 1 ton coke, avg. 0.45 tons coke to produce 1 ton iron.
3. Based on avg. 1.6 tons iron ore to produce 1 ton iron.
4. Based on avg. 1.8 tons limestone for 1 ton iron.

Sources:
U.S Department of Energy, Office of Energy Efficiency and Renewable Energy, "Energy and Environmental Profile of the U.S. Mining Industry," prepared by BCS, Inc., Dec., 2002.
U.S. Department of Energy, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," prepared by Energetics, Inc., July 1999.

2. Integrated Steelmaking

The flow of materials, from cokemaking to forming and finishing, is depicted in Figure 5 and energy use data for these processes are given in Table 4. Metallurgical-grade coal is the primary input to the cokemaking process, in which the coal is heated to high temperatures (1,650-2,200° F) in an oxygen deficient atmosphere. Iron ore, coke, flux (limestone as well as dolomite), and sinter, are the main inputs into the blast furnace, which produces molten pig iron, often referred to as hot metal. The hot metal and metal scrap (typically 25-35%) are fed into the basic oxygen furnace, along with high purity oxygen to produce molten steel. The molten steel is further refined, and then continuously cast into a semi-finished shape, such as a billet, bloom or slab. These semi-finished shapes are further processed by reheating, hot rolling, cold rolling, and cleaning, during the forming and finishing stage to form strips, bars, rods, pipes, sheets and other structural shapes.

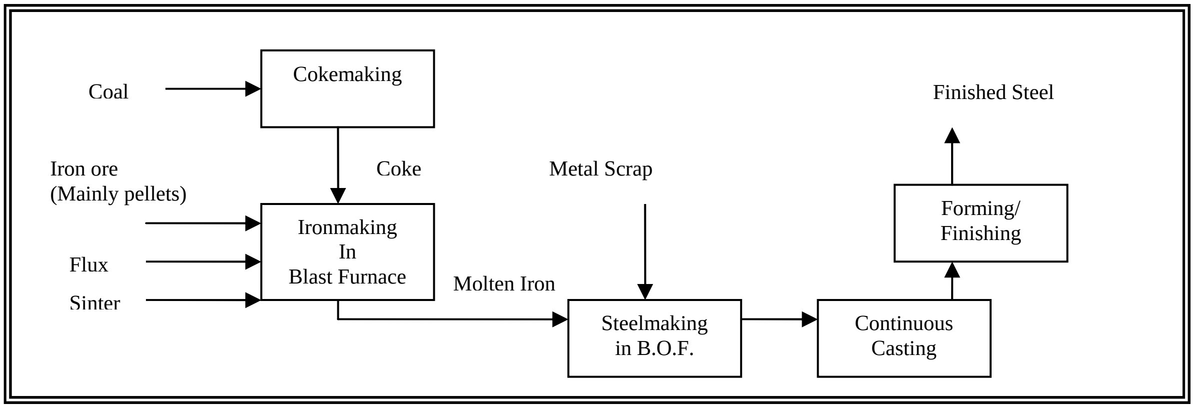

Figure 5. Simplified Process Flow of Integrated Steelmaking

Table 4. Energy Use: Integrated Steelmaking

Process	**Total Primary Energy(1)** (MMBtu/ton steel)
Sintering	0.30
Cokemaking(2)	1.24
Pulverized Coal Injection	0.01
Ironmaking	10.73
BOF Steelmaking	0.88
Vacuum Degassing and Ladle Metallurgy	0.62
Continuous Casting	0.29
Slab Mill	2.72
Hot Rolling (inc. reheating)	2.30
Pickling (Hot Rolling)	1.21
Tempering and Finishing	0.42
Cold Rolling (inc. cleaning and annealing)	1.60
Tempering and Finishing (Cold Rolling)	1.33
Total	**23.65**

1. Uses a conversion factor of 10,500 Btu/kWh.
2. Data for cokemaking reported per ton coke, converted to per ton steel using 0.45 tons coke/1 ton iron, 0.825 iron/ton steel.

Source:
U.S. Department of Energy, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," prepared by Energetics, Inc., July 1999.

3. Energy Saved in Remanufacturing by Reusing Steel in an Office Panel

The energy savings associated with reusing the steel components of an office panel are presented in Table 5. Assuming five panels are used to construct an office, the energy savings attributable to remanufacturing an office are calculated as well. The last column presents an estimate of the yearly amount of energy conserved by remanufacturing of office panels at Davies. These numbers are based on Davies' average weekly production volume of 1,200 panels, or 240 offices, 50 weeks of production per year.

By reusing the steel portion of the panel in remanufacturing, 0.58 MMBtu are saved per panel, 2.92 MMBtu are saved per office and over 35 million Btu are conserved each year. These are conservative estimates since energy estimates for tube forming, stamping, punching, cutting, and welding are not included in our analysis, though these energy uses are small in comparison to the upstream processes.

Table 5. Energy Saved in Remanufacturing through Reuse of Steel in Office Panels

Process	Energy Saved/ Ton Steel Reused (MMBtu/ton Steel)	Energy Saved/ Panel (MMBtu/panel)	Energy Saved/ Office (MMBtu/office)	Energy Saved/ Year (1) (MMBtu/year)
Mining (Extraction and Processing)	0.38	0.01	0.05	552
Integrated Steelmaking	23.65	0.57	2.87	34,482
Total	**24.03**	**0.58**	**2.92**	**35,034**

1. Based on an average weekly volume at Davies of 1,200 panels or 240 workstations per week, 50 weeks of production per year.

4. Interpreting the Energy Savings Estimates

The following facts can shed light on the relative magnitude of the savings associated with remanufacturing office furniture.

- **The energy savings from remanufacturing 1 office workstation (5 panels) could power 10 average American households for one whole day.**
- **Remanufacturing 100 workstations could power 3 households for one year.**[6]

[6] Based on 102.3 MMBtu per household, delivered energy consumption (2002 estimate). U.S. Department of Energy, "2004 Buildings Energy Databook," http://buildingsdatabook.eren.doe.gov/docs/1.2.4.pdf

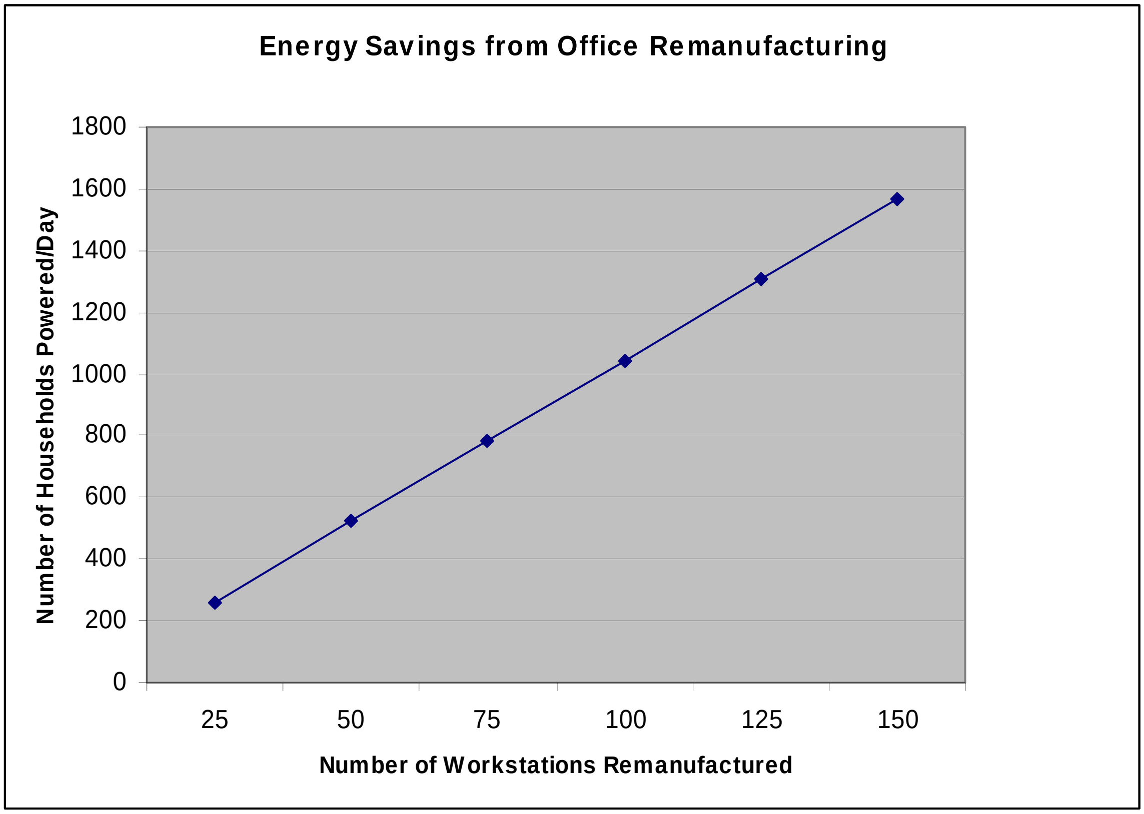

Figure 6. Energy Saving from Office Panel Remanufacturing

- **Each year, remanufacturing of office panels at Davies *results in energy savings* that could power 342 average U.S. households for one year.**[7]

[7] Based on an average volume of 1,200 panels, or 240 workstations, per week.

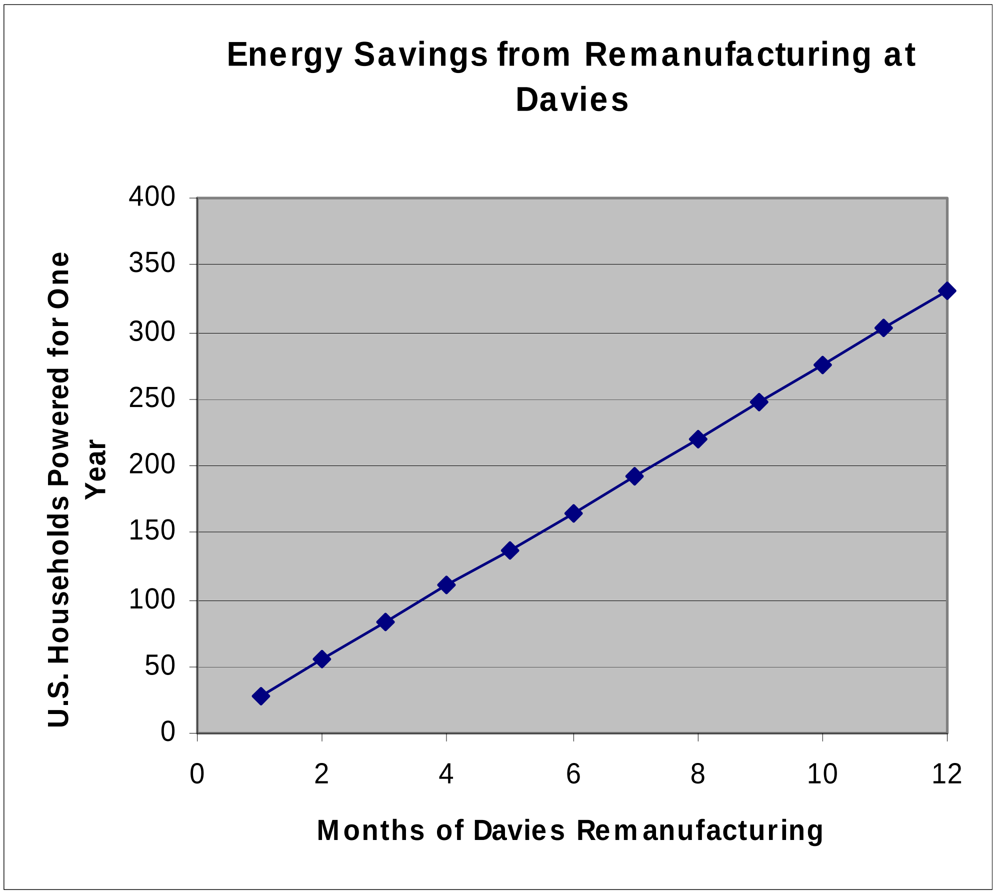

Figure 7. Energy Savings from Remanufacturing at Davies each Month

E. Environmental Analysis of Davies' Remanufacturing Process for Office Panels

There are a number of ways in which the remanufacturing of an office panel brings about environmental benefits, as follows:

1. Office panels that are remanufactured are not disposed of in landfills or subjected to the metals recycling process which, while preferable to landfilling, does have environmental impacts.

2. By reusing the materials in the panel, i.e., steel, fiberglass, cardboard, etc., the environmental impacts of extracting the virgin material needed to produce these materials for a new panel is avoided.

3. By avoiding the consumption of energy to manufacture a new panel, the emissions associated with energy generation are avoided as are the impacts from obtaining, processing and transporting the fuels to make that energy.

4. As described in Table 1, General Comparison of the OEM and Remanufacturing Processes for Office Panels, and Table 2, Process Comparison for OEM and Davies Remanufacturing of Office Panel, far fewer steps must be performed at Davies' facility to produce a panel and with each step avoided; the potential to create pollution is avoided as well.

Greater detail is provided on these environmental categories below.

1. Municipal Solid Waste Reduction

Office panels that are remanufactured are not disposed of in landfills or subjected to the metals recycling process. The weight of the 45 inch panel is 55.2 pounds. Assuming that if the panel is not remanufacturing, the entire steel portion would be recycled and only the non-steel portion of panel is landfilled   Based on this conservative assumption, 6.6 lbs/panel, or 33 lbs/office of solid waste, would be landfilled. The chart below illustrates the avoidance of waste to landfill, in tons.

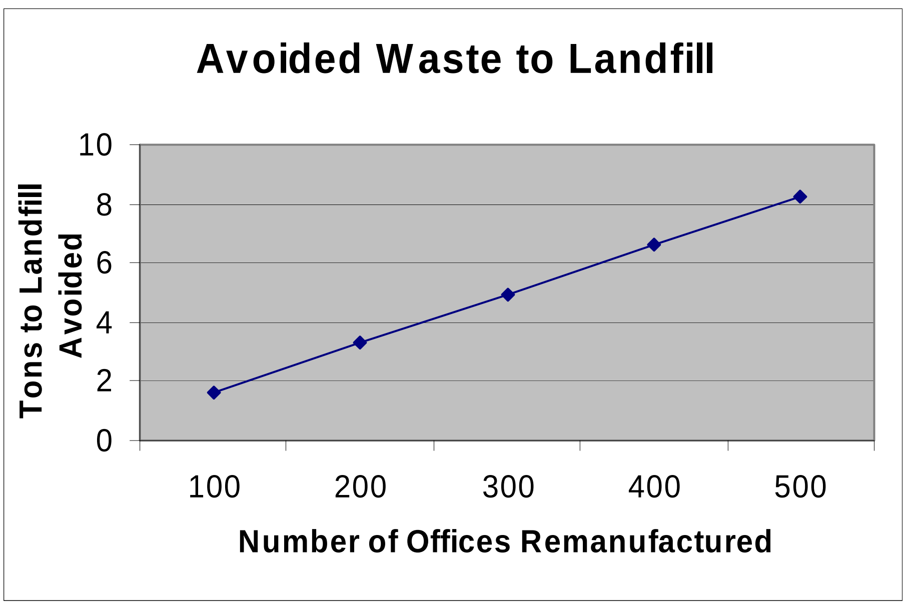

Figure 8. Avoided Waste to Landfill

2. Natural Resource Conservation

The production of one ton of steel requires the mining and consumption of close to three times the quantity of raw materials.[8] Only a fraction of the materials required to produce an office panel are part of the physical make-up of the finished product. The rest is waste in the form of by-products from mining and processing of raw materials, and manufacturing of the final product.

The conservation of raw materials is a critical component of sustainability because the earth's supply of raw materials is limited. The U.S. consumes 30 percent of materials produced worldwide, but accounts for less than 5 percent of the world's population.[9] Remanufacturing conserves the materials that are used in the product, as well the materials that are used and become waste during the production processes.

By recovering used office panels, Davies is able to reduce the amount of raw material extraction needed to produce a functional office panel. The production of a ton of steel, the main constituent in an office panel, requires 2.9 tons of raw material extraction (See Table 3). Table 6 presents the avoided raw material extraction and natural resource consumption associated with one panel, one office, 100 offices and one year of Avenir® office panel production at Davies.

Table 6. Avoided Raw Material Extraction and Natural Resource Consumption through Remanufacturing of Office Panels at Davies

Avoided Raw Material Extracted/Conserved			
lbs/Panel	**lbs/Office**	**lbs/100 Offices**	**lbs/Annual Production at Davies**
140.9	704.7	70,470	8,456,400

One year of office panel remanufacturing at Davies conserves approximately 8.5 million pounds of *raw materials*

[8] U.S. Department of Energy, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," prepared by Energetics, Inc., July 1999.

[9] Young, J.E., "The Coming Materials Efficiency Revolution," in Extended Producer Responsibility: A Materials Policy for the 21st Century, Inform: New York, NY, 2000.

3. Pollution Reduction

As stated earlier in this report, an average, estimated 98% of the materials, by weight, of each panel is reused by Davies. This means that for every panel remanufactured, 54.1 pounds of steel and other materials of construction are not produced. Furthermore, emissions to the environment, stemming from all the steps required to manufacture these components, will not occur.

Focusing only on the steel fraction, Table 7 provides fuel combustion related emissions estimates for EPA "criteria air pollutants" and CO_2 for the processes used in integrated steelmaking. These emissions can be considered conservative since they exclude emissions from combustion of coke oven and blast furnace gases, which constitute approximately 10% of total ironmaking fuel use. Using these estimates, Table 8 presents estimates for emissions avoided by recovering the steel in one panel, one office, 100 offices and one year of office panel production at Davies. Table 9 shows the quantity of avoided emissions of substances with potential human toxicity, stemming from the reuse of steel in remanufacturing at Davies.

Table 7. Emissions of Criteria Air Pollutants and CO_2 from Integrated Steelmaking

	Pollutant (lbs/ton Steel) (1)					
Process	**CO2**	**SOx**	**NOx**	**CO**	**Particulate**	**VOCs**
Sintering	69	0.676	0.258	0.083	0.194	0.001
Cokemaking	102	---	---	---	---	---
Pulverized Coal Injection	1	0.015	0.006	0.002	0.004	0.000
Ironmaking	2000	26.470	10.270	3.267	7.624	0.062
BOF Steelmaking	490	0.320	0.165	0.050	0.089	0.003
Vacuum Degassing and Ladle Metallurgy	78	0.469	0.220	0.067	0.130	0.003
Continuous Casting	39	0.421	0.160	0.051	0.116	0.001
Ingot Casting	n/a	2.277	1.033	0.319	0.632	0.014
Slab Mill	334	1.407	0.779	0.232	0.393	0.014
Hot Rolling (inc. reheating)	376	1.160	0.650	0.193	0.325	0.012
Pickling (Hot Rolling)	155	1.175	0.502	0.157	0.325	0.006
Hot Dip Galvanneal	534	3.260	1.517	0.466	0.905	0.021
Tempering and Finishing (Hot Rolling)	55	0.469	0.192	0.060	0.130	0.002
Cold Rolling (includes cleaning and annealing)	229	1.305	0.593	0.183	0.362	0.006
Tempering and Finishing (Cold Rolling)	175	1.643	0.651	0.207	0.454	0.006
Total	**4637**	**41.067**	**16.996**	**5.337**	**11.683**	**0.151**

(1) Includes only combustion related emissions. Does not include emissions generated by the use of coke oven gas and blast furnace gas.

Source: Department of Energy, Office of Industrial Technologies, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," Prepared by Energetics, Inc., August 2000.

Table 8. Avoided Criteria Pollutants and CO_2 Emissions from the Reuse of Steel in Office Panel Remanufacturing at Davies

	Emissions Avoided			
	lbs/Panel	lbs/Office	lbs/100 Offices	lbs/Yearly Production at Davies
CO2	112.76	563.78	56,378	6,765,383
SOx	1.00	4.99	499	59,917
NOx	0.41	2.07	207	24,797
CO	0.13	0.65	65	7,787
Particulate	0.28	1.42	142	17,045
VOCs	0.004	0.02	2	220

4. Greenhouse Gas Emissions

One by-product of the steelmaking process is carbon dioxide (CO_2), a Greenhouse Gas (GHG) that is widely considered to be contributing to global warming. Within the integrated steelmaking process, CO_2 is mainly produced when the metallurgic coal is oxidized in the blast furnace during the manufacture of pig iron. As indicated in Table 7, the production of one ton of steel generates over two times the amount of CO_2 emissions to the atmosphere.

One year of office panel remanufacturing at Davies avoids the release of more than 6.9 million pounds of CO_2 into the environment

Table 9. Avoided Emissions of Substances that are Potentially Toxic to Humans, from the Reuse of Steel in Office Panel Remanufacturing at Davies

	lbs/ton Steel	lbs/Panel	lbs/Office	lbs/100 Offices	lbs/Yearly Production at Davies
Acrolein	1.20E-05	2.90E-07	1.45E-06	1.45E-04	1.74E-02
Aldehydes, unspecified	1.07E-02	2.60E-04	1.30E-03	1.30E-01	1.56E+01
Antimony	6.00E-06	1.46E-07	7.29E-07	7.29E-05	8.74E-03
Arsenic	4.29E-05	1.04E-06	5.21E-06	5.21E-04	6.25E-02
Benzene	1.70E-05	4.14E-07	2.07E-06	2.07E-04	2.48E-02
Beryllium	4.98E-06	1.21E-07	6.05E-07	6.05E-05	7.27E-03
Cadmium	1.11E-05	2.70E-07	1.35E-06	1.35E-04	1.62E-02
Chromium	6.88E-05	1.67E-06	8.36E-06	8.36E-04	1.00E-01
Cobalt	1.71E-05	4.15E-07	2.07E-06	2.07E-04	2.49E-02
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	6.53E-11	1.59E-12	7.93E-12	7.93E-10	9.52E-08
Ethene, tetrachloro-	1.14E-05	2.76E-07	1.38E-06	1.38E-04	1.66E-02
Ethene, trichloro-	1.13E-05	2.74E-07	1.37E-06	1.37E-04	1.65E-02
Formaldehyde	4.19E-03	1.02E-04	5.09E-04	5.09E-02	6.11E+00
Lead	4.19E-05	1.02E-06	5.09E-06	5.09E-04	6.11E-02
Manganese	1.35E-04	3.29E-06	1.64E-05	1.64E-03	1.97E-01
Mercury	2.32E-05	5.63E-07	2.81E-06	2.81E-04	3.38E-02
Metals, unspecified	1.87E-04	4.53E-06	2.27E-05	2.27E-03	2.72E-01
N-Nitrodimethylamine	2.52E-06	6.13E-08	3.06E-07	3.06E-05	3.68E-03
Naphthalene	8.11E-07	1.97E-08	9.86E-08	9.86E-06	1.18E-03
Nickel	1.83E-04	4.45E-06	2.22E-05	2.22E-03	2.67E-01
Phenol	3.38E-05	8.21E-07	4.10E-06	4.10E-04	4.93E-02
Selenium	8.56E-05	2.08E-06	1.04E-05	1.04E-03	1.25E-01
Benzo(a)pyrene	1.11E-02	2.69E-04	1.34E-03	1.34E-01	1.61E+01
Cadmium, ion	4.04E-04	9.82E-06	4.91E-05	4.91E-03	5.89E-01
Chromate	9.79E-06	2.38E-07	1.19E-06	1.19E-04	1.43E-02
Cyanide	1.27E+00	3.08E-02	1.54E-01	1.54E+01	1.85E+03

Sources:

Data accessed through the National Renewable Energy Laboratory (NREL), operated by the Midwest Research Institute (MRI) for the U.S. Department of Energy (DOE), "U.S. LCI Database Project." Data downloaded on Feb. 7, 2005 from http://www.nrel.gov/lci/ cold rolled steel production.

NREL data was obtained from the following sources:

a. Markus Engineering Services, "Cradle-To-Gate Life Cycle Inventory: Canadian and US Steel Production by Mill Type." Revised by: The ATHENA Sustainable Materials Institute, February 2003.

b. Franklin Assoc., Ltd, Franklin USA 98 Library: Inventory data for North American materials, energy and transport (data from late 1990's), 2001.

c. Stelco Technical Services Ltd., "Raw materials balances, energy profiles and environmental unit factor estimates: Structural Steel Products," 1993.

5. Industrial Waste and Pollutants

The U.S. steel industry as a whole annually generates approximately 39 million tons of solid wastes and residues, which include slags, sludges and dust.[10] More than 80% of this waste originates from integrated steel mills, where the steel for office panels is made.

6. Pollution Avoided through Reduced Energy Consumption

The substantial energy savings provided through remanufacturing office panels has direct environmental benefits. Coal, used to produce coke, provides nearly half of the energy requirements of the steel industry. Cokemaking emits air-born particulates and volatile organic compounds (VOC's), as well as generating hazardous wastes.

Electricity accounts for approximately 25% of the energy required in steelmaking. Currently in the U.S., fossil fuel combustion accounts for about 70% of our electric power generation. Utilizing less energy conserves natural resources and reduces the quantity of pollutants generated at fossil-fuel combustion electrical utilities. The EPA reports that these utilities are the single largest source of air pollution; responsible for 67% of sulfur dioxide emissions, 27% of nitrogen dioxide emissions, and 40% of man-made carbon dioxide, as well as carbon monoxide, lead, and particulate matter.[11]

F. Conclusion

Compared to the new or OEM manufacturing of office panels, remanufacturing of office panels at Davies Office Refurbishing, Inc. has significant energy and environmental benefits. The benefits calculated in this report stem from the reuse of steel within the office panel. Steel constitutes 88.15% of the panels' total weight. By reusing the steel, all of the energy and environmental impacts related to producing steel can be avoided. This includes energy use, natural resource conservation and pollution reduction.

Beyond the benefits associated with reusing the steel, Davies' reuse of the inner core, fiber tackboard and other materials generates additional benefits, not quantified in this report. Therefore, the energy and environmental benefits presented here can be considered conservative, in light of the additional benefits associated with the avoided manufacturing of these non-steel materials.

[10] U.S. Department of Energy, "Energy and Environmental Profile of the U.S. Iron and Steel Industry," prepared by Energetics, Inc., July 1999.
[11] U.S. Environmental Protection Agency, Office of Compliance, "EPA Office of Compliance Sector Notebook Project, Profile of the Fossil Fuel Electric Power Generation Industry," EPA/310-R-97-007, 1997.

APPENDIX

Table A-1. Step-By-Step Process Comparison for OEM and Davies Remanufacturing of Office Panel

Process Steps	OEM	Davies/ Reman	Qty/Panel
Hollow Tube Frame			
Produce steel	Yes	No	1
Welding	Yes	No	1
Punching	Yes	No	1
Raw metal Pre-treatment	Yes	No	1
Refinish Pre-treatment	No	No	1
Powder coat spray	Yes	No	1
Powder coat curing	Yes	No	1
Side Support Brackets			
Produce steel	Yes	No	2
Welding	Yes	No	2
Punching	Yes	No	2
Raw metal Pre-treatment	Yes	No	2
Refinish Pre-treatment	No	No	2
Powder coat spray	Yes	No	2
Powder coat curing	Yes	No	2
Top Bracket			
Produce steel	Yes	No	1
Welding	Yes	No	1
Punching	Yes	No	1
Raw metal Pre-treatment	Yes	No	1
Refinish Pre-treatment	No	No	1
Powder coat spray	Yes	No	1
Powder coat curing	Yes	No	1
Top Cap			
Produce steel	Yes	No	1
Welding	Yes	No	1
Punching	Yes	No	1
Raw metal Pre-treatment	Yes	No	1
Refinish Pre-treatment	No	Yes	1
Powder coat spray	Yes	Yes	1
Powder coat curing	Yes	Yes	1
End caps with bottom sliders			
Produce steel	Yes	No	2
Welding	Yes	No	2
Punching	Yes	No	2
Raw metal Pre-treatment	Yes	No	2

Process Steps (cont.)	OEM	Davies/ Reman	Qty/Panel
Refinish Pre-treatment	No	Yes	2
Powder coat spray	Yes	Yes	2
Powder coat curing	Yes	Yes	2
Galvanized channel			
Produce steel	Yes	No	1
Soil and grease removal	Yes	No	1
Fluxing	Yes	No	1
Galvanizing	Yes	No	1
Finishing	Yes	No	1
Inspection	Yes	No	1
Snap on Steel Frame			
Produce steel	Yes	No	2
Surface preparation	Yes	No	2
Paint	Yes	No	2
Bottom Bracket			
Produce steel	Yes	No	1
Welding	Yes	No	1
Punching	Yes	No	1
Raw metal Pre-treatment	Yes	No	1
Refinish Pre-treatment	No	No	1
Powder coat spray	Yes	No	1
Powder coat curing	Yes	No	1
Adjustable Legs			
Produce steel	Yes	No	5
Welding	Yes	No	5
Punching	Yes	No	5
Raw metal Pre-treatment	Yes	No	5
Refinish Pre-treatment	No	No	5
Powder coat spray	Yes	No	5
Powder coat curing	Yes	No	5
Leg Brackets			
Produce steel	Yes	No	2
Welding	Yes	No	2
Punching	Yes	No	2
Raw metal Pre-treatment	Yes	No	2
Refinish Pre-treatment	No	No	2
Powder coat spray	Yes	No	2
Powder coat curing	Yes	No	2
Kick Plates			

Process Steps (cont.)	OEM	Davies/ Reman	Qty/Panel
Produce steel	Yes	No	2
Welding	Yes	No	2
Punching	Yes	No	2
Raw metal Pre-treatment	Yes	No	2
Refinish Pre-treatment	No	Yes	2
Powder coat spray	Yes	Yes	2
Powder coat curing	Yes	Yes	2
Produce Retainer Clips	Yes	No	2
Produce Screws	Yes	No	N/A
Produce Locator Screws	Yes	No	4
Produce Top cap clips	Yes	No	2
Produce Fiber mat	Yes	No	2
Produce Cardboard	Yes	No	1
Produce Tack-board	Yes	No	2
Produce Fabric Cover	Yes	Yes	2
Produce Glue	Yes	Yes	1
Produce Foam side seal	Yes	No	2
Transport components from suppliers to OEM producer	Yes	No	1
Unpack components from suppliers	Yes	No	1
Return panel from customer site to factory	No	Yes	1
Inspect returning panel for damage	No	Yes	1
Disassemble panel	No	Yes	1
Remove external powder coat items for refinishing	No	Yes	1
Remove fabric cover for replacement	No	Yes	1
Assemble panels from components	Yes	Yes	1

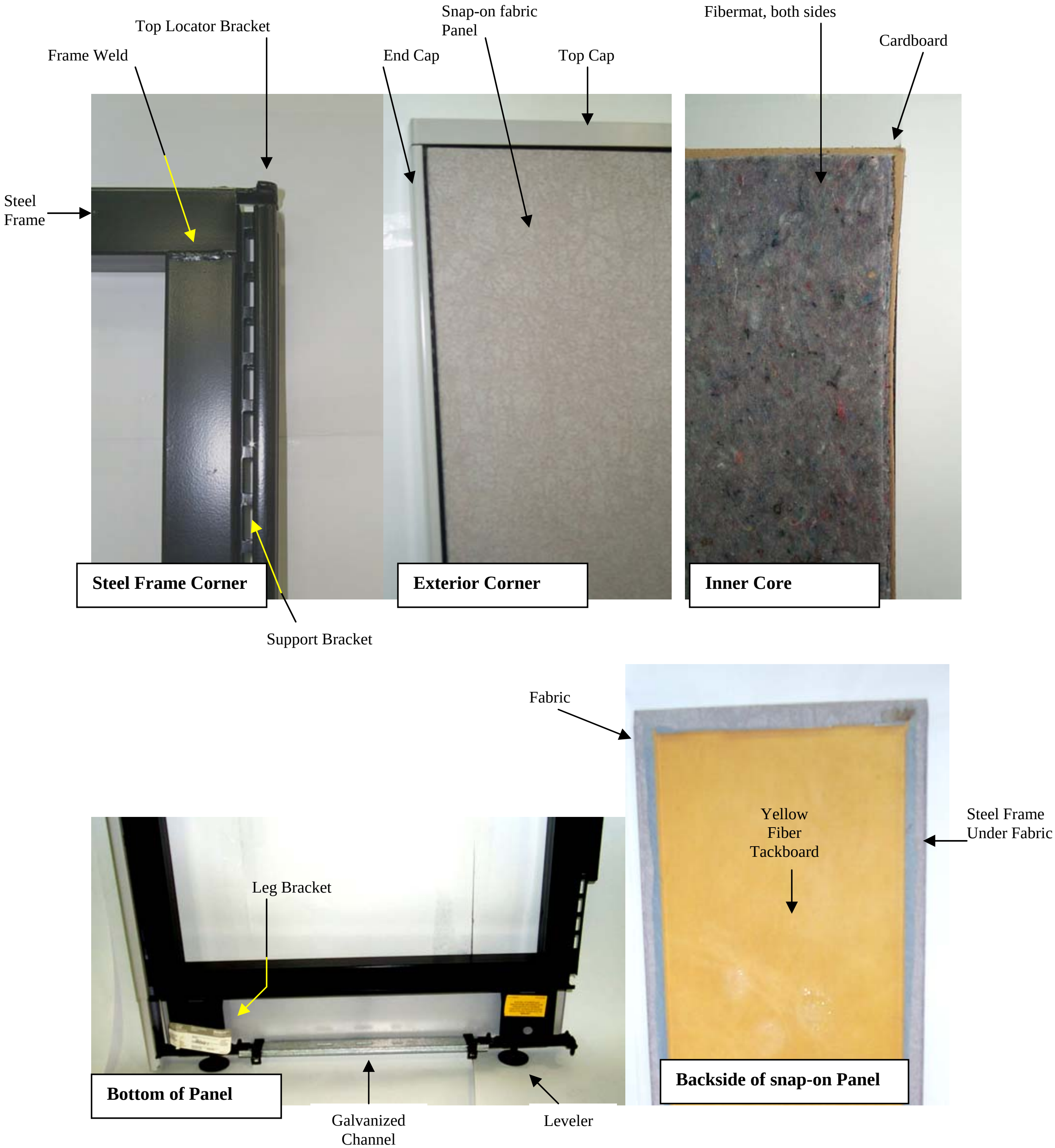

Figure A-1 Photographs of an Office Panel