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Center for Sustainable Systems
University of Michigan

Development of Steelcase Wood Products Manufacturing Division Environmental Performance Measures Project

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1. Executive Summary

As a global leader in the furniture manufacturing industry, Steelcase, Inc. has made an important commitment to sustainability. Corporate environmental accountability is increasingly important for industry as the global consumer base demands more 'sustainable' products. However, as the demand for sustainability grows stronger there is no roadmap for achieving sustainable industry. Today some 1500 companies report on environmental, social, or sustainability issues worldwide, and three of the top ten most reported companies are in the US.[1] Industries that adapt a proactive stance may very well pave the way to sustainability, establishing themselves as environmental leaders to stakeholders and the public.

Aggressive environmental goals at Steelcase, Inc. clearly state the environmental commitment that distinguishes its brand and products from competitors. But the operational challenge of industrial environmental stewardship requires appropriate tools for efficiently managing resources, time, and energy. This project establishes the fundamental metrics by which the Steelcase Wood Products Division (SWD) and possibly other Steelcase divisions will assess their environmental performance into the future.

Within this project, Environmental Performance Indicators (EPIs) for energy use and greenhouse gas emissions (GHG) have been established for historical, current, and future environmental performance of the SWD. Baselines have been established for historical comparison between calendar year 2006 to 2007 operations and the time period from November 2003 to April 2004 that evaluates plant consolidation efforts. Environmental metrics were developed and applied to calculate material production, transportation, and total fuel cycle impacts for SWD operations from cradle to gate using direct Steelcase data and aggregated industry average datasets like Economic Input -output Life Cycle Assessment and the US Commodity Flow Survey. The accuracy of all indicators developed in this work depends on the ability of industry average aggregate data to represent actual Steelcase supply-chains or manufacturing processes and/or the availability of Steelcase specific supply-chain or operations data to replace aggregated datasets. Continued use of such aggregated industry datasets is not recommended as Steelcase specific data becomes available which will increase the accuracy and usefulness of Environmental Performance Indicators. Calculated metrics include absolute physical quantities of characterized environmental impact and the same set of impacts normalized by various economic measures. Results from the 2003/2004 to 2006/2007 historical comparison show at least an 11% increase in environmental performance for every benchmark indicator, with a maximum improvement of 19% in the CO_2Equivalent per net-dealer-net value (NDN) indicators for that time period (NDN serves a direct proxy for product list price).

Sensitivity analysis compared the effects of scrap rate reduction, increased material shipment distances to SWD operations, and insourcing scenarios against 2006-2007 operational data to test the efficacy of the model in capturing operational changes. Results indicate that the model reflected the changes as expected, with a 6-8% increase in environmental performance eco-efficiency indicators when wood scrap rate was reduced by 10%, a 6-8% decrease in environmental performance eco-efficiency indicators when 3 Steelcase Material Purchase Codes were re-sourced from Taiwan, and a 0-4% increase in environmental performance eco-efficiency indicators when material purchase values were decreased by 10% and SWD process energy was increased by 10%.

2. Acknowledgements

The project team at the Center for Sustainable Systems at the University of Michigan would like to gratefully acknowledge the support of the Steelcase Wood Division, specifically Kevin Kuske, General Manager, for sponsoring this work. His input and help in getting data have been invaluable. The project team would also like to thank Angela Nahikian, Denise VanValkenburg, Steven Baar and Mary Ellen Mika at Steelcase for their help in finding the right contacts and getting the best data possible from a variety of Steelcase resources.

3. Project Description

The Development of Steelcase Wood Products Manufacturing Division Environmental Performance Measures Project builds upon an existing partnership between the Center for Sustainable Systems (CSS) in the School of Natural Resources and Environment at the University of Michigan and Steelcase, Inc. (SCS). This chapter provides a brief background of this partnership and the need for this project, project objectives, and an overview of how this project relates to SCS corporate goals.

3.1 Introduction and Background

3.1.1 Consumer Demand for Product and Corporate Sustainability

A shifting international furniture market has created new challenges and opportunities for SCS. Faced with exponentially increasing environmental regulations,[2] fierce domestic and international competition,[3] and an increasing consumer demand for environmentally responsible products, SCS has adapted a constructive stance towards the sustainability of its operations.

Global furniture corporations rate consumer demand as a top motivator for seeking ISO environmental reporting.[4] Additionally, sustainable business practices may reduce investment risk and subsequently increase a company's stock price by up to 5%.[5] These motivators within SCS, coupled with a desire to reduce environmental impact and increase operational efficiency, have lead to a strong interest in sustainability initiatives.

3.1.2 CSS-SCS Partnership

The relationship between SCS and CSS began with a 1991 study "Waste Reduction in Furniture Manufacture: Case Study Report of Steelcase, Inc." sponsored by the Office of Waste Reduction Services, State of Michigan Departments of Natural Resources and Commerce.[6] More recently, the SCS - CSS partnership has included a comprehensive on-site data collection and in depth life cycle assessment (LCA) of three different pieces of SCS furniture in the lateral file, work surface, and panel products lines in 2003.[7] This work was supplemented by a 2006 life-cycle assessment of three different SCS products in the AirTouch, Garland, and Siento product lines.[8] These studies measured environmental impacts using life cycle assessment techniques throughout each product life cycle from raw materials acquisition to end-of-life disposal. Insights from this assessment are helping to influence future designs and production to make more environmentally responsible products. On an operational level, a 2006 CSS-SCS study was commissioned to measure the total greenhouse gas emissions at SCS for use in a corporate GHG target program through the USEPA.[9] Additionally, a concurrent SCS-CSS project is focusing on the product level with a software tool to guide product design in very early stages of development.[10]

3.1.3 Challenges in Measuring Sustainability

There are countless challenges in defining and achieving sustainable business enterprise. The entire SCS corporate footprint must be evaluated, requiring study beyond the product level system boundaries of life-cycle assessment. In its entirety, the corporate footprint should include not only the manufacturing footprint of all its products, but also the overhead footprint associated with the enterprise. As the focus shifts from product to enterprise level, the complexity of the system studied increases along with the detail and quantity of supporting data. There is little consensus on the definition of a "sustainable business", so a set of goal-oriented sustainability criteria for SCS must be defined. Cooperation and motivation within an enterprise has been shown to have a large impact on the success of sustainability initiatives,[11] as corporate stance varies from resistant adaptation to pro-active.

Recent operational changes within the Steelcase Wood Products Division (SWD) have likely impacted its environmental performance and footprint. However, there are no existing metrics to quantify this change, and no benchmarking tools available to track environmental improvements moving forward. The need for such metrics and a standardized method for calculating them provides the motivation for this project.

3.2 Project Objectives

This project focuses on the development of a set of metrics to measure the environmental performance of SWD over time. These metrics establish the point of reference for future improvement at SWD and provide feedback on new process implementations. Specifically, the project aims to:

1. Develop of a set of environmental performance measurement methods and allocation procedures for the highly dynamic Wood Products Division, maintaining adherence to standardized international environmental impact metrics (such as ISO 14040).
2. Apply energy consumption and GHG emissions metrics for benchmarking and ongoing monitoring of division environmental performance. Specific data collection requirements will be established for these two metrics to direct data collection operations and integration with division accounting and operational databases wherever possible.
3. Establish a baseline quantification of energy and GHG metrics and, to the extent possible consider the availability of historical data and undertake a comparative environmental impact case study of division operations before and after recent consolidation and conservation efforts.
4. In cases where historical data collection is possible, completion of a comparative environmental impact analysis of past and current Wood Products Division operations. To supplement this comparison, sensitivity analysis on the framework will be carried out to determine efficacy.
5. Establish a long-term plan for monitoring and data analysis.

In particular, this effort will assist division managers in:

1. Accurately estimating the environmental performance (energy and GHG emissions) of the Steelcase Wood Products Division based on standardized environmental performance metrics.
2. Identifying tradeoffs among decision options for changes in operations, product lines, and outsourcing.

3. Tracking environmental progress using standardized, comparable metrics over time.

Additionally, the project aims to provide a toolset for use in achieving SCS corporate sustainability beyond SWD. The use of corporate wide databases and industry average datasets will streamline future implementation across the corporation. As a test bed for the techniques and processes involved with this project, SWD will help corporate managers evaluate and adapt these tools before widespread adoption at other divisions, increasing the overall efficiency of environmental indicator implementation across the SCS enterprise.

3.3 Steelcase Corporate Ecological Footprint and Energy Reduction Goals

This study does not attempt to set or assess specific environmental performance targets for Steelcase, Inc. (e.g., "Protocol and Preliminary Greenhouse Gases (GHG) Emissions Inventory Steelcase, Inc." [12] was developed to assess specific goals pledged for the USEPA Climate Leaders program). Rather, this project will provide the means for continuous footprint monitoring that can be used as a decision-making tool to compare and measure the impacts of operational changes. This project will help SCS achieve sustainability targets by providing feedback on the impacts of business decisions, but will not measure environmental impacts for any specific target.

3.3.1 USEPA Climate Leaders Program

The Climate Leaders (CL) program is a voluntary industry-USEPA partnership committed to reducing greenhouse gas emissions. SCS joined the CL program with a pledge to reduce its US greenhouse gas (GHG) emissions by forty percent per dollar (measured by Net-Dealer-Net (NDN) value for Steelcase) from 2004 to 2009. An initial GHG Inventory Management Plan (IMP) has been developed by Shanin in accordance with the USEPA GHG Protocol Program that catalogues six major greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC's), perfluorocarbons (PFC's), and sulfur hexafluoride (SF_6). [13] The IMP will serve as an ongoing resource to SCS as a metric for the CL pledge, carbon trading market, marketing materials and this project. The metrics created in this project will measure GHG's and therefore prove useful for achieving the GHG reduction pledge.

3.3.2 SCS Corporate Ecological Footprint Reduction Target

SCS has set a goal to reduce corporate ecological footprint by twenty-five percent by 2012. This project will provide a means for decreasing corporate footprint. The metrics developed here will be universally applicable within SCS and could therefore by implemented to achieve other division specific goals if adapted throughout the company.

3.4 Project Team

This project involved collaboration between a number of CSS researchers who were primarily responsible for the development of modeling theory, model structure, and data analysis and team members from Steelcase who provided information on current and past sourcing, energy purchasing, facility operations, and financial data. Specific project participants included:

Center for Sustainable Systems

Blake Marshall, Research Assistant
Michael Lepech, Research Fellow
Gregory Keoleian, Co-Director
Ben Massie, Graduate Student

Steelcase, Inc.

Kevin Kuske, General Manager, Steelcase Wood
Denise Van Valkenburg, Senior Environmental Manager
Angela Nahikian, Global Environmental Strategy
Steven Baar, Sourcing Service Center
Michelle Ringleka, Sourcing Service Center
Patrick Sherman, Sourcing Service Center
Mary Ellen Mika, Buyer
Donna Roscoe, Buyer
Heather Salmon, Buyer
Sam Spadafore, Global Supply Chain Management
Kent Koth, Inbound Logistics
Karen Andrus, Environmental Engineer
Robert Ruthven, Supply Chain Leader
Sharon Albaugh, Manufacturing Engineer

4. Literature Review

4.1 Drivers of Environmental Performance Quantification

Benchmarking through the use of indicators is a common business practice that affords industries a technique for self-improvement[14]. Benchmarking can be internal, competitive or generic and generally asks "who performs better, why they are performing better, and how a company can improve?"[14] While various forms of benchmarks exist for many different industries this project will focus on Environmental Performance Indicators (EPIs) used for internal benchmarking.

4.2 Criteria and Challenges for Successful Environmental Performance Metrics

Calculation of direct environmental performance impacts (i.e.,, tons of GHG emissions or MJ of energy consumed) for dynamic business operations is problematic because these absolute metrics don't provide information relative to the scale of operations. As shareholders expect SCS to grow, absolute global footprint becomes more difficult to reduce as an absolute measure. Therefore, normalization of metrics is a priority. Simple metrics that produce one, two or three dimensional outputs are preferable. One-dimensional outputs focus on only one of the three "legs" of sustainability; environmental, social, or economic. Two-dimensional outputs combine two of these legs into one output, e.g., socio-economic or eco-economic metrics. Three-dimensional outputs, arguably the most complex, involve all three legs into a single or group of interrelated metrics.

According to Perrato et al.,[15] a successful indicator is measurable with available/obtainable data, uses a transparent standardized methodology, has means for monitoring, and is politically acceptable. ISO 14031 standards classify indicators into two main categories: Environmental Performance Indicators (EPI) and Environmental Condition Indicators (ECI) with various sub-categories. Though there are many indicators that do not explicitly adhere to ISO 14031 throughout the literature, standardized metrics have the benefits of being generally more reproducible, transparent and well tested.

For comparison, both within a process over time, and between various processes or industries, Olsthoorn et al.[16] recommend that for increased transparency and credibility, all environmental data be normalized, and then possibly standardized or aggregated to suit particular informational needs. Financial quantities are often used for normalization of impact metrics.

There are a number of challenges to address when developing indicators that asses environmental performance in the context of sustainability initiatives. Seven major categories of limitations to the functionality of EPI's for Sustainability have been defined by Wehrmeyer and Tyteca:[17]

1. Lack of standardization between performance indicators has occurred
2. Integration of measures into a wider context has not happened

3. Impacts are often inadequately formulated from performance measures
4. Operations based indicators for firms are inadequately defined and used
5. Valuations combining impacts in different environmental media sources (e.g., air, water, soil, etc.) remain subjective.
6. Few studies analyze environmental effects over time.
7. Impact categories fail to incorporate all environmental impacts, such as changes to biodiversity.

Business managers should remain confident with chosen indicators to ensure consistent reporting and benchmarking into the future. According to Zobel et al.,[18] business managers questioned the reproducibility of EPI results because environmental issues are dynamic, assessment routes are subjective, assessment criteria must be subjectively updated with environmental science progress, and metrics often vary between units of the same company. This becomes a greater concern when EPI results are tied to division or division manager evaluation and compensation. To ensure management cooperation and reproducibility, metrics must be easy to calculate, based on objective and available data, remain robust as environmental science progresses, and remain applicable to other divisions within Steelcase.

Indicators are most useful when they are normalized and/or standardized, as noted by Wehrmeyer and Tyteca.[19] The International Standards Organization (ISO 14031), the British Standards (BS 7750) and the European Union's Eco Management and Auditing Scheme (EMAS) all provide guidance on indicator development and standardization.[20] Adhering to these standards, which are maintained within this study, will help ensure the future utility of the metrics chosen for SWD.

While metrics must be based on objective and available datasets, there is a trade-off between the feasibility (both time and cost) of data collection and the robustness of the data collected. When the Canadian National Roundtable for the Environment and the Economy (NTREE) assessed eco-efficiency indicators in eight corporate partners to measure the feasibility of establishing EPI metrics, the lack of systematic methods for data collection was cited as a major challenge and insufficient data resulted in many cases.[12] It was also noted that third party supplier data was often unavailable and inaccurate when provided.

Eco-efficiency indicators, defined as a value of production normalized by environmental impact by the World Business Council for Sustainable Development (WBCSD), can also be sensitive to changes in aggregated product or service value stemming from product price, market share, margins, or market mix.[21] However, in its 1998 "State-of-Play" report, the WBCSD concluded that the use of a product output figure or a financial figure for the normalization of environmental data seemed to be widely accepted. For financial metrics, value added, total sales, or revenue are most often used.[22]

The Canadian National Roundtable for the Environment and the Economy (NTREE), in their feasibility study on eco-efficiency indicators for energy and material intensity[23] found that the resource productivity index used by some firms, defined as a percentage of usable outputs of materials and energy divided by the energy and materials consumed in the production of those products, was found to be less useful and feasible than direct energy intensity and material intensity indicators. A basic eco-efficiency core indicator (i.e., product service or value divided by environmental influence) was most useful for managers, with supplementary indicators used on a voluntary basis for both energy and material intensity. A large set of indicators was preferred to a sole indicator by most companies. However, larger corporations like Proctor and Gamble and 3M have found misleading results by applying eco-efficiency indicators because of shifting product mix. This is an immediate concern at SWD.

4.3 Classifying Environmental Performance Metrics

According to Thoresen,[24] there are five functionally distinct uses for EPI, categorized into macro and micro levels.

Macro level uses:

- Regulation, control and surveillance of individual companies carried out by international and national environmental authorities.
- An intended influence on individual companies from various, external stakeholders, to secure a sustainable performance by the companies or to protect their own stakeholder interest.
- The supply of relevant environmental information from individual companies to external stakeholders.

Micro level uses:

- Internal goal setting, control and surveillance of product performance and performance of primary processes and sub-processes in individual companies.
- Continuous process and product improvements triggered by benchmarking compared to a competitors' performance or a branch average process or product performance.

The two micro-level uses are consistent with continuous product improvement and comparisons over time via benchmarking. Additionally, EPI's are typically classified into the following three groups:

(1) Product lifecycle performance
(2) Environmental performance of selected process technology
(3) Environmental performance of operations

This project specifically focuses on the third type of EPI from this list which characterizes the environmental performance of an entire business operation. Previous life cycle assessment projects carried out by CSS for Steelcase have addressed the first type, examining the lifecycle performance of a specific product. Comparative life cycle emission studies carried out by Steelcase, often in conjunction with McDounagh Broungart Design Consultant (MBDC), have focused on the second set of EPIs. Examples of this include eliminating certain toxic solvents, stains, or paints from SCS operations.

Unlike the Thoresen EPI distinction which is based upon the boundaries of the environmental assessment (i.e., product boundary, process boundary, or operational boundary), Bennett and James[25] describe three classifications based on the intended use of the EPI.

(1) First-generation indicators describe the business process, indicators on regulated emissions and wastes, and indicators for costly resources and compliance.
(2) Second-generation indicators reflect energy and materials usage/efficiency and significant emissions and wastes, as well as financial and implementation indicators.
(3) Third-generation environmental indicators (EIs) include relative indicators, eco-efficiency, stakeholder, environmental condition and products indicators (ECI & EPI), and the use of a balanced scorecard of these indicators.

First generation indicators are most often used for environmental compliance or public reporting (i.e., USEPA or RCRA). Second generation indicators can be used for efficiency improvements over time within a defined operational system. Within well-defined operational boundaries, such energy and materials usage/efficiency improvements over time can serve as good indicators for improving environmental performance. Third generation indicators allow for measurement of dynamic operational systems which exhibit constantly changing inputs and output, making direct comparison over time highly complex.

As noted by Fiksel,[26] each of these types of indicators can be used for performance tracking (first-generation), decision making (second-generation), and external reporting (third-generation). In the case of Steelcase Wood Products (SWD), the indicators of energy consumption and carbon footprint fit between the second-generation and third-generation set of indicators. Rather than measuring these metrics for compliance or process description reasons, SWD is looking to make decisions based on these relative indicators. The tracking of these metrics, and any improvements made over time, may be used in SWD marketing and promotional materials to tout environmental improvements. However, such claims should be made with great care noting the absence of a large number of indicators and the lack of a "balanced scorecard" to weigh a variety of impacts on a diverse group of stakeholders.

While a variety of environmental influence or impact quantities have been established and can be directly measured for use in EPIs (i.e., megajoules of primary energy consumed, carbon equivalents emitted, etc.) the determination of a economic or financial quantity for normalization remains the topic of considerable debate. A number of potential economic or financial metrics are discussed herein. However, others may be devised by SCS financial groups that result in more appropriate EPI formulations. The use of normalized environmental performance measures should not be skewed to allow for the selection of normalization values in order to portray environmental improvement in the face of increased emissions. Rather, the selection of normalization values should reflect the true economic value of operations during which resources are consumed and emissions or wastes are produced.

Net value added can be used as a representative financial quantity, as it quantifies the contribution of the manufacturing or processing activity to the global economic welfare. In this regard, concerns of product price, market share, profit margins, and market mix are alleviated so long as dollars are normalized to an indexed year. One clear downside to value added is that while it is well defined at a macroeconomic level (i.e., Gross Domestic Product), it is less well defined at a corporate level (and even less so at the divisional level). Because of this, it is not always easy to observe and therefore not always reported.[27] In the case of BSO/Origin, Inc. net value added was defined as value added less value lost. Value added included:

- Personnel Costs
- Depreciation, Provisions
- Financial Expenses
- Taxation
- Net Profit

Value lost was defined as the cost of environmental effects caused directly by the company's operations, less the company's expenditure on mitigation. This value lost includes:

- Environmental costs of treatment
- Costs of residual effects
- Payment for third party mitigation services
- Environmental taxes
- Gains from environmental grants

While this single quantity can be used in some limited applications, it fails to capture external environmental costs that are neither taxed nor mitigated (i.e., GHG releases). Further, it can severely discount or negate environmental improvements realized during periods of corporate growth. Therefore rather than using this metric of "value added", ratios are more often used to normalize environmental quantities based on overall productivity of operations.

In some firms, the quantity of goods sold or physical production numbers can be used as a financial measure when a single production output is dominant (e.g., kWh of electricity for an electrical generation facility). However, in multiple product industries or firms, such as SWD, comparisons over time become difficult as a result of numerous product and process changes. In this case, shipment value may also be used. However, this leaves EPIs vulnerable to corporate pricing and product discounting decisions.

The number of employees may also be a financial proxy, particularly since it is easy to quantify and not as subject to product mix, value, or profit margin. However, changes in labor intensity over time due to employee learning, new processes adoption, or automation may not necessarily signify improvements in environmental performance. Similar problems arise with the adoption of standard work hours or other labor-related economic quantities like Model Unit Counts (MUCs).

Sustainable energy indicators have been proposed[28] to evaluate changes in energy mixes as companies choose more renewable sources. At SWD, such an indicator would give management a way to improve environmental performance. However, energy sources could just as easily be included in more comprehensive indicators. Data redundancy ("double counting") would have to be carefully avoided.

4.4 Organizations Focusing on Indicators

As summarized by Olsthoorn et al.,[29] a number of organizations and initiatives worldwide have focused on the development of environmental indicators. These include:

- Association of Chartered Certified Accountants (ACCA) (England)
- Global Reporting Initiative (GRI)
- EU Eco-management and Audit Scheme
- ISO 14031 – Environmental Performance Evaluation
- Guide to Corporate Environmental Indicators by the German Federal Environmental Agency
- World Business Council for Sustainable Development Report on Eco-efficiency Metrics
- National Round Table of the Environment and Economy (Canada)
- European Environmental Agency (EEA)
- World Resources Institute (WRI)

4.5 Specific Indicators

As discussed previously, the International Standards Organization (ISO 14031), the British Standards (BS 7750) and the European Union's Eco Management and Auditing Scheme (EMAS) all provide guidance on indicator development and standardization. This takes the form of an Economic Indicator, as shown in Equation 4.1.

$$\text{Economic Indicator} = \frac{\text{Physical and/or Environmental}}{\text{Economic and/or Financial}} \qquad (4.1)$$

Conversely, the World Business Council for Sustainable Development[30] recommends a measure of "eco-efficiency" (Equation 4.2).

$$\text{Eco-efficiency} = \frac{\text{Product or Service Value}}{\text{Environmental Influence}} \qquad (4.2)$$

According to the WBCSD,[31] generally acceptable indicators for these values include,

- Product or Service Value – Quantity of Goods or Services, Net Sales, Other Financial Indicators (i.e., Gross Margin, Value Added, Share Value, Liabilities)
- Environment Influence – Materials, Energy, Water, Greenhouse Gas, Ozone Depletion, Acidification, Total Waste

In essence, the Economic Indicator and Eco-efficiency equations are calculating the inverse of the same ratio.

Specifically, Sony Europe defines the resource productivity (eco-efficiency) to compare three types of batteries as shown in Equation 4.3:[32]

$$RP = \frac{\text{(economic value added) x (product lifetime)}}{\text{material (consumed – recycled) + energy (for production, use and recycling)}} \qquad (4.3)$$

Such an indicator allows the service life of the product to be taken into account. Therefore, the benefits of designing for superior quality or service are recognized. Such a metric may become useful when comparing premium product lines to standard product lines within SCS.

The use of multiple indicators for each benchmark criterion allows for comparisons within each benchmark criterion and will allow options if an indicator behaves perversely with respect to a specific data set. For instance Tahara *et al.*[33] used the following set of complimentary indicators (paraphrased here in terms of intensity) for CO_2 eco-efficiency of companies (Equations 4.4-4.6):

$$\text{Total } CO_2 \text{ Intensity} = \frac{\text{Producer's price}}{\text{Direct and Indirect } CO_2 \text{ Emissions}} \tag{4.4}$$

$$\text{Direct } CO_2 \text{ Intensity} = \frac{\text{Gross value added}}{\text{Direct } CO_2 \text{ Emissions}} \tag{4.5}$$

$$\text{Indirect } CO_2 \text{ Intensity} = \frac{\text{Cost of materials}}{\text{Indirect } CO_2 \text{ Emissions}} \tag{4.6}$$

Though all three equations aren't always necessary to establish a benchmark, they may prove useful when data is less available or when assessing the supply chain for specific changes. With respect to SWD strategies, numerous indicators may be useful for targeting the source of poor performance. Many businesses have been found to prefer a larger number of indicators to a small number of core indicators.[23]

The BASF Story[34]

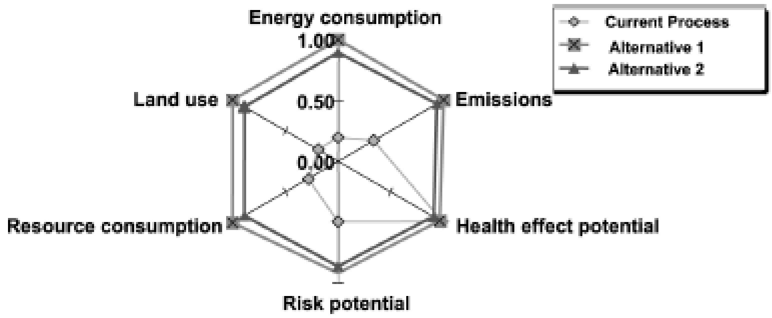
BASF's eco-efficiency methodology was developed in 1996, and to date over 220 analyses have been completed. It is based on the principles of ISO 14040, with additional enhancements that allow the results to be used as a concise decision-making tool.[35]

Six environmental categories are evaluated:

(1) Raw materials consumption.
(2) Energy consumption.
(3) Land use.
(4) Air, water and solid waste emissions.
(5) Toxic potential of the substances employed and released.
(6) Potential for misuse and risk potential.

Life-cycle data are compiled for each of these categories, a weighting scheme is used to aggregate the results, which are normalized in order to calculate the overall ecological footprint (Figure 4.1). The best alternative lies towards the center of this spider chart. This clearly depicts the relative impacts of the alternatives in each of the environmental categories.

To address the economic aspects of sustainability, cost data for the life cycle of the product is gathered. This includes but is not limited to costs for production, transport, maintenance, labor, etc. In this way the economic impacts and viability of the alternatives are evaluated.



Note: 1.0 = worst position, better results ordered relatively <1

Figure 4.1 Ecological footprint characterization by BASF

4.6 Criteria Specific to Steelcase Wood Products Division

The terms ecological and carbon footprint have become very popular for describing the effect of an individual or organization on the larger environment, but little consensus exists on the definitions or boundaries of these terms. Weidmann and Minx[36] analyzed disparate descriptions of carbon footprint by different organizations and synthesized the following definition for a proposed standard:

> "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."

This definition includes life-cycle data and direct and indirect sources of carbon, but does not include greenhouse gases (GHGs) other than carbon dioxide (CO_2). Since other GHGs can be calculated along with carbon dioxide emissions for SWD, and combined using IPCC Global Warming Potentials (GWPs), a more comprehensive approach to determining footprint would also include methane (CH_4) and nitrous oxide (N_2O) in footprint calculations. The above definition is oriented toward the product level, which could be easily adapted to SWD by modifying as follows:

> The GHG footprint is a measure of the exclusive total amount of GHG emissions directly and indirectly caused by Steelcase Wood Products Division and its product lines, including those accumulated over the life stages of the product line from cradle to gate.

Appropriate boundaries must be set that only reflect the domain of decision-making for Steelcase Wood managers while still providing managers with a clear view of the complete set of the impacts of their business decisions. In this regard, all upstream carbon emissions and wastes are included in this analysis since the choice of supply chain rests with SWD managers. Likewise, the energy and emissions required for transportation of raw materials or finished components to SWD for further manufacture is also included in these footprint calculations. At this time there is insufficient data regarding the user, transportation to user, and end of life phases for SWD products so they will not be included within this project. However, managers should be cognizant of the impacts of decisions outside their immediate sphere of influence. For instance, construction of a new plant far from a central customer base will increase shipping energy and GHG emissions. While the location of consumers is not considered in this study, such an external characteristic of business reality should be weighed in the context of the larger business decision. The boundaries of the calculations will be discussed further in Section 5.

As mentioned previously, many pitfalls arise when using normalized ratios for environmental performance evaluation. Foremost among these is the misconception that "relative improvement" is always good. While relative improvement to previous operations is beneficial, as the absolute volume of operations increases the absolute volume of carbon emissions and energy use may also increase. While corporate goals may be normalized by economic output, climate change resulting from greenhouse gas emissions is based on absolute atmospheric carbon equivalent levels. The importance of absolute reductions in carbon levels should not be marginalized.

Other pitfalls may arise from the use of improper normalization quantities. In such cases, the economic value arising from an operation or process is not matched correctly with the environmental influence quantity tied to that operation or process. Additionally, changes in labor or capital efficiency over time (i.e., employee learning or process automation) can incorrectly signal improving environmental and resource efficiency over time if not corrected.

5. Data Collection and Methodology

5.1 Time Scope

The models developed within this study are designed to be used continuously on an annual, semi-annual, quarterly, or monthly basis to gauge SWD carbon footprint and energy use performance. Calculations are mostly based on SWD energy and supplier purchases. Therefore new carbon and energy footprint values can be calculated as often as these records are updated. For historical case studies, analysis periods were selected to capture the effect of recent SWD restructuring and compare the impacts of this restructuring to current SWD operations where historical data were available.

5.1.1 Benchmarking and EPI Footprint Calculations

This study establishes data collection and calculation techniques for current benchmarking and future measurement of carbon and energy indicators. To prevent anachronous comparisons, all monetary calculations are adjusted using Consumer Price Index (CPI) values. With minimal user input, adjustments for inflation using the various data sets and purchase data are modeled automatically. For accurate results, the end user must input data from a consistent time (i.e., all data needs to reflect the same time interval) and inflation information must be updated in the tracker model (discussed in detail in Appendix A).

5.1.2 Historical Case Studies

Plant consolidation, shifting product lines, new plant construction and a variety of other historical events within SWD have impacted the division's environmental performance. To evaluate the environmental effects of these events retroactively, historical data was examined for changes at selected times indicated by periods "a" and "b" in Figure 5.1. Two snapshots in time were evaluated where data was available and representative of steady-state operations both before and after recent divisional plant restructuring: November 2003 – April 2004 and calendar years 2006-2007.

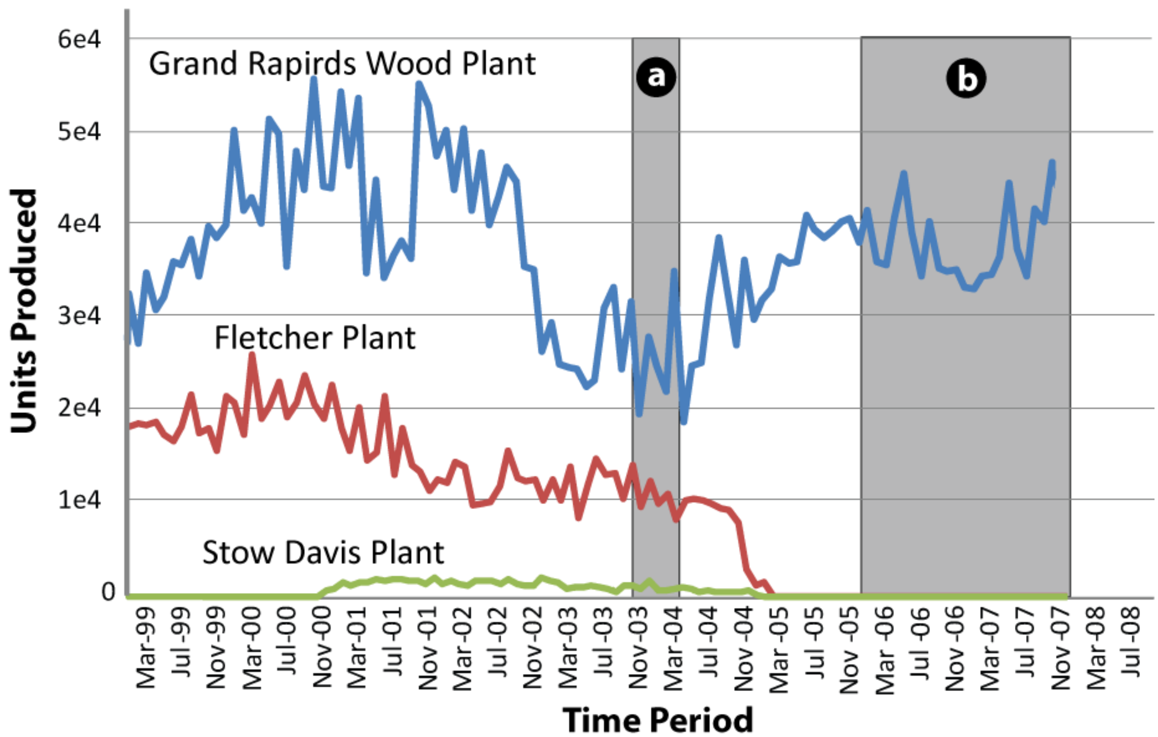


Figure 5.1 Units produced by the three largest SWD facilities over time indicating "a", the historical case study from November2003-April2003 and "b", the historical case study from 2006-2007.

To assess the environmental effects of plant consolidation within these historical snapshots, three SWD facilities were included within the study boundaries. Of eight domestic SCS production facilities that manufactured SWD products since 2003, only three – Grand Rapids Wood Plant (GR), Fletcher (FL), and Stow Davis Furniture (SD) - produced enough product or value to be considered. The other five plants consistently produced less than ten percent of the total SWD product units and value and are therefore ignored. From Nov03-Apr04 all three facilities (GR, FL, and SD) were producing SWD products, while during 2006 and 2007 the GR Wood Plant was responsible for all SWD production based on reports and data from SWD personnel.

Two significant events at the GR plant may influence environmental performance measurement, one of which falls within the scope of this project. First, around November 2001 there was a several month transition period from the old GR plant to the current LEED certified facility. Though important, we were unable to include this event within the scope of our project for three reasons:

1. Lack of consistent energy data at the GR plants over this time period
2. A loss of data resolution due to the merging of energy purchase information from both plants into a single data set
3. Lack of data from SD and FL plants during the same time period

Second, during March 2006 Grand Rapids Laminate (a non-SWD production line) moved into the Grand Rapids Wood Plant. This event is within the scope of study and is evaluated within this project through a process energy allocation discussed in sections 5.2.6 and 5.3.2.

5.2 System Boundaries

5.2.1 SWD Footprint Boundary

Life cycle assessment (LCA) is an analytical framework for measuring environmental, economic, and social impacts of a product system or technology by evaluating the inputs and outputs of a product or process throughout its life cycle, including raw material acquisition, production, use, final disposal or recycling, and transportation (denoted by the "T" arrows) needed between these phases. A generic product life cycle for Steelcase Wood products is shown in Figure 5.2.

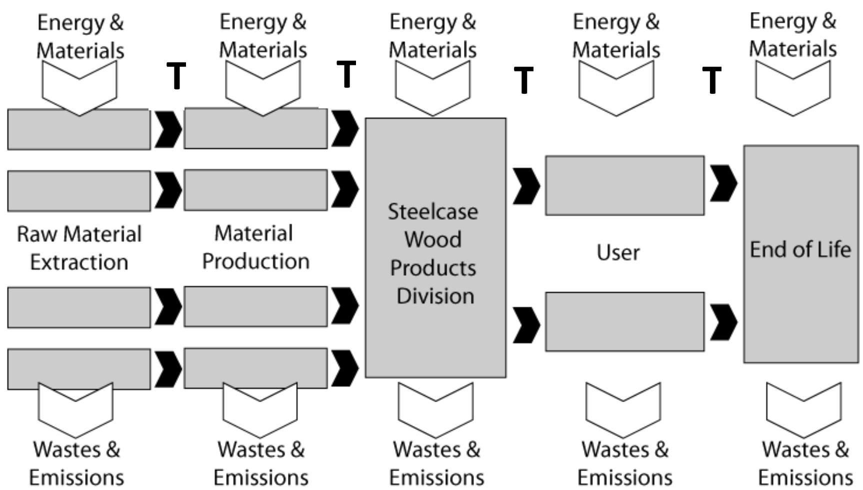


Figure 5.2. Generic SWD product life cycle

As discussed above, typical life-cycle analysis studies focus on individual products, processes, or technologies. However such a product or process focused assessment makes little sense for manufacturing division responsible for the production of a cadre of products using a number of different processes. Therefore, the notion of an operational footprint is used. To model this footprint, aggregate supplier environmental data, commodity averages, energy consumption and GHG emissions for groups of supplied materials and commodities can be estimated for various operations within the value chain shown above, somewhat analogous to life-cycle analysis. As shown in Figure 5.3, this study calculates environmental impacts from cradle-to-gate for all products sold by SWD for a given time period, which includes raw material acquisition, transportation (denoted by the "T" arrows) and process stages required to create the finished products. This study does not include transportation away from SWD or the products use or end-of-life life-cycle stages. As more information about SCS product sales becomes available, system boundaries could be extended to include transportation to the customer as a first step for expanding this model. However, since most environmental impacts of SCS furniture have been characterized upstream of the user phase in life cycle assessment[37] this model is a useful tool for management decisions in its current form.

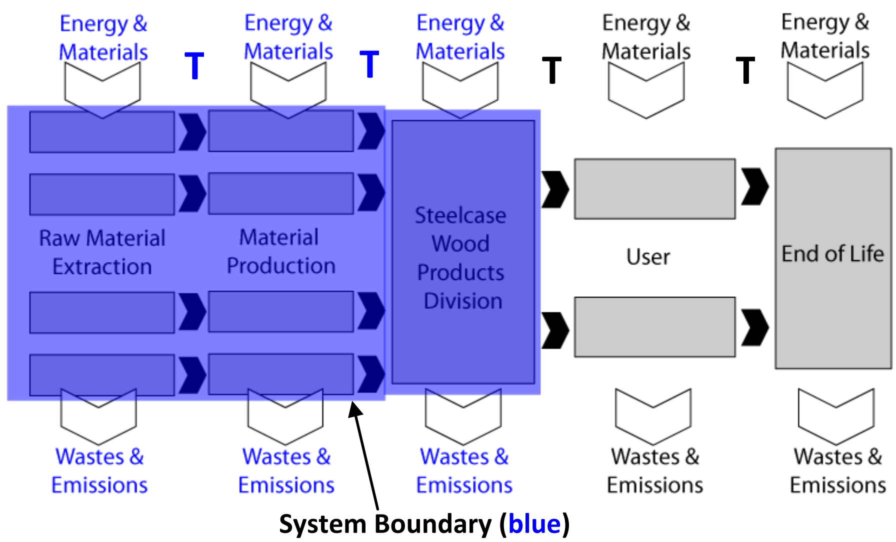


Figure 5.3. System boundary for SWD footprint calculations

5.2.2 Total Fuel Cycle Energy and Greenhouse Gas Emissions

In addition to the energy and emissions resulting from the combustion of fossil fuel directly at SWD (i.e., heating and manufacturing process natural gas consumption), additional energy is needed for acquisition, transport, and refinement of fuel in upstream life cycle stages. These upstream stages are calculated from cradle-to gate in addition to the direct energy and GHG from direct combustion at SWD plants. Only carbon dioxide, methane and nitrous oxide emissions are included within the scope of total fuel cycle calculations. According to EIOLCA environmental impact characterization for the Wood office furniture manufacturing sector (NAICS 337211), carbon dioxide, methane, and nitrous oxide account for roughly 86%, 9%, and 3% of the total greenhouse gases. The remaining 2% of GHG emissions are assumed negligible for SWD fuel use.

5.2.3 Material Production Energy and Greenhouse Gas Emissions

All GHG and energy involved in the production of materials used in the production of SWD products is captured with the boundaries of this model. This includes feedstock energies, which account for energy embodied in materials made from energy sources (e.g., oil used as a feedstock for plastic). For such materials, the total amount of material production energy includes both fuels burned in material processing and the energy content of the material itself. GHG associated with combustion of feedstock energy are not counted within this study since the end-of-life stage is uncertain and outside the scope of this model.

5.2.4 Total Primary Energy

Total primary energy is the principle measure of energy consumption in the benchmark indicators within this project. It is the sum of the material production energy (feedstock and process energy) and the total fuel cycle energy (combustion and upstream energy) described above. Total GHG calculations in this model have the same scope as total primary energy – direct and indirect emissions from cradle-to gate.

5.2.5 Transportation Modeling

Transportation energy and GHG emissions resulting from transportation of materials are included using direct information from SWD for direct suppliers and using industry and commodity average data to estimate intermediate transportation stages. Transportation from SWD to the client is not included. Total fuel cycle energy for transportation fuels is included, but fuel use associated with vehicle and infrastructure construction and maintenance is not.

5.2.6 Allocation

Due to the dynamic and shifting product mix between the various SCS production facilities, the project boundaries are shifted to include or exclude portions of SWD plant as appropriate. This is necessary in the current Grand Rapids Wood Plant where a portion of the total energy consumed by the plant is used to process Grand Rapids Laminate products which are not SWD products. Energy purchases at SCS are accounted for on a plant-wide basis and therefore could include energy for operations outside the SWD footprint. Allocations have been made based on floor space used by each division or product line in both historical case studies and current operations models and will need to be updated into the future based on shifting capital asset al.location. Specific allocation assumptions are detailed in Section 5.3.2.

5.3 Model Construction

This section describes the construction of the model along with procedures to collect and utilize data for SWD indicator calculations. Data formats and the general input procedure are described, the E-GHG tracker model is introduced, and the methods for analyzing results from the tracker are discussed.

5.3.1 Data Sources

Primary information sources were provided by SCS personnel and financial and environmental accounting records in a variety of formats, including anecdotal SWD history information, staff preferences for useful indicator selection, environmental management reports, financial accounting records, and purchasing tables. Indirect information from a variety of data sets was also used, as described below.

Steelcase Sourcing Service Center (SSC)

The SCS Sourcing Service Center (SSC) maintains a variety of records for global SCS operations and provided information organized by individual material purchase for each SCS plant. A query to SCS returns data in an excel spreadsheet for the categories summarized in Table 5.1 below.

TABLE 5.1 SSC Output described by column in order received from SSC

Excel Column	SSC Labeled Column header	Column Description	Required for Model Calculations
A	{merged} Material Group	Material Group number	Y
B	{merged} Material Group	Material Group description	N
C	{merged} Vendor (SupplySync)	Supplier name	N
D	{merged} Vendor (SupplySync)	Supplier code	N
E	Name 3	Supplier code name	N
F	Street Name	Supplier street address	N/Y
G	Location	Supplier city	N/Y
H	{merged} Region	State code	N/Y
I	{merged} Region	State	N/Y
J	Postal Code	Postal code	Y/N
K	Telephone 1	Telephone number	N
L	Supplier Email Contact	Supplier email contact	N
M	Steelcase Supplier Contact	Steelcase supplier contact	N
N	{merged} Material	Material short code	N
O	{merged} Material	Material description	Y
P	Invoice $ yy	Purchase price	Y
Q	Invoice qty yy	Purchase quantity	N

From this information the purchase dollars, material group numbers, material descriptions, and supplier locations (either by zip code or physical address) are all necessary for EPI calculation. This data is input directly to the tracker model in the format it was received from SSC. Calculation steps involving this data within the tracker model are discussed in Appendix A.

Steelcase Wood Division Personnel and Energy Buyers

A large amount of information from SWD has been reviewed and analyzed so that only the most useful and comprehensive data is included in this report to streamline future implementation and to ensure accuracy. The data sources characterized by a wide scope and limited detail such as purchase dollar amounts for the division proved more useful than data with a narrower scope and detailed information like toxic release inventory data for the GR wood plant. This is primarily due to the vast number of materials and supplies that SWD uses every year and the often incomplete nature of environmental tracking data. In trying to manage the 8000+ purchases made annually by SWD, automated algorithms were always sought for calculating environmental data from complete data sources.

For the historical case studies, SWD personnel provided a brief history of SWD operations and helped in identifying critical restructuring moments in the past to evaluate environmental performance. Plant consolidation, relocation and the inclusion of Grand Rapids Laminate into the GR Wood Plant were found to be the most important events to consider, which led to the selection of the November 2003 to April 2004 and calendar year 2006 to 2007 time periods. These periods represented steady-state SWD operations between times of large change.

Direct energy information was provided through SWD personnel in the form of energy purchases and environmental management reports. These two independent sources were compared for consistency and then used as input for the tracker model. For the 2006 to 2007 time period, only energy purchase data was used and for the November 2003 to April 2004 time period, both sets of data were used in a complementary fashion to reconstruct data gaps. For future implementation, only energy purchase information should be used for accuracy and consistency. Prior to entry into the tracker model, the energy use data must be summed for the entire analysis period and converted to kWh for electricity use and therms for natural gas use if the data are in any other format.

SWD personnel also estimated the portion of energy consumed within the GR Wood plant that was used for the processing the Grand Rapids Laminate line that is not a SWD product. As mentioned previously, this was done on a floor space allocation. This information was used to adjust the models boundaries within the GR Wood Plant to include only SWD activities. This allocation scheme can be updated within the tracker model as necessary.

For transportation modeling, SWD personnel confirmed manufacturing locations for 26 suppliers for 2006-2007 shipments. This represented approximately 54% by value of all products purchased from suppliers. SSC supplied supplier addresses were used whenever confirmed manufacturing locations were unavailable.

All financial information used in the indicator calculations came from financial accounting records provided by SWD personnel. The metrics provided and their descriptions are outlined in Table 5.2 below.

TABLE 5.2 Financial accounting records provided by SWD personnel

Economic metric	Description
NDN (normal dealer net)	Half the list price of units sold in dollars
MUC (model unit count)	Derivative of standard hours, i.e., labor efficiency
Units (total production units)	Count of all units sold - any type, value or size
Material cost	Sum of materials cost from SSC purchase data
NDN-Material cost	NDN minus the sum of all purchases, i.e., value added

Carnegie Mellon University EIOLCA Dataset (http://www.eiolca.net)

The Carnegie Mellon University's Economic Input-Output Life Cycle Assessment (EIOLCA) dataset was used in this study to calculate material production energy and emissions for material purchase values from cradle to gate for tier-one SWD suppliers. Essentially, all energy use and GHG emissions shown in Figure 5.3 up to transportation from the suppliers to SWD operations are captured by the EIOLCA dataset.

This dataset is based on a variation of life-cycle assessment that uses linear algebra techniques to allocate US environmental impacts over the 500 different commodity and service sectors within the US commodity/commodity Input-Output (IO) matrix developed by the US Department of Commerce. This is a dollar-value driven model. To use EIOLCA to calculate the environmental impact of a specific supplier purchase at SWD, the description of each item purchased by SWD is matched to an analogous industrial sector within the EIOLCA matrix. Based on this link with the EIOLCA model, the dollar value for that purchase and the appropriate set of environmental impacts to be evaluated (e.g., GHG emissions) are entered. The details of this linking process are described in the tracker manual in Appendix A. In the tracker model this process is simplified by normalizing all impact categories (e.i. that correspond to a material purchase code used by SWD) by a purchase price of one dollar. This normalized value is then automatically multiplied by the correct purchase price within the tracker model. In this way, EPI calculations are made independently of the online EIOLCA model. The current EIOLCA model is based on the 1997 US Department of Commerce Input output matrix. Therefore, all purchase prices are converted to 1997 USD within the tracker model automatically to calculate the appropriate amount of energy consumed and GHG emissions released.

This dataset makes benchmarking possible with limited data but introduces limitations in model accuracy. Industry average aggregate data will never perfectly represent actual Steelcase purchases because of regional and operational supply chain variations. Furthermore, SCS direct data is aggregated prior to input into the EIOLCA dataset into material purchase codes that will never represent the same supply chains as the NAICS codes used in EIOLCA. Output from the EIOLCA dataset is aggregated again for environmental impact characterization. Though inflation is adjusted for within the model, inflation rates of individual commodities are not. Therefore unusual inflation rates will have a disproportionate effect on environmental impact calculations since characterization of impacts is based on dollar values. In a survey of life cycle based sustainability metrics, Keoleian and Spitzley[38] also note that price inhomogeniety within a sector can cause errors since EIOLCA computes impacts linearly. For example, “the resource and environmental intensity for production of a $50,000 vehicle is not expected to be 2.5 times that of a $20,000 vehicle.”

Care should be taken to update the tracker model with new EIOLCA values following the next update of the EIOLCA dataset. This dataset is publicly available online at http://www.eiolca.net for future tracker updating (Appendix A).

The use of this modeling can be expanded on a limited basis to other countries by selecting the German, Spanish, or Canadian EIOLCA matrices (also available at http://www.eiolca.net). The current model will require adaptation to the different industry sector aggregations in these international datasets. Additionally, greater industry aggregation in these international models (fewer industry classifications) only intensifies modeling errors stemming from averaging industry sector data. The existence of these international models however, does allow for the application of this model to a portion of Steelcase’s global manufacturing operations.

US Commodity Flow Survey

The US Commodity Flow Survey (CFS) is a joint publication between the US Bureau of the Census, the US Department of Commerce, and the Bureau of Transportation Statistics, to provide data on shipment characteristics by commodity type for goods shipped by truck, rail, freighter, or air in North America. The CFS classifies commodities by Standard Classification of Transported Goods Codes (STGC) and gathers commodity shipment information through the use of commercial and industrial surveys. The latest CFS available at the time of this report was for 2002 data.

The CFS is used in transportation modeling to provide a weight per dollar for a given STGC code (paired with a SCS material purchase code) which is used to find the weight of purchases by SWD. Since transportation energy and emissions modeling is based on shipping weight and distance quantities (i.e., ton-mile), the weight of materials purchased by SWD is needed. However, only the dollar value of purchases is currently recorded by SWD. In the tracker model, purchase prices are divided by dollar per ton values from CFS data to yield total weight for that purchase. Prior to input in the tracker model, CFS data must be downloaded and computed to the normalized 1 dollar per ton value. Within the tracker model, conversion of purchase price is automatically converted to 2002 US dollars (the most recent publication of the US Commodity Flow Survey) to calculate inflation adjusted purchase weight.

In some cases, product descriptions were detailed enough to calculate weight of purchases without CFS data. For instance, it was possible to derive $/ton values for veneer and woodcore material group codes directly from SSC information using volumetric dimensions provided in the material description column (O) and the Invoice quantity (Q) columns and common material densities. This “value density” quantity was then given a unique code within the tracker model by appending the prefix “111” to the existing material group codes 062 and 064 and used for transportation energy calculations in place of the commodity flow survey data used to estimate masses of shipped materials. The value density referenced within the tracker model is the average value density for all products within the material code that contained enough information to calculate product weight. Future EPI efforts should continue this process by adding SWD specific value densities for materials in various material product codes or tracking material shipping weights as purchases arrive at SWD loading docks.

Franklin Associates Data

Franklin Associates life cycle inventory energy data provides information on the direct and indirect energy use and GHG emissions associated fuel combustion. Since direct information on fossil fuel purchases was available for SWD plants, this dataset was used to calculate the upstream energy and GHG emissions associated with the fuel extraction, processing, and transportation to SWD facilities. For transportation modeling this dataset was used to estimate both combustion and upstream energy and GHG emissions for each transportation mode (i.e., truck, freighter, and rail). Values from this dataset are embedded in automatic calculations within the tracker model and do not require user input for EPI calculations. This dataset should nonetheless be updated as new information becomes available to reflect changing technology.

Energy Information Administration, US Department of Energy

The electricity used by SWD plants is analyzed using a local fuel source mix for electricity generation to accurately model upstream energy use and GHG emissions. The US EIA provides annual summaries of electrical power generation by state which can be downloaded in spreadsheet format. Once the proportion of each fuel used to provide a given amount of energy is known, total fuel cycle energy and GHG can be calculated for the electricity purchased at each SWD plant.

Shipping Distance Information from Google Maps (http://www.local.google.com)

Transportation energy and GHG calculations require a known shipping distance, which is estimated using an online driving directions service from Google, Inc. at www.local.google.com. Since exact driving distances for each supplier are not known for material purchases, the accuracy provided by this service is adequate for the scope of this project and should not require adjustment into the future. As mentioned previously, care must be taken to identify the address of point-of-manufacture rather than the corporate headquarters for each SWD supplier. Additional concerns arise from sourcing from a parts distributor. Point-of-manufacture addresses were verified by SCS buyers for 26 large suppliers that represent 54% of the total purchase value for or all purchases in the 2006-2007 case study.

Global Warming Potentials from Intergovernmental Panel on Climate Change

Global warming is driven by the release of greenhouse gases. Nitrous oxide (N_20), carbon dioxide (CO_2), methane (CH_4), sulfur hexafluoride (SF_6), and two classes of man-made gases – hydrofluorocarbon (HFC's) and perfluorocarbons (PFC's) – all have unique atmospheric effects such that some gases have a much stronger impact on global warming that others. Global Warming Potential (GWP) is a measure of the different impact of each greenhouse gas within the atmosphere. GWP's for each GHG are normalized by CO_2 to yield CO_2-equivalents that equate the amount of CO_2 necessary to create an atmospheric effect with the atmospheric effect of a mix of GHG emissions. For example, with a GWP of 25 based on IPCC 2007, methane released to the atmosphere will have an atmospheric impact 25 times greater than the same amount of CO_2 released. Therefore, if 4 pounds of methane were released into the atmosphere, its atmospheric impact would equal a release of 100 pounds of CO_2, or 100 pounds of CO_2-equivalents. This normalization is useful so that methane, CO_2 and N_2O emissions can be added to yield a total GHG number that accurately reflects the relative impact of each gas based on their individual effects within the atmosphere. N_20 emissions from all fuels for transportation and processing at SWD were calculated using "2006 IPCC Guidelines for National Greenhouse Gas Inventories" from IPCC because Franklin data either lacked these values or assumed N_2O emissions equal to 10% of NO_X emissions.

Data Flow and Calculations

Figure 5.4 indicates the major data sources used in the context of the supply chain life cycle stages. Figure 5.5 shows how the same data sources are used to characterize energy and GHG footprint. In depth calculation details are discussed in section 5.3.3 and Appendix A.

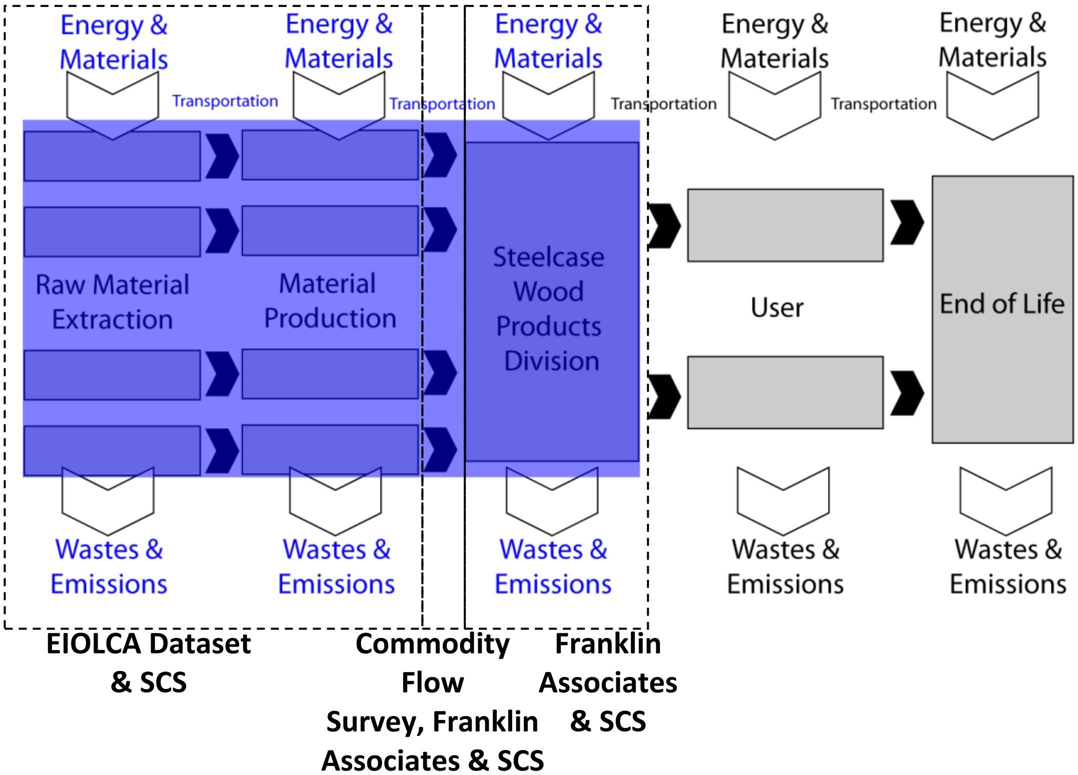


Figure 5.4 Relationship between datasets and product life cycle stage

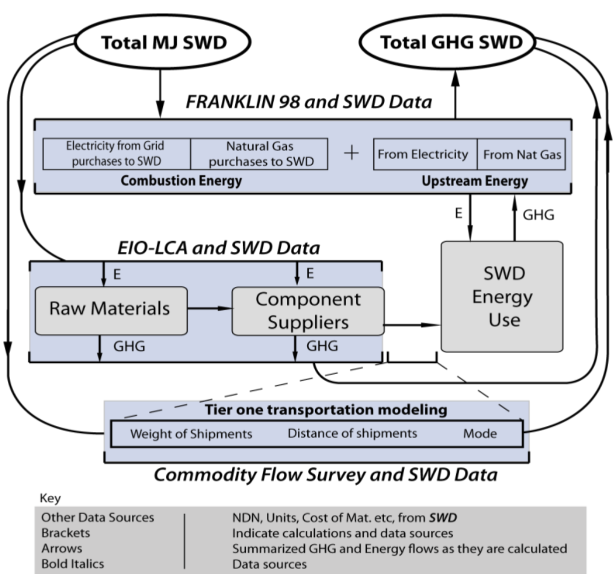


Figure 5.5 Major data sources used for characterizing selected environmental impacts as inputs and outputs to SWD operations and material supply chain

Comparison Between Process Based and EIOLCA Characterization Data

Division level, process-based life cycle inventory data insufficiencies require the use of EIOLCA data for calculating all impacts of purchased materials at SWD. However, within two material purchase codes, both process based LCA and EIOLCA life-cycle data for energy consumption and GHG emissions were available and impacts were calculated for comparison. Direct comparisons between these two techniques provide a perspective on:

- Comparability/Interchangeability of process based and EIOLCA datasets for this project
- The affects of aggregation of sector categories in EIOLCA
- The variability of local, process specific data compared to average data
- The effects of system boundaries on energy and greenhouse gas calculations for glass and woodcores

Sufficient data was available at SWD to complete process based energy consumption and GHG emission life cycle inventories on 99.6% of Woodcore and 82.9% of Glass (based on purchase value) material purchase code purchases for the 2006-2007 time period using material purchase data from SWD, EIOLCA, and the SimaPro software databases[39]. Process based calculations utilized part dimensions from purchase information from SSC and standard density information for the specified material to convert each purchase to a mass of material purchased, these masses were then used in process based LCA to determine associated life cycle energy and GHG impacts. Only two glass dimensions were available in the purchase information so all glass thickness was assumed to be one-eighth of an inch. Though data is sufficient for calculations using these purchases, the specific system boundaries and product classification into dataset categories are not identical for these two techniques, limiting direct comparability.

TABLE 5.3 Comparison between process based and economic input-output life-cycle energy consumption and GHG characterization data using SWD purchases from two material purchase codes

Dataset	Material Category	Material Production MJ	Material Production MT CO2Eq
Material Group Code 023 - Glass			
EIOLCA	Flat Glass Manufacturing (32721A)	8.2E+06	5.7E+02
PRé Consultants	Flat glass, coated, at plant/RER U	5.7E+05	4.6E+01
PRé Consultants	Float glass, coated ETH U	5.3E+05	4.2E+01
Material Group Code 065 - Woodcore			
EIOLCA	Reconstituted wood product manufacturing (321219)	1.3E+07	9.6E+02
PRé Consultants	Particle board, indoor use, at plant/RER U	1.1E+08	1.4E+03
PRé Consultants	Wood board ETH U	1.9E+07	1.2E+03

Compared to process based LCA data, the energy and GHG impacts for the glass material group code using EIOLCA characterization were considerably higher (Table 5.3). This may be the result of the aggregation of high energy intensity goods into the Flat Glass Manufacturing sector of EIOLCA (which also includes optical glass, Christmas tree ornaments, scientific glass, and glass product manufacturing using purchased glass) that would raise the average environmental impact of the entire sector. Alternatively, the commodity inflation price of glass may have exceeded average Consumer Price Index inflation rates since the 1997 EIOLCA data was published, which would in turn characterize the environmental impacts of a larger quantity of glass than was actually purchased by SWD. The assumption that all glass purchases are one eighth of an inch thick may also impact this comparison.

Process based energy consumption and GHG data compared well to EIOLCA data for the woodcore material purchase code. Material production energy consumption and GHG emissions impacts are higher with both process level assessments than they are for EIOLCA. Aggregation, system boundary misalignment, commodity inflation rates and other constraints may perversely affect environmental impact characterization for this material purchase code as well.

Data Adjustments and Assumptions

There were a number of instances in both current and historical data which required slight adjustments to the dataset or additional modeling assumptions.

- Process Energy data
    - March 04 FL gas anomaly – assumed decimal error – recorded value of 873770 therms was 9.8 times the average of the preceding and succeeding monthly totals. Value was divided by ten for calculations.
    - FL and GR cyclic gas adjustments calculated by ((cycle crest within snapshot + cycle trough before snapshot)/2)*6 months to yield 494973 and 719916 therms respectively (Appendix B).
    - Petroleum category in US grid mix data from EIA, USDOE was assumed to be 100% residual fuel oil for all emissions and energy calculations based on a typical 19:1 RFO:DFO ratio for power generation in 1996 according to Franklin Associates 98.
    - Two sources of data were used for process energy – energy purchase data for GR Wood through all time periods and environmental management reports for Fletcher and Stow Davis.
- NDN data
    - 2006-2007 NDN data lacking in November and December data 2007 - 2 year NDN data calculated by averaging NDN over 22 available months and multiplying by 24 months.
- Transportation data
    - Based on item dimensions in purchase information from SSC and common density values for wood products. $/ton values were calculated manually for Veneers and Woodcores. This is basically an adjustment of CFS data to be SWD specific. CFS data is not consistently used overall.
    - STGC code 305 (Leather and articles, luggage of related materials, and dressed furskins) Value density based on 1997 CFS data adjusted for inflation because of a lack of data in 2002 CFS.
    - All transportation assumed to be the following vehicles from Franklin Associates 98 – Ocean freighters, Tractor-trailer diesel powered trucks, and diesel powered locomotives

  - For first-tier suppliers who distribute materials from a variety of different companies, the average distance between SWD and each known second-tier supplier was used for every distance calculation for first-tier supplier (E.g., Rice Veneer from SSC data represents both Atlantic and Freeman Veneer whose average distance of 726 miles from SWD is used for all calculations from Rice Veneer).
  - When transportation mode is unknown, diesel truck transportation is assumed for North American shipments and a combination of ocean freighter and diesel trucks are used for international shipments.
  - For any supplier within Grand Rapids, a transportation distance of ten miles by diesel powered tractor-trailer is assumed.
  - Shipping distances were not accurately accounted for in the 2003-2004 historical case study. 2006-2007 should be used as the first data point baseline tracking.
  - In the absence of a confirmed manufacturing location for a supplier (26 confirmed in 2006-2007 data), SSC supplier locations are used for shipping distances which may not accurately reflect point-of-manufacture for these materials.
- Purchase Data
  - Purchases were aggregated into material group codes which were then aligned with the relevant NAICS sector in EIOLCA. Information on the NAICS sectors on the EIOLCA website were compared to the material descriptions field from the SSC purchase data to synchronize the two using subjective analysis.
  - Markup from SCS suppliers was assumed zero for material purchases. Actual purchase prices from SSC purchasing were used in calculations, whereas the EIOLCA model is based on production price of a material. Accounting for supplier markup would decrease the footprint of SCS slightly, but such data will likely remain unavailable.

5.3.2 Allocation Procedures

Allocation calculations are performed by multiplying total energy use for a plant by the fraction of plant floor space that is responsible for the processing of SWD products. The only current active allocation in this project is the allocation of energy and GHG from process energy at the GR Wood plant to GR Laminates rather than SWD. The proportion of total energy use attributed to SWD was allocated at 80% based on estimations from process engineers within the Wood Plant. Process energy used on Finished Goods and Computer Line products within the Wood Plant were assumed negligible based on estimates from SWD personnel and were therefore allocated using 0% of process energy.

Further refinement of the allocation of process energy can be made if the SWD (or total non-SWD) machine draw and total floor space for SWD plants is known based on the following formula, which adds SWD process energy to the proportion of overhead attributed to the SWD as allocated by the proportion of floor space.

$$P_{SWD} = \frac{\overbrace{(Process_{SWD}}^{\textit{Process allocation}} + \overbrace{(E_{tot} - Process_{tot}) * (F_{SWD}/F_{tot}))}^{\textit{Overhead allocation}}}{E_{tot}} \quad (5.1)$$

P_{SWD}: Proportion of energy allocated to SWD
$Process_{SWD}$: Process energy for SWD activities (non-overhead)
$Process_{tot}$: Process energy for all plant machines (SWD + all other; non-overhead)
F_{SWD}: Plant floor space occupied by SWD
F_{tot}: Total plant floor space
E_{tot}: Total energy use for plant

Future changes in process energy allocation based on this or other allocation calculations can be accounted for in the tracker model, see Appendix A.

Supplier purchase data does not require allocation because it is specific to SWD, but any supplier purchase information that includes multiple divisions would need to be allocated accordingly prior to entry into the tracker model by omitting purchases outside the project scope. The tracker model does not currently provide an input field for allocation of purchase data or economic data.

5.3.3 The Tracker Model

The tracker model is an excel spreadsheet responsible for the calculation of all EPI data. The model was designed to be dynamic, automated, and transparent with a minimum of user inputs for data sources listed above. Any data preparation steps are outlined in this section while calculations within the tracker model are detailed in Appendix A.

The primary output from the tracker model is an absolute measurement of physical environmental quantities and a relative EPI ratio that compares these physical environmental footprint amounts to economic quantities.

Absolute Physical Environmental Quantities

Total primary energy consumption and total GHG emissions were selected as the two physical environmental quantities measured within the scope of this project.

Total primary energy is calculated by summing material production energy (calculated from purchase values and EIOLCA data), total fuel cycle energy for energy purchases at SWD plants (calculated using Franklin Associates data), and total fuel cycle transportation energy (calculated from purchase prices, transportation distances, Franklin Associates, and CFS data). Calculation steps are described in detail in the tracker model manual (Appendix A) and notes within the tracker model itself.

Total GHG is calculated by first summing the masses of the three major GHG’s associated with SWD operations -methane, nitrous oxide and carbon dioxide - emitted in material production (calculated from purchase values and EIOLCA data), transportation (calculated from purchase prices, transportation distances, Franklin Associates, and CFS data), and process emissions at SWD (calculated from total fuel cycle emissions for energy purchases at SWD plants using Franklin Associates data) separately. The mass of each gas is then converted to CO_2-equivalents by multiplying by GWP values from IPCC data (shown in Table 5.4) and summed. Calculation steps are described in detail in the tracker model manual (Appendix A) and notes within the tracker model itself.

TABLE 5.4 GWP's for gases studied within this project

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298

Absolute Economic Quantities

Economic quantities have been well documented by existing financial accounting mechanisms within SWD. The only changes to economic data within this study were summations or averages over an analysis period to yield a single value, i.e., the sum of all NDN for a period, and data adjustments outlined in Appendix C . Values from the six month November 2003 – April 2004 time period were also extrapolated to match the length of the two year 2006 – 2007 period by increasing values by a factor of four for NDN and MUC values (see Appendix A). All economic data was provided directly from SWD personnel.

Environmental Performance Indicator Calculation

EPI ratios normalize a physical environmental quantity by an economic metric and output a single value for comparisons over time. This comparison is a simple ratio and is calculated by dividing an absolute physical environmental metric by an economic metric (Equation 4.1). For this model, a number of Environmental Indicators values are computed. These are shown in Table 5.5.

Table 5.5 environmental performance indicators computed

Metric	Derivation
Energy Consumption	**Total Energy [MJ]**
Energy Intensity (Total Value)	**Total Energy [MJ] / NDN [$]**
Energy Intensity (SWD Value Added)	**Total Energy [MJ] / (NDN – Material Purchases) [$]**
GHG Emissions	**Total CO_2 Equivalents [MT CO_2eq]**
GHG Intensity (Total Value)	**Total CO_2 Equivalents [MT CO_2eq]/ NDN [$]**
GHG Intensity (SWD Value Added)	**Total CO_2 Equivalents [MT CO_2eq]/ (NDN – Material Purchases) [$]**

SCS value added is based on NDN dollar values less the value of all material purchases made by SWD. This value should capture the difference in value between products leaving the SWD and raw materials and assemblies arriving at SWD. In other words, the value created by SWD operations.

6. Results and Discussion

6.1 Case Studies and Sensitivity Analysis

To assess the responsiveness of the EPI output, historical case studies involving SWD and three sets of sensitivity analysis are assessed. Sensitivity analysis scenarios were designed to simulate a possible change in SWD operations.

November 2003 – April 2004 Case Study

SWD Products were produced in the Stow Davis furniture, Fletcher, and Grand Rapids Wood plants from November 2003 to April 2004. EPI calculations were computed for all plants within this time period, with the exception of material production and transportation impacts from the Stow Davis plant (due to lack of data).

Calendar Year 2006 – 2007 Case Study

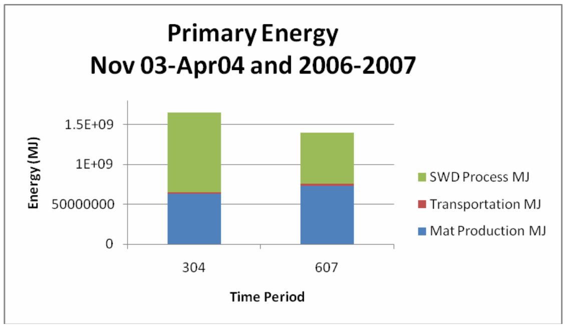
Since 2004, all SWD goods have been produced within the new GR wood plant. There are no major data omissions within this time period. EPI data from this time period will be compared to 2003-2004 operations and all sensitivity analysis scenarios.

Comparing November 2003 – April 2004 and 2006 – 2007

The impact of plant consolidation can be assessed by comparing these two historical time periods, as the Fletcher and Stow Davis furniture plants were combined into the GR Wood Plant. Since this time period is one-quarter the length of the 2006-2007 time period, all values are extrapolated from November2003-April2004 to match the two year time period.

6.1.1 EPI Results Comparing November 2003–April 2004 and 2006–2007 Case Studies

Figures 6.1 and 6.2 and Table 6.1 compare the absolute and relative changes in environmental impacts between the 2003-2004 and 2006-2007 analysis periods. In general, the absolute environmental burdens have decreased between these periods. Total GHG emissions and total primary energy consumption at SWD decreased by about 16% and 13% respectively. Of the entire SWD operation, total process energy decreased fastest with a reduction of 36% while transportation increased most rapidly with a roughly 100% increase in transportation energy and GHG emissions. The transportation modeling for the 2003-2004 time period are not an accurate representation of actual impacts due to missing data, so the increase in transportation impact is artificially inflated here. Environmental performance indicators show that SWD emits and consumes less per dollar sold and per dollar sold minus material costs between these two periods.



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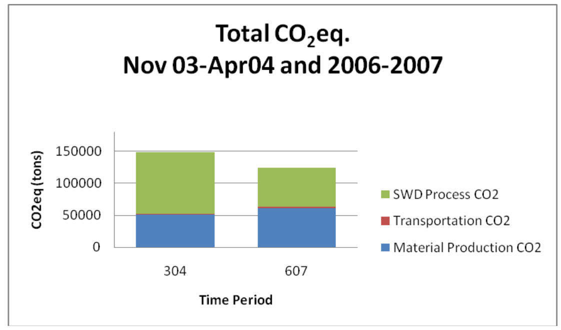
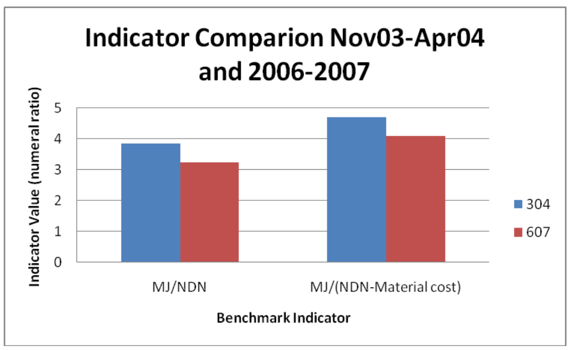


(b)

Figure 6.1 a and b. Comparison of absolute environmental performance metrics for SWD operation and its components between Nov2003- Apr2004 and 2006-2007 based on a. total primary energy in MJ and b. total emissions in CO_2equivalents



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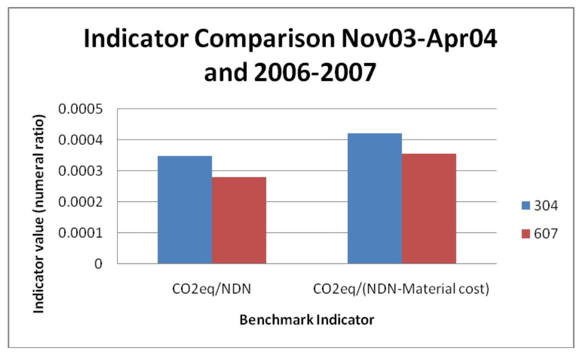


(b)

Figure 6.2a and b. Comparison of four EPI values for SWD operations between Nov2003-April2004 and 2006-2007 based on environmental quantities measured in a. total primary energy in MJ and b. total emissions in CO_2equivalents

Table 6.1 Absolute and relative environmental performance metrics and their percent change for SWD operations from Nov2003 – Apr2004 to 2006-2007.

Metric	2003-04	2006-07	% Change from 2003-04 to 2006-07
Mat Production MJ	6.4E+08	7.6E+08	20
Transportation MJ	1.3E+07	2.6E+07	100
SWD Process MJ	1.0E+09	6.4E+08	-36
Primary E MJ	1.6E+09	1.4E+09	-13
Material Production CO2	5.1E+04	6.1E+04	20
Transportation CO2	9.5E+02	1.9E+03	101
SWD Process CO2	9.7E+04	6.2E+04	-36
Total CO2	1.5E+05	1.2E+05	-16
MJ/NDN	3.8E+00	3.2E+00	-16
MJ/(NDN-Material cost)	4.7E+00	4.1E+00	-13
MJ/Unit	1.9E+03	1.7E+03	-11
CO2eq/NDN	3.5E-04	2.8E-04	-19
CO2eq/(NDN-Material cost)	4.2E-04	3.5E-04	-16
CO2eq/unit	1.7E-01	1.5E-01	-14

Material Purchase Code Analysis Comparing November 2003-April 2004 and 2006-2007 Data

High data resolution for individual purchase values allow for in depth analysis of purchase trends over time for the entire SWD operation. A set of calculations (independent of benchmark EPI calculations) in the tracker model sums purchases into environmental impact characterization categories to facilitate the analysis of purchase trends at the material purchase code level. This treatment may aid SWD decision-making processes by identifying growth patterns in material types and finding material purchase groups with high environmental impacts.

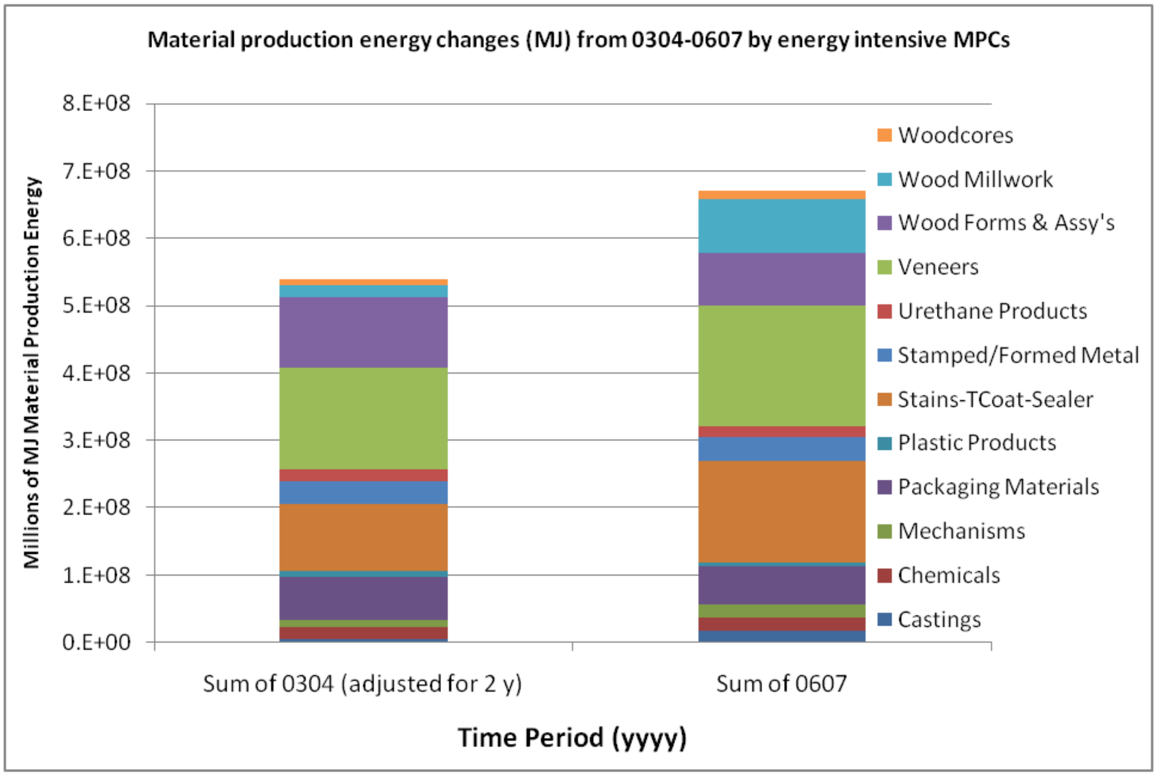


Figure 6.3. Comparison of material production energies of twelve selected material purchase groups from November 2003-April 2004 (adjusted temporally to align with 2 year data) to 2006-2007.

Comparison of material purchase codes from November 2003-April 2004 to 2006-2007 in Figure 6.3 shows the change in material production energies calculated from twelve of the material purchase groups that have the highest effect on the benchmark measurements. The Wood Millwork, Stains-TCoat-Sealer, and Castings material purchase codes exhibited a strong growth in material production energy while impacts from the Wood Forms & Assy's purchases decreased noticeably. To compare the change in material production energy by material purchase codes in relation to the rate of change in overall purchases for SWD over the same time periods, refer to Figure 6.4.

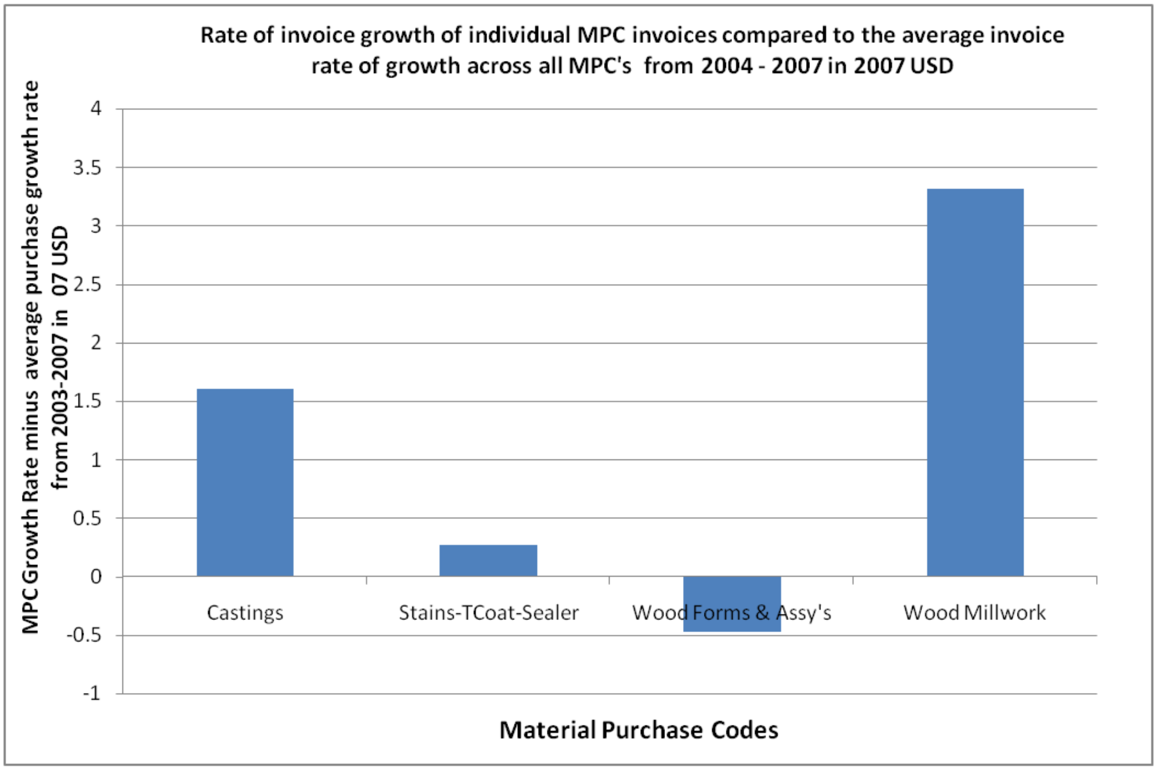


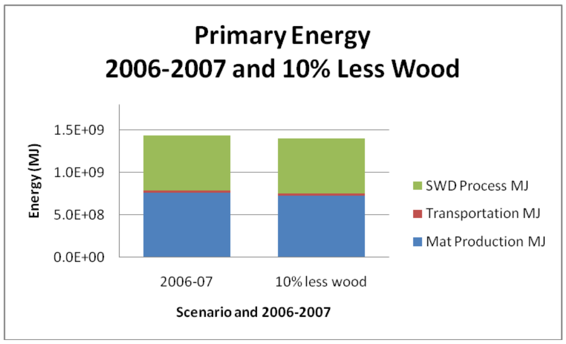
Figure 6.4. Comparison of the rate of change (06-07/03-04) in material production energies of four selected material purchase groups subtracted from the average rate of purchase price change of 1.21 (21% growth) for all material purchase groups from November 2003-April 2004 (adjusted temporally to align with 2 year data and adjusted for inflation into 2007 dollars) to 2006-2007.

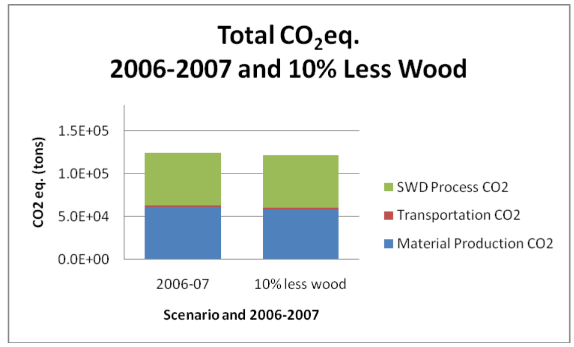
From Figures 6.3 and 6.4 we can clearly see that an increase in Wood Millwork purchases in the historical case study resulted in an increase in material production energy disproportionate to the overall rate of material purchase growth over the same period by a factor greater than three (453% absolute growth; 332% growth more than the average of 121%). Conversely, though Wood Forms & Assy's contributes significantly to overall material production energy, its effect has decreased faster than the overall rate of material purchase growth. Most of the remaining selected material purchase codes change at a rate close to the overall rate of material purchase growth within this comparison.

6.1.2 Scrap Rate Reduction Sensitivity Analysis

This scenario models a 10% theoretical reduction in wood scrap rates over the 2006-2007 analysis period. This is reduction is modeled by a 10% reduction of the material purchase values for wood purchases in the Veneer, Woodcore, Wood Forms & Assemblies, and Wood Millwork material purchase groups, as more efficient wood use would lead to less wood purchases required per unit or value of output. All other data within the scenario is identical to the 2006-2007 historical case study.

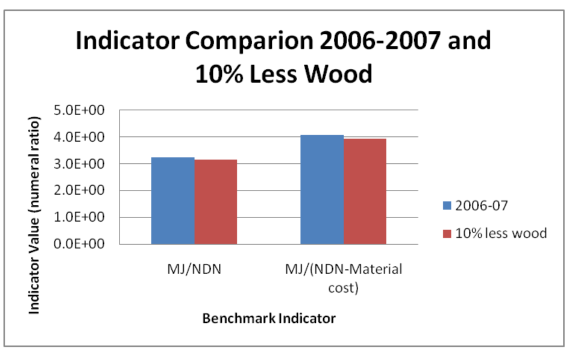
Figures 6.5 and 6.6 and Table 6.2 compare the absolute and relative changes in environmental impacts between the 2006-2007 case study and the scrap rate reduction scenario. This scenerio decreses environmental burdens in all categories. Total primary energy consumption dropped by about 3% while GHG reductions are negligible. Small eco-efficiency improvements were seen among all EPIs.

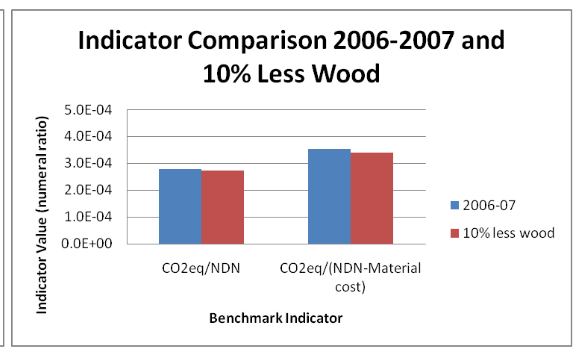




(a) **(b)**

Figure 6.5a and b. Comparison of absolute environmental performance metrics for SWD operation between 2006-2007 and a 10% reduction in wood scrap rate scenario based on a. total primary energy in MJ and b. total emissions in CO2equivalents





(a) **(b)**

Figure 6.6a and b. Comparison of four EPI values for SWD operations between 2006-2007 and a 10% reduction in wood scrap rate scenario based on environmental quantities measured in a. total primary energy in MJ and b. total emissions in CO_2equivalents

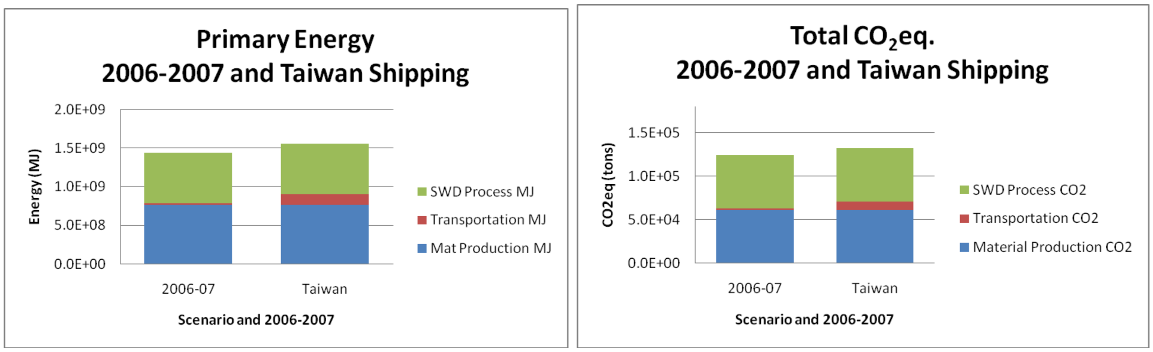
Table 6.2 Absolute and relative environmental performance metrics and their percent change for SWD operations for 2006-2007 and a 10% reduction in wood scrap rate scenario

Metric	2006-07	10% less wood	% change from 2006-07 to Scenario
Mat Production MJ	7.6E+08	7.3E+08	-5
Transportation MJ	2.6E+07	2.5E+07	-6
SWD Process MJ	6.4E+08	6.4E+08	0
Primary E MJ	1.4E+09	1.4E+09	-3
Material Production CO2	6.1E+04	5.8E+04	-5
Transportation CO2	1.9E+03	1.8E+03	-6
SWD Process CO2	6.2E+04	6.2E+04	0
Total CO2	1.2E+05	1.2E+05	-2
MJ/NDN	3.2E+00	3.1E+00	-3
MJ/(NDN-Material cost)	4.1E+00	3.9E+00	-4
MJ/Unit	1.7E+03	1.6E+03	-3
CO2eq/NDN	2.8E-04	2.7E-04	-2
CO2eq/(NDN-Material cost)	3.5E-04	3.4E-04	-4
CO2eq/unit	1.5E-01	1.4E-01	-2

6.1.3 Overseas Sourcing Sensitivity Analysis

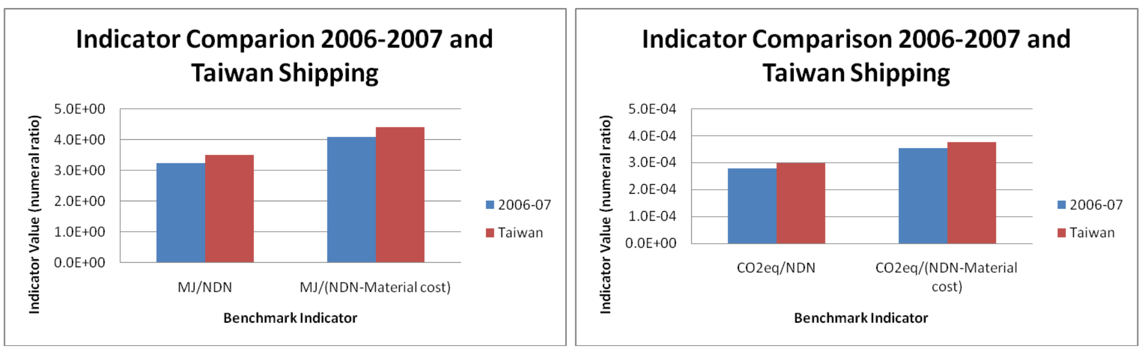
This scenario models an increased shipping distance for three arbitrary material purchase codes to evaluate the impacts of implanting and overseas supply chain. Shipping distances for the Plastics, Stains, and Wood Forms & Assemblies material purchase codes are changed from their 2006-2007 values to a distance roughly equivalent to the shipping distance from Taiwan (5569 miles ocean freighter plus 1856 miles diesel truck). All other data, including supplier environmental performance, is identical to the 2006-2007 historical case.

Figures 6.7 and 6.8 and Table 6.3 compare the absolute and relative changes in environmental impacts between the 2006-2007 case study and the overseas sourcing scenario. This scenario mostly affects absolute measures of transportation related environmental quantities such as the 438% increase in total transportation energy. Such a large increase in transportation energy only affected the EPI ratios slightly because of the small absolute impact of transportation on total primary energy, with a 6-8% increase seen for all ratios.



(a) **(b)**

Figure 6.7a and b. Comparison of absolute environmental performance metrics for SWD operation between 2006-2007 and a Taiwan supplier scenario based on a. total primary energy in MJ and b. total emissions in CO_2equivalents



(a) **(b)**

Figure 6.8a and b. Comparison of four EPI values for SWD operations between 2006-2007 and a Taiwan supplier scenario based on environmental quantities measured in a. total primary energy in MJ and b. total emissions in CO_2equivalents

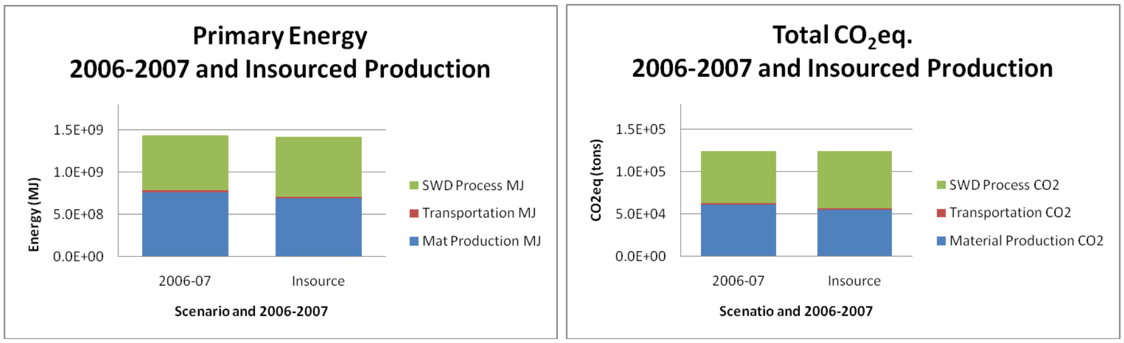
Table 6.3 Absolute and relative environmental performance metrics and their percent change for SWD operations for 2006-2007 and a Taiwan supplier scenario

Metric	2006-07	Taiwan	% change from 2006-07 to Scenario
Mat Production MJ	7.6E+08	7.6E+08	0
Transportation MJ	2.6E+07	1.4E+08	438
SWD Process MJ	6.4E+08	6.4E+08	0
Primary E MJ	1.4E+09	1.5E+09	8
Material Production CO2	6.1E+04	6.1E+04	0
Transportation CO2	1.9E+03	9.9E+03	420
SWD Process CO2	6.2E+04	6.2E+04	0
Total CO2	1.2E+05	1.3E+05	6
MJ/NDN	3.2E+00	3.5E+00	8
MJ/(NDN-Material cost)	4.1E+00	4.4E+00	8
MJ/Unit	1.7E+03	1.8E+03	8
CO2eq/NDN	2.8E-04	3.0E-04	6
CO2eq/(NDN-Material cost)	3.5E-04	3.8E-04	6
CO2eq/unit	1.5E-01	1.6E-01	6

6.1.4 Simulated Insourcing Sensitivity Analysis

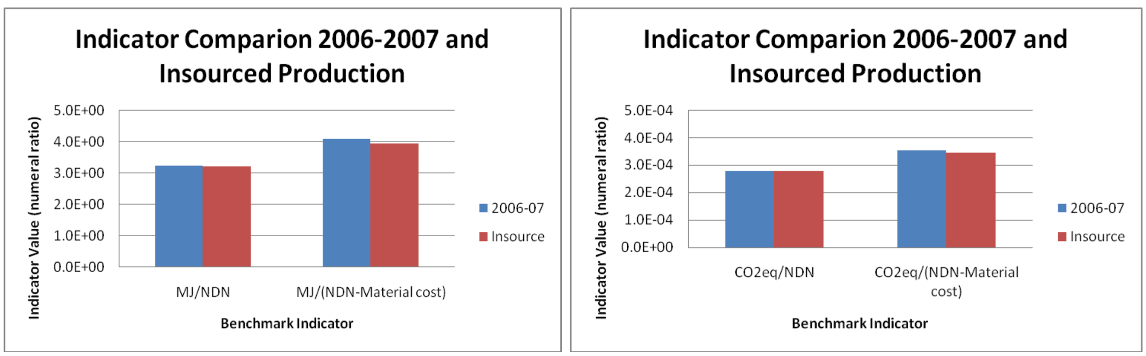
This scenario models decreased outsourcing at the GR Wood plant by decreasing the value of material purchases and increasing the material process energy used at GR wood. A 10% decrease in material purchase value and a 10% increase in total production energy is modeled (though there is no way of knowing the actual effect insourcing would have on material value and process energy values). All other data is identical to the 2006-2007 historical case.

Figures 6.9 and 6.10 and Table 6.4 compare the absolute and relative changes in environmental impacts between the 2006-2007 case study and the simulated insourcing scenario. This scenario had very small impacts on overall absolute or relative environmental impacts because increasing process energy was countered by decreasing upstream material production energy. Total primary energy decreased by 1% and the fastest changing benchmark indicator was total primary energy per NDN minus material cost with a 4% decrease in value. Due to the aggregation of the overall model, such small changes should be considered negligible.



(a) **(b)**

Figure 6.9a and b. Comparison of absolute environmental performance metrics for SWD operation between 2006-2007 and a simulated insourcing of three material purchase groups to GR Wood plant scenario based on a. total primary energy in MJ and b. total emissions in CO_2equivalents



(a) **(b)**

Figure 6.10a and b. Comparison of four EPI values for SWD operations between 2006-2007 and a simulated insourcing of three material purchase groups to GR Wood plant scenario based on environmental quantities measured in a. total primary energy in MJ and b. total emissions in CO_2equivalents

Table 6.4 Absolute and relative environmental performance metrics and their percent change for SWD operations for 2006-2007 and a simulated insourcing of three material purchase groups to GR Wood plant scenario

Metric	2006-07	Insource	% change from 2006-07 to Scenario
Mat Production MJ	7.6E+08	6.9E+08	-10
Transportation MJ	2.6E+07	2.4E+07	-10
SWD Process MJ	6.4E+08	7.1E+08	10
Primary E MJ	1.4E+09	1.4E+09	-1
Material Production CO2	6.1E+04	5.5E+04	-10
Transportation CO2	1.9E+03	1.7E+03	-10
SWD Process CO2	6.2E+04	6.8E+04	10
Total CO2	1.2E+05	1.2E+05	0
MJ/NDN	3.2E+00	3.2E+00	-1
MJ/(NDN-Material cost)	4.1E+00	3.9E+00	-4
MJ/Unit	1.7E+03	1.7E+03	-1
CO2eq/NDN	2.8E-04	2.8E-04	0
CO2eq/(NDN-Material cost)	3.5E-04	3.4E-04	-3
CO2eq/unit	1.5E-01	1.5E-01	0

6.1.5 Observations Based on Sensitivity and Case Study Analysis

The environmental performance indicators and environmental impact calculations performed were robust for both the historical case studies and the sensitivity analyses. Plant consolidation between 03/04 and 06/07 reduced the absolute amount of process energy required for the production of SWD enough to offset a 20% increase in material production energy and a 100% increase in transportation energy for an overall 13% drop in total primary energy consumption. The scrap rate reduction scenario was shown to improve environmental performance slightly, as expected with no perverse results. The shipment of three entire material group codes from Taiwan greatly affected the overall transportation energy requirements for SWD in this case, having a large impact on the rate of change of total primary energy consumption and benchmark indicators. However, the shipment of three entire material purchase codes from Taiwan is perhaps the most unrealistic scenario within the set of sensitivity analysis because the magnitude of the change in distance between current suppliers and Taiwan is very large. Further, it is unrealistic to assume that suppliers in Taiwan would have operations emissions similar to those in the US (assumed by using the EIOLCA dataset).

It is important to note that sensitivity analysis scenarios are not standardized in any way and are therefore not directly comparable. 10% changes were arbitrarily computed for two variables in two of the scenarios, and a dramatically different transportation distance was chosen for the third analysis based on SWD interest in assessing the environmental impacts of sourcing options from overseas suppliers. Each scenario is only relevant to the control data, which in each case is the 2006-2007 case study data that is not explicitly altered in the scenario descriptions.

6.2 Dataset Remarks

The only major data source omission from this report is the purchase value of materials used in the Stow Davis manufacturing plant during the period from November 2003 – April 2004. Since purchase data is used to calculate material production physical environmental quantities, transportation weights, and the NDN-Material Cost eco-efficiency denominator, this omission has an unknown but probably small effect on EPI values. During this time period, Stow Davis produced about two percent of the total units for the SWD – about thirty five times less than GR wood plant production by unit volume. Additionally, supplier locations were not confirmed for Fletcher or Stow Davis suppliers that no longer do business with the division, and unconfirmed shipping addresses were used calculating transportation impacts in all plants when confirmed addresses were not available.

Two independent sets of grid electricity purchase data were available for Fletcher and Grand Rapids plants so cross-referencing was possible. When compared, the two data sets match reasonably well within the bounds of this study.

7. Conclusions and Observations

7.1 Comparisons with Previous Studies

The results of previous LCA and GHG Emission Profile studies completed by the Center for Sustainable Systems for Steelcase are available upon request from the Center. The findings of this study are in line with those of the previous product-based LCA studies on the Answer panel, universal file cabinet, straight-front work surface, Airtouch table, Garland desk, and Siento chair. In those studies, transportation (including supplier-to-Steelcase and Steelcase-to-distributor) was responsible for roughly 5% to 10% of energy consumption or GHG emissions. In this study, transportation was slightly lower than this amount, since Steelcase-to-distributor transportation was not included. Unfortunately, energy and emission data in previous studies were not classified as Steelcase vs. outsourced, therefore comparison of those metrics is not possible.

Although the results seem consistent, great care should be taken when comparing these results to previous analysis. This is due to a number of factors including the incorporation of EIOLCA methods in this study, changes in system assumption (i.e., the transportation boundary discussed above), and changes in calculated impacts due the use of 1997 industry sector data. Apart from these concerns, the complete life cycle assessment story for North American Steelcase products and operations appears to be telling a consistent story among various studies.

7.2 Further Investigation

This model comprises a compact method for computing energy use and carbon footprint (GHG emissions) based on a limited amount of financial data, supplier purchase data, and energy purchase records. However, a great deal of research remains in the long term use of this model or generalizing its application to the wider Steelcase Corporation. Examples of challenges which require further research are noted below.

- The use of US-based EIOLCA data limits the applicability of this model to western economies, and likely only those operations based in North America. Expansion of this paradigm to other countries would require the use of different, but similar, economy-wide model (currently available for Germany, Spain, and Canada).
- The identification of specific “environmentally green” suppliers by SWD is not captured by this model. In this regard, only those suppliers that are closest to SWD operations are favored (since only the lower transportation impact will be realized). For suppliers that are “greener” than average within their industrial sector. Research must be carried out on improved methods for incorporating these suppliers into the model and verifying the purported environmental performance of such green suppliers.
- The generalization of this model to other Steelcase divisions, particularly those that are not involved with manufacturing, requires additional research. The accounting and allocation of travel, general overhead, green product design, and other value-adding, but hard to recognize, efforts should be incorporated to get a true view of the corporate footprint.

7.3 Determining the Energy and GHG Footprint at Steelcase Wood Division

This study found that the creation of an energy and carbon (GHG) footprint was possible for a North American manufacturer based on a limited amount of mainly financial data (e.g., purchases, sales values, etc.). Having well-developed accounting and financial tracking systems in place, most companies and industries can immediately use such a framework for estimation of corporate footprint.

Associated with this loose connection between limited financial data and more extensive environmental impact metrics is a relatively poor resolution within the model to small changes in operation. Resulting from the use of economy-wide EIOLCA data, specific supply chain sourcing by SWD to reduce environmental impact is not captured in this model. Since supplier transportation distance is accurately captured, this single metric (supplier location) receives too high a weight in this model. To rectify this loss of resolution, SWD is encouraged to request supplier energy and GHG footprint data in future sourcing decisions. However, the transparency of the data and differences in system boundaries between suppliers must be carefully considered to avoid unfair comparisons.

Regarding the historical and sensitivity case studies, the consolidation to a single manufacturing location in Grand Rapids, and the construction of an energy efficient LEED certified plant has resulted in a significant reduction in both energy use and GHG emissions for the SWD since 03/04. These improvements are due to reduction of both materials purchased and energy consumption at SWD facilities. Additional savings in elimination of inter-plant transportation were also likely realized, but not captured in this analysis. Missing data from the Stow Davis Furniture plant and transportation shipment locations from the 03/04 case study also underestimated the environmental impacts for 03/04 operations in this analysis.

As a corporation, Steelcase has set a number of very ambitious environmental goals for the near future. One major hurdle to reaching those goals is the establishment of a sound method for measurement of environmental performance metrics across the entire company. This study marks the first attempt at creating a data-driven model for characterization of energy and GHG footprint. The use of these methods will serve to further Steelcase's overall corporate environmental mission while providing a defensible basis for business decisions and management. As with previous Steelcase LCA work, this project will continue to bridge communities within the Steelcase Corporation and lead to products that excite customers while reducing the global environmental impact.

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APPENDIX A

Using the E-GHG Tracker Model

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Introduction

The E-GHG tracker model was developed for the Steelcase Wood Products Division (SWD) to provide a framework for calculating absolute greenhouse gas (GHG) and energy use along with a core set of relative Environmental Performance Indicators (EPI's) to create a baseline for environmental performance moving forward. This model calculates energy use and GHG emissions based upon available data sources and a number of underlying assumptions (See full project report for assumption discussion).

The tracker was developed using Microsoft Excel 2007 (version 12) in a Microsoft Windows XP environment. This platform was chosen to provide high transparency, compatibility with existing systems, and a fast learning curve. The tracker consists of eight worksheets and sixteen tables (previously known in Excel as lists) that interact to produce various outputs. Limitations from using the Excel platform were addressed by using a variety of excel-specific techniques discussed in the next section.

Programming Techniques and Formulas

General Information Flow Throughout the Model

A Environmental Performance Indicator (EPI) is calculated using three general information flows - one from purchase information in “mat_trans”, one from process energy in “ecalc”, and one from input cells in the “Ind_finance table”. Input to “mat_trans” has the highest resolution and undergoes the most calculation steps before summing with the information from “ecalc”. Within “mat_trans”, each individual purchase is categorized into an EIOLCA sector and an STGC sector for material production and transportation calculations based on the numeric material purchase code for that purchase. For more specific data flow information, refer to figures A-1 and A-2.

Structured Referencing

Table structured referencing was always used over absolute references in calculation steps where possible to increase calculation transparency and robustness. Each table is globally unique and referenced directly as an object rather than through a relative or absolute position on a worksheet. The only absolute or relative references in the worksheets are text fields used for notes outside of calculation tables. This allows columns of tables or entire tables to be moved without affecting calculated cells. Additionally, calculation steps are easier to decipher using structured references because they include table names, column names, and other qualifiers such as “[#This row]” or “[#Totals]”.

Dynamic Tables

All data and calculations are within tables to enable structured referencing and ease new calculations. Pasting data into the tracker will in most cases autofill formulas and provide output with little or no extra work. Tables will expand automatically to accommodate new information, though columns that contain multiple calculations will need to be filled manually. Tables also allow flexibility in the worksheet layout to improve usability. Since calculations never reference worksheets within a workbook, tables can be moved anywhere within the file to improve user experience. Additionally, tables provide sorting, filtering and totals row options that allow for more dynamic operation.

“Formula Tags”

The N() formula was used in calculation steps to explain the calculation step for increased transparency. Any outside data sources are also referenced here. Due to the formulas output, it could not be used in all cases.

Pivot Tables for Output

For the visual representation of output, pivot tables are utilized to aid in data comparisons. This allows fast and easy comparisons that update dynamically and remain flexible.

Workbook Protection for Non-input Cells

All calculation cells and non-input cells are locked and protected to ensure that formula errors are not introduced. There is no password to unlock the sheets, so any end user can assume editing capabilities.

Cell Fill Styles

Input cells are colored red with opacity at 20% (pink) while calculation cells are formatted as banded blue rows in the tracker model and Table A-1. Calculation cells should remain locked and should not require routine updating. Column headers and totals rows are dark blue.

Table A-1. Input, header and calculation cells

Material Group	Date (yyyy)	Mat Descp	Vendor (SupplySync)	Vendor Code
INPUT	INPUT	CALCULATION	INPUT	INPUT
002	0607	Adhesives	FRANKLIN INTERNATIONAL INC	543746
002	0607	Adhesives	L & D ADHESIVES, INC	531163
002	0607	Adhesives	BOSTIK FINDLEY INC	504931
002	0607	Adhesives	L & D ADHESIVES, INC	531163

Lookup Tables

To ensure robust and consistent calculations, lookup tables are used so that each formula requiring a specific lookup (such as inflation rates in "lookupCPI") refers to the same table rather than to separate calculations or a column within an existing table. This condenses the table structure because routine calculations are performed automatically without introducing extra columns.

Independent and Parallel Calculations

The tracker was designed to make every table as independent as possible. E.g. mat-trans is a very large worksheet that is summarized more manageably in the MPC_x tables while Ind_x tables summarize this data even further. Rather than referring to the MPC tables, IND_x refer back to the original data in mat_trans to ensure that an error in the MPC table calculation will not affect other tables. Any calculations using lookup tables refer to as few tables as possible.

Formulas Used

Table A-2. Formulas used in the tracker model.

SUM	SUMIFS	SUBTOTAL	IF	VLOOKUP
SUMIF	N	AVERAGE	IFERROR	ISERROR

Tracker Sheets and Tables

Roadmap

The following roadmap shows these worksheets and tables, as well as a summarized flow of information to and from these tables and a textual summary of the inputs and outputs. Black arrows in the roadmap indicate some flow of data between worksheets, though all information actually only flows through globally referenced tables, not to the worksheets themselves. Red arrows indicate required input data.

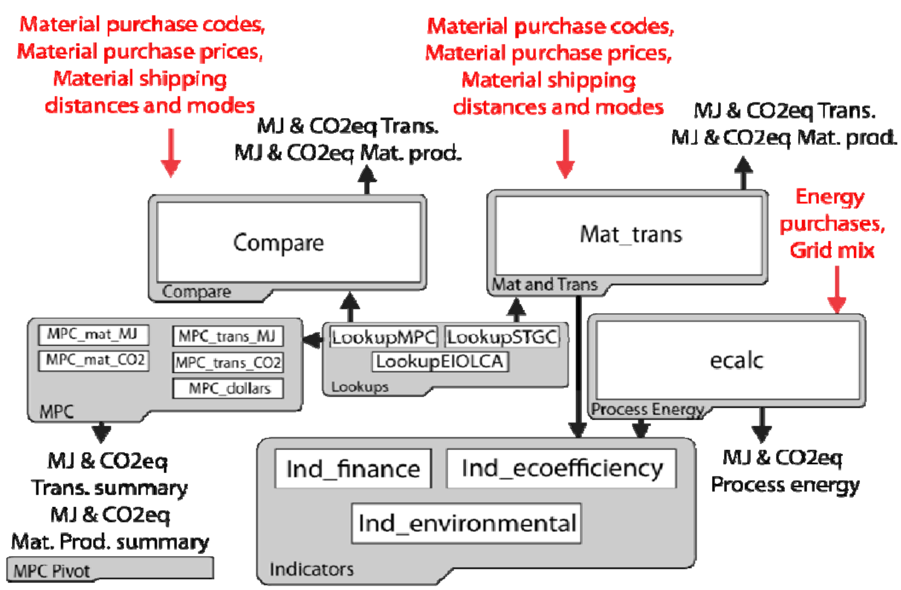


Figure A-1. Roadmap indicating general information flow throughout the tracker model including red arrows for data input, black arrows for data output in relation to table orientation in named worksheets

Worksheets

- Mat and Trans – contains the mat_trans table
- Process Energy – contains the ecalc table

- MPC – contains the MPC_mat_MJ, MPC_mat_CO2, MPC_trans_MJ, MPC_trans_CO2, and MPC_dollars.
- MPC Pivot – contains various Pivot tables and charts that reference the tables in MPC
- Compare – contains the compare table and two charts based on the compare table
- Indicators – contains the tables Ind_finance, Ind_environmental, and Ind_ecoefficiency.
- Lookups – contains the tables lookupEIOLCA, lookupSTGC, loookupMPC, and lookupCPI.
- Notes – contains various notes and keys relating to the trackers setup, data sources, use, etc.

Tables

- Mat_trans – this table calculates material production energy/GHG, and transportation E/GHG for every material purchase within a given analysis period.
- Ecalc – calculates E/GHG from the upstream fuel acquisition and combustion of fossil fuels utilized by SWD
- MPC_mat_MJ – summarizes material production energy by material group code
- MPC_mat_CO2 – summarizes material production GHG by material group code
- MPC_trans_MJ - summarizes transportation energy by material group code
- MPC_trans_CO2 - summarizes transportation GHG by material group code
- MPC_dollars – summarizes the material purchase values by material group code
- Compare – calculates material production energy/GHG for specific purchases
- Ind_financial – summarizes economic data to be used for indicator ratios and includes input fields for inflationary and time period adjustments.
- Ind_environmental – summarizes environmental data to be used for indicator ratios and includes input fields for time period adjustments.
- Ind_ecoefficiency – computes various benchmark indicator eco-efficiency ratios for the input time periods.
- lookupMPC – returns material product code names and EIOLCA and STGC sector names and numbers based on the material product code number
- lookupCPI – returns inflation adjustment rates between years in the matrix
- lookupEIOLCA – returns E/GHG per dollar value from based on EIOLCA codes
- lookupSTGC – returns $/ton value based on STGC code

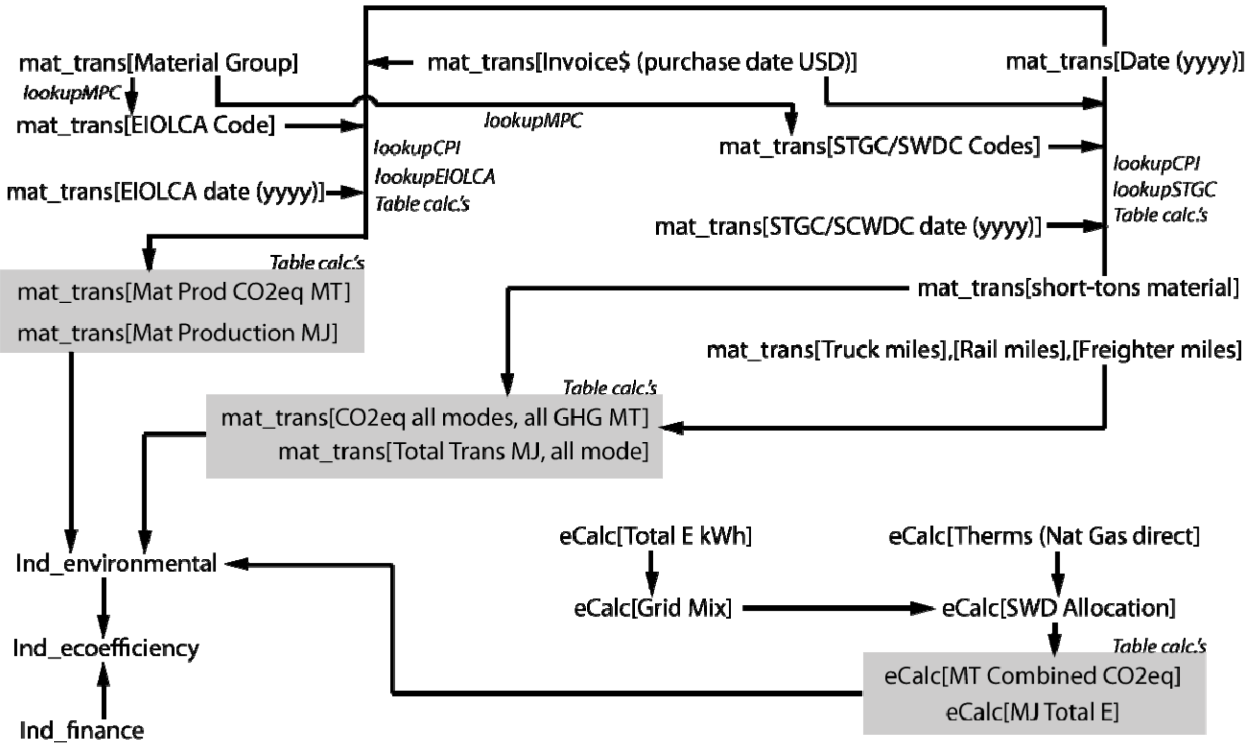


Figure A-2. Specific information flow pathways throughout the tracker model indicating characterized environmental impacts in grey boxes, calculation information in italics, and arrowed lines to indicate directional information flow

Data Input

Input cells are filled with a red background set at 20% opacity. These cells are not protected and may require a variety of input formats. Any data input that is not in the correct format for that cell as outlined in the table below will result in an error.

Table A-3. Description and format of input data including table and column information.

Table	Column	Origin, conditions, and formatting of data
Mat_trans	[Material Group]	• From SSC data • Use escape character (‘) before each number, i.e. (‘005, ‘062, etc.) • 3-digit number stored as text (with ‘ escape character from SSC)
	[Date (yyyy)]	• User defined • 4-digit number • MUST be unique for each time period and consistent throughout model
	[Vendor (SupplySync)]:[Supplier Code]	• Various data from SSC • [Confirmed Production Zip] is for confirmed manufacturer locations from non-SSC data • Any format • Not required for calculations
	[Invoice$ (purchase date USD)]	• From SSC data • Any-digit Number, dollar formatted
	[Truck miles],[Rail miles],[Freighter miles]	• Distance estimates from www.local.google.com, choosing mode as known • Any-digit number
eCalc	[Date (yyyy)]	• User defined • 4-digit number • MUST be unique for each time period and consistent throughout model
	[Total E kWh]	• Data from SWD in kWh • One number for entire time period repeated • Any-digit number
	[Therms]	• Data from SWD in Therms • One number for entire time period • Any-digit number
	[Grid Mix]	• Data from http://www.eia.doe.gov/cneaf/electricity/st_profiles/ by state • Proportion of grid mix by source • “Carbon & Emission neutral sources” could be used for any non-fossil E that doesn’t impact C or GHG. i.e. A switch to wind/solar/renewable biomass could be accounted for here
	[SWD Allocation]	• Allocates the proportion of total energy use in [Total E kWh*] and [Therms] that is used in processing the material purchases in mat_trans. • Proportional to the total amount of electricity used at a specific plant • Any-digit number less than or equal to 1
compare	[Date (yyyy)]	• User defined • 4-digit number • MUST be unique for each time period and consistent throughout model
	[Supplier]	• Input supplier for a material purchase decision • Any formatting • Not required for calculations
	[Product]	• Input product description for purchase • Any formatting • Not required for calculations

	[Purchase $]	• Input dollar amount of purchase • Any-digit number
	[Material Group Code]	• Input MPC number for calculations • Use escape character (‘) before each number, i.e. (‘005, ‘062, etc.) • 3-digit number stored as text
	[Truck miles],[Rail miles],[Freighter miles]	• Distance estimates from www.local.google.com, choosing mode as known • Any-digit number
Ind_financial	[Date (yyyy)]	• User defined • 4-digit number • MUST be unique for each time period and consistent throughout model
	[Adjust date (NDN and Material Cost)]	• All financial output will be converted to this date in USD • User defined • 4-digit number
	[Time Period Length (proportion)]	• A multiplier numeral to adjust time periods for comparison. Any numbers can be used; a value of 1 outputs actual data, a value of 2 outputs values twice actual data for that time period, etc. • Any-digit number
	[Units (sale year time period)]	• From SWD data • Any format
	[MUC Avg (sale year time period)]	• From SWD data • Any-digit number
	[NDN (sale year USD, time period)]	• From SWD data • Any-digit number
Ind_environmental	[Date (yyyy)]	• User defined • 4-digit number • MUST be unique for each time period and consistent throughout model
	[Time Period Length (proportion)]	• A multiplier numeral to adjust time periods for comparison. Any numbers can be used; a value of 1 outputs actual data, a value of 2 outputs values twice actual data for that time period, etc. • Any-digit number
Ind_ecoefficiency	[Date (yyyy)]	• User defined • 4-digit number
lookupCPI	[CPI]	• From US Dept of Labor http://www.bls.gov/cpi/ • Any-digit number

Data Output

There is a variety of different outputs from the tracker that are summarized in different ways. A selection of useful table outputs is summarized in the following table.

Table A-4. Description and format of output data including table and column information.

Table	Column	Table output
Mat_trans	[Mat Prod CO2eq MT]	Metric tons of CO2equivalents from material production for individual purchases
	[Mat Production MJ]	MJ of energy from material production for individual purchases
	[Total Trans MJ, all mode]	MJ of energy from transportation of individual purchases to SWD
	[CO2eq all modes, all GHG MT]	Metric tons of CO2 equivalents from transportation of individual purchases to SWD
Ecalc	[MT Combined CO2eq]	Metric tons of CO2 equivalents from process energy at SWD including upstream
	[MJ Total E]	MJ from process energy at SWD including upstream
MPC_mat_MJ	[yyyy], e.g. [0607]	Material production MJ of energy for individual MPC's
MPC_mat_CO2	[yyyy], e.g. [0607]	Material production CO2 equivalents for individual MPC's
MPC_trans_MJ	[yyyy], e.g. [0607]	Transportation MJ of energy for individual MPC's
MPC_trans_CO2	[yyyy], e.g. [0607]	Transportation CO2 equivalents for individual MPC's
PivotTableX		Various graphical data representations
compare	[Material Production and Transportation MJ]	Material production and transportation MJ of energy for an individual purchase
	[Material Production and Transportation GHG MT CO2eq]	Material production and transportation CO2 equivalents for an individual purchase
Indicators	various	Various indicator ratios
Ind_data1	various	Various data summaries for entire SWD

Pivot Tables

For the graphical representation of analysis data referring to the Material Purchase Codes, pivot tables are used. This provides a flexible and fast way to find the fastest growing MPC's, the MPC purchase price distribution etc. This information may be useful for decision-making and is a flexible option for output data. Important: Pivot tables do not refresh as data is changed within the tables to which they are linked. To ensure that the pivot tables reflect accurate data, be sure to click the "refresh" or "refresh all" button in the "Options" ribbon that appears after clicking on one of the pivot tables or charts.

Compare

The compare table provides real-time output for the comparison of Material production and transportation energy between seven user specified materials (though the table could be extended to any length). After MPC, purchase value and time periods are input, outputs are calculated. This output is intended to provide fast analysis of a variety of material purchase options as a decision making tool. The results are also displayed by primary energy and total GHG in the two graphs below the table.

Model Use Suggestions

Data Management

The tracker is dynamic and should theoretically accommodate any amount of data, but in reality the performance of the model will decrease as data increases. The performance limits with large amounts of data have not been tested and are currently unknown. The model may benefit from data purging at a certain time interval after saving the model as a unique file with the new time period appended to the file name for convenience.

Tips and Suggestions

Sorting/filtering - Consistent use of tables for all data manipulation allows for easier sorting and filtering within columns of any set of data within the tracker. Most formulas in the summary tables in the MPC and Indicators worksheets use the SUMIF and SUMIFS functions to automatically sort by year, but when using the mat_trans table, it is often most useful to use sorting and filtering to organize information as quickly as possible. Important: When copying, pasting, or otherwise manipulating data, sort and filter the columns so that the cells you are working with within the table are adjacent. For instance, if you want to paste new purchase data for a specific MPC into Mat_trans where data already exists, it is best to sort the material group or material purchase codes column first *before* filtering out other Material group or Material purchase Codes. This will result in speedy calculations, whereas calculations involving non-adjacent cells can take a large amount of processing time.

Step-by-step Input Tutorial

Benchmark Indicator Calculations

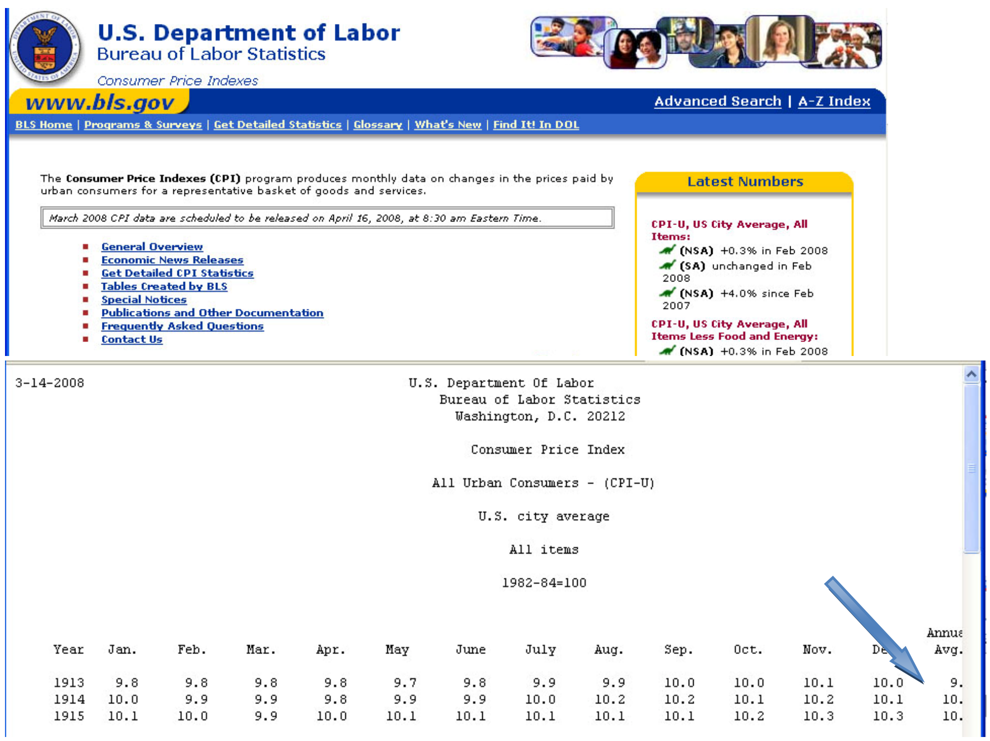
1. Input data
    a. SSC purchase data for SWD.
        i. Formatted as an xls or svg spreadsheet containing line items for each individual purchase for the wood plant over the desired analysis period. Copy and paste

data “as values” (right click -> paste special -> as values) into the corresponding mat_trans columns - purchase price, material group code (numeric), and manufacturing location are all required for calculations. At this point, the name of the mpc, the EIOLCA code and STGC code should appear automatically in columns to the right.

ii. **Important**: If the above information does not automatically fill, there may be a formatting error within the [Material Group] column. “mat_trans” is set up around the exact formatting received from SSC, with all cells displayed using a custom format that always displays three digits. The “‘” escape character precedes all values in the SSC spreadsheet, forcing the numeric values to be treated as text. If this escape character is not present, it will need to be added, or all Material groups codes throughout the entire file will need to be converted to numbers from text for calculations to occur.

b. Date

i. Start by loading the website http://www.bls.gov/cpi/ and open the table called “Table Containing History of CPI-U U.S. All Items Indexes and Annual Percent Changes From 1913 to Present” (various other tables will also contain the same information.)



Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	De	Annua Avg.
1913	9.8	9.8	9.8	9.8	9.7	9.8	9.9	9.9	10.0	10.0	10.1	10.0	9.
1914	10.0	9.9	9.9	9.8	9.9	9.9	10.0	10.2	10.2	10.1	10.2	10.1	10.
1915	10.1	10.0	9.9	10.0	10.1	10.1	10.1	10.1	10.1	10.2	10.3	10.3	10.

ii. Find the CPI value that corresponds to your data period. From the above table, use the annual average value for a given year.

iii. Input the CPI value into the [CPI] column in table “lookupCPI” in a blank row

iv. Input a four digit numeral to identify your time period ***without any spaces or non-numeric characters***.

v. Input the same time code in “mat_trans” in the [Date (yyyy)] column. At this point, material production energy and GHG emissions should be calculated, along with short-tons (2000 pounds) of material for each purchase.

c. Shipping distances

i. Confirm the manufacture location provided in step 1.a.1. with SWD sourcing to ensure that the locations are actually point-of-production facilities and input the zip code in the [Confirmed Production Zip]. Estimate shipping distances from production zip codes, using unconfirmed business addresses when confirmed zipcodes are unavailable using www.local.google.com, driving directions service to the SWD GR Plant. Break this distance up by mode where known, assuming truck transport when unknown and input the miles into [Track miles], [Rail Miles], or [Freighter Miles]. Transportation energy and GHG will now be calculated.

d. Process Energy

i. Energy purchase data may be acquired through both the SWD energy purchaser and through SWD environmental management. Convert natural gas into therms (1 hundred of cubic feet (CCF) = 1.03 therms) and keep electric in kWh. Input the four-digit date code for the time period of interest exactly as it appears in “mat_trans” for each energy source – one row of direct and five rows of indirect. In [Total E kWh], Input the total kWh for SWD ***in each row*** that corresponds to you time analysis period and “grid” in [Delivery], leaving the “direct” rows empty or zeroed. Input total therms only into the single row that reads “direct” in [Delivery] for your time period, leaving all other cells in the row empty or zeroed**.** Important: Time periods shorter than one year must account for cyclic seasonal energy purchases through estimation. If data is available for a full year surrounding your time interval of interest, multiply the sum of the annual energy purchases by the proportion of the year that your period corresponds to. (e.g. four months of data would be calculated summing energy purchases and multiplying by one-third). If the annual energy purchases are not available, an average between an adjacent seasonal high and low purchase month can be multiplied by the number of months studied (APPENDIX B).

ii. Navigate to http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html and open the link to the state profile in which the electricity was purchased from the grid. Scroll down to the tables listed at the bottom of the page and download Table 5. Electric Power Industry Generation by Primary Energy Source, 1990 Through 20XX. In the appropriate year column, divide the numbers in the Coal, Petroleum, Natural Gas, and Nuclear rows under the “Electric Utilities” subheading by the total number for the same subheading to get the proportions of each fuel used in the regional energy mix. Now fill the cells in [Grid Mix] that correspond to the source and year of interest in the form of a proportion. After coal, petroleum, nuclear, and natural gas are filled in, add all values and subtract the total from one to get the value for Non-fossil/renewable. Non-fossil/renewable fuels are currently not calculated for emissions, but a future increase in their use will reduce the proportion of other fuels, reducing overall emissions. At this point, total fuel cycle GHG and MJ will be calculated by source.

Michigan Energy Mix 90-05 (DOE)

Table 5. Electric Power Industry Generation by Primary Energy Source, 1990 Through 2006 (Megawatthours)

http://www.eia.doe.gov/cneaf/electricity/st_profiles/michigan.html

Michigan

Energy Source	1990	1991	1992	1993	1994	1995
Electric Utilities	**89,058,681**	**94,567,383**	**82,679,444**	**92,250,107**	**83,720,636**	**92,478,772**
Coal	65,295,742	65,138,291	61,434,530	61,558,991	67,538,611	65,425,002
Petroleum	689,461	553,863	498,159	619,777	655,860	687,264
Natural Gas	665,142	998,058	1,021,751	680,194	656,757	1,163,390
Other Gases	-	-	-	-	-	-
Nuclear	21,610,500	27,021,214	18,848,731	28,525,000	14,144,281	24,448,397
Hydroelectric	1,492,822	1,651,742	1,647,175	1,639,359	1,536,190	1,486,539
Pumped Storage	-694,986	-795,785	-770,902	-773,214	-811,063	-731,820
Other	-	-	-	-	-	-
Independent Power Producers and Combined Heat and Power	**11,001,056**	**11,410,741**	**12,642,495**	**14,118,442**	**14,586,753**	**14,965,840**
Coal	1,771,128	1,739,932	1,912,172	2,400,089	2,233,005	1,775,643
Petroleum	172,264	104,704	130,608	141,798	169,663	167,990
Natural Gas	7,172,814	7,501,020	8,506,888	9,340,019	9,779,792	10,411,464
Other Gases	340,949	217,829	243,754	3,371	4,634	1,430
Hydroelectric	135,096	99,926	135,096	122,483	124,078	110,647
Other Renewables	1,408,805	1,719,109	1,682,787	2,073,571	2,260,274	2,483,380
Other	-	28,221	31,190	37,111	15,307	15,286
Total Electric Industry	**100,059,737**	**105,978,124**	**95,321,939**	**106,368,549**	**98,307,389**	**107,444,612**
Coal	67,066,870	66,878,223	63,346,702	63,959,080	69,771,616	67,200,645
Petroleum	861,725	658,567	628,767	761,575	825,523	855,254
Natural Gas	7,837,956	8,499,078	9,528,639	10,020,213	10,436,549	11,574,854
Other Gases	340,949	217,829	243,754	3,371	4,634	1,430
Nuclear	21,610,500	27,021,214	18,848,731	28,525,000	14,144,281	24,448,397

SEPT05MI | Notes | Relevant calc

e. Economic data

   i. Economic data was obtained directly from SWD from two different sources. NDN, unit, and MUC values are well documented and can be summed over the period of interest with relative ease.

   ii. Input the Date code (yyyy) (the year the data were collected in), the Adjustment date code (yyyy) (the date to adjust financial measures to to adjust for inflation into another time period for comparison- usually most current date), Time period length (the proportion of the lengths of various periods to align temporal system boundaries), and the economic values from SWD in "Ind_financial" where appropriate. All economic data will be adjusted for inflation and time period length output in USD in the date in [Adjustment date (yyyy)]. At this point, Indicator values should be calculated.

f. Adjusting output calculations to account for the comparison of two time intervals representing different lengths of time.

   i. Adjustments to different time period lengths are made in the "Ind_X" tables in the "Indicators" worksheet. Find the "[Time Period Length (proportion)]" columns in the financial and environmental tables and input the proportion of the time interval lengths. This proportion is multiplied by real values so the proportions can be normalized to any convenient period. If a consistent data period length is used, it is recommended that this interval be set to one to display unadjusted values for that time period. All time periods must be in proper proportion to each other for indicator output to remain accurate.

g. Creation of new Indicators
   i. Four ISO 14031 compliant Environmental Performance Indicators in the form of eco-efficiency ratios were chosen for this project, but any of the above data may be used in an absolute or ratio format to evaluate environmental performance. Unit counts and Model unit counts (MUC's) were easily obtainable economic indices that are not calculated within the tracker.
   ii. To add eco-efficiency ratios to the tracker model, add new columns to "Ind_ecoefficiency", and label the column headers with the appropriate headers.
   iii. Add formulas for new indicators using combination of information in the "Ind_ecoefficiency" table using global-style structured referencing formulas like those in the existing columns for robustness and easy upkeep.

Material/supplier Trade-off Comparison Calculations

When comparing specific materials and suppliers, input the same information as contained in steps 1.a,b, and c above. The date and material purchase codes must match values in the left-most column of lookupCPI and lookupMPC respectfully for successful calculation, but purchase price and transportation modes and distances can be filled with any properly formatted theoretical data without affecting the benchmark indicator calculations. This calculation is entirely independent of the other tables and should not be used to store actual SWD data for any kind of long-term use.

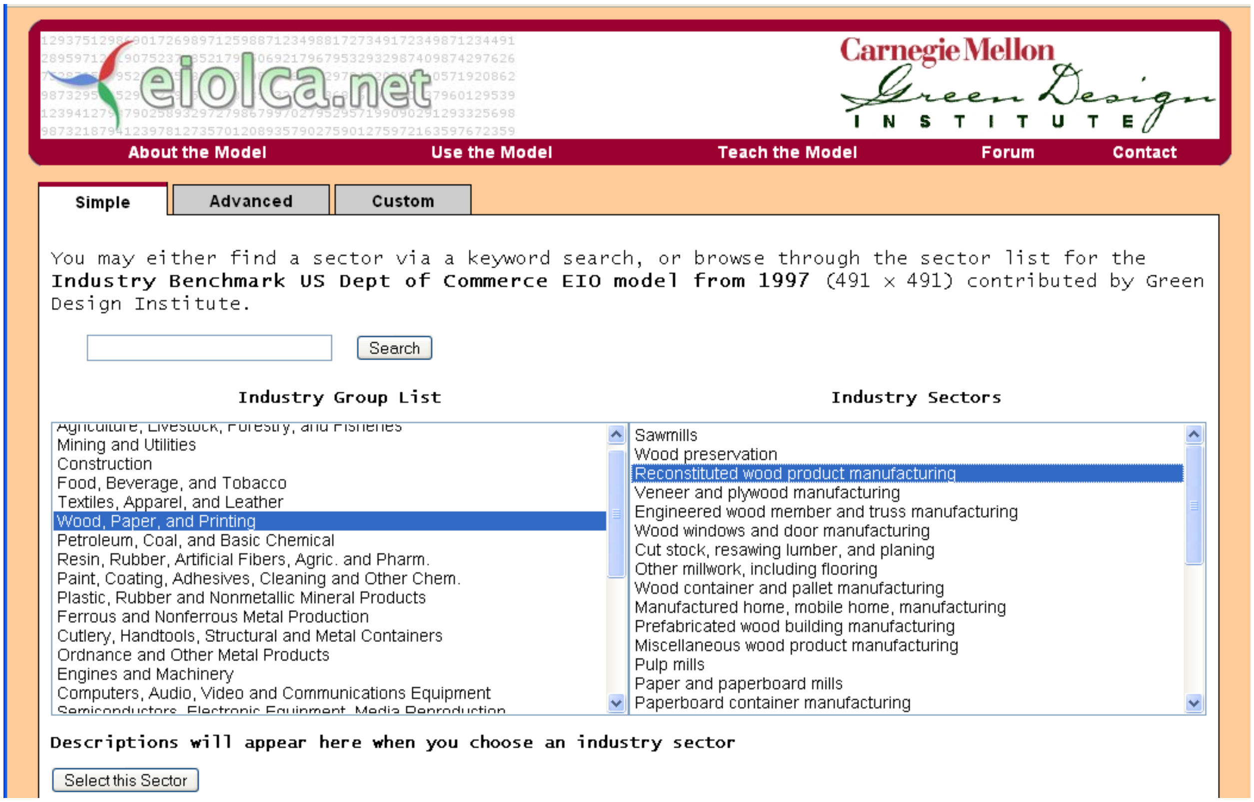
Updating Averaged Datasets

Material Production Energy/GHG : EIOLCA Dataset

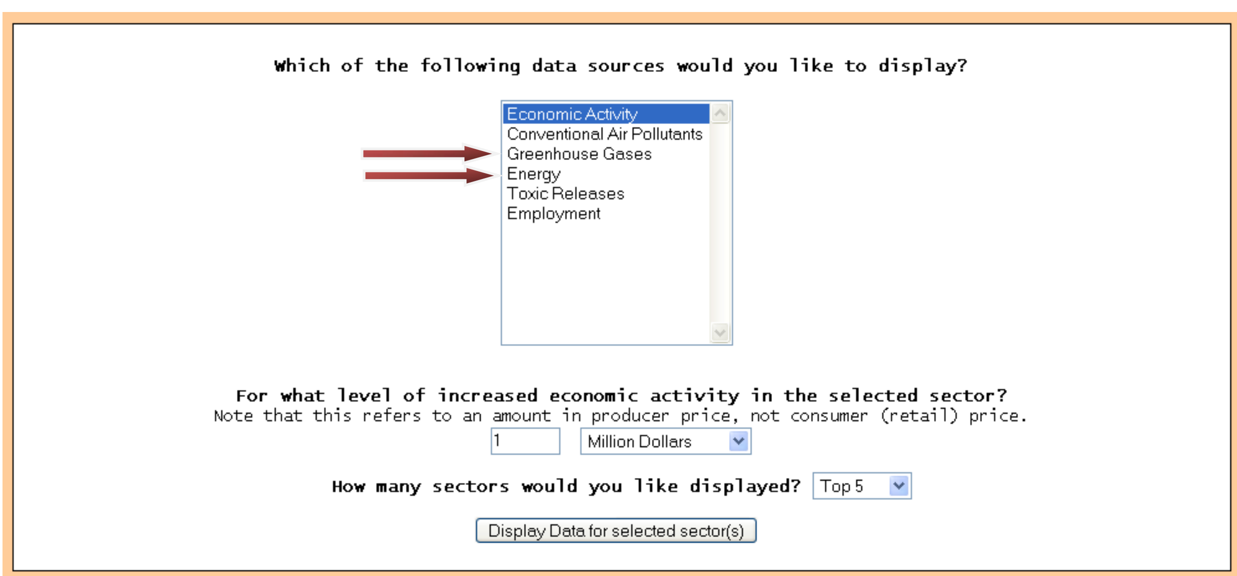
The Economic Input-Output Life Cycle Assessment (EIOLCA) dataset used by the tracker model were developed by Carnegie Mellon University and are available online at http://www.eiolca.net/use.html. This dataset is used to calculate material production energy and greenhouse gas emissions based on the 1997 Department of Commerce Input-Output matrix. This dataset has been updated in 1992 and 1997 but revisions are not consistent and cannot be predicted at this time. When new information becomes available, or if a new set of data is chosen to use in place of the EIOLCA data this section will describe the update procedure.

- Find the "lookupEIOLCA" table in the "lookups" worksheet of the tracker file. Only the necessary values are filled in, but all NAICS codes used by EIOLCA are listed within this table in case future material purchase changes require them. To find out how material purchase groups are classified, scroll over to the "lookupMPC" table on the same worksheet.

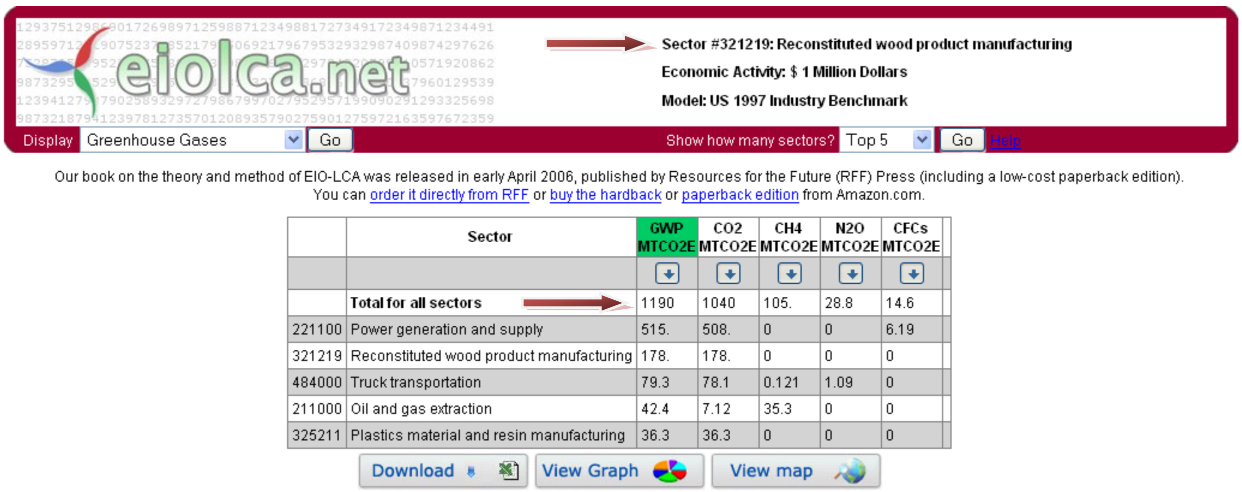
- Load http://www.eiolca.net/use.html. Highlight the sector of interest by searching or browsing and scroll down the page to double-check the sector description and click the “select this sector” button in the bottom left when ready.



- In the next screen, select either “Greenhouse Gases” or “Energy” as your category as both categories are required for calculations. Keep the economic activity set at its default value of one million dollars and click “Display Data for selected sector(s)”.



- The last screen displays a sector number in the upper right corner that should roughly match the code in "lookupEIOLCA" (NAICS codes are displayed in different ways that don't affect our use – if the code in "lookupEIOLCA" and this site are roughly the same with appended 0's, 1's, or letters it is describing levels of organization and aggregation within the same sector and is the right sector to use) and a matrix showing the total metric tons of CO2equivalents for the top sectors and greenhouse gases (or the corresponding energy use data).



	Sector	GWP MTCO2E	CO2 MTCO2E	CH4 MTCO2E	N2O MTCO2E	CFCs MTCO2E
	Total for all sectors	1190	1040	105.	28.8	14.6
221100	Power generation and supply	515.	508.	0	0	6.19
321219	Reconstituted wood product manufacturing	178.	178.	0	0	0
484000	Truck transportation	79.3	78.1	0.121	1.09	0
211000	Oil and gas extraction	42.4	7.12	35.3	0	0
325211	Plastics material and resin manufacturing	36.3	36.3	0	0	0

- Record the upper left hand value under the green column header labeled "GWP MTCO2E" (or corresponding energy header) in the "Total for all sectors" row. Divide this value by one million dollars (selected in the previous step) to yield the amount of CO2equivalents emitted (or energy consumed) for the production of one dollar of material in that sector. Lastly, paste this value into the [MT CO2eq/$ (97)] or [MJ/$ (97)] column in "lookupEIOLCA".

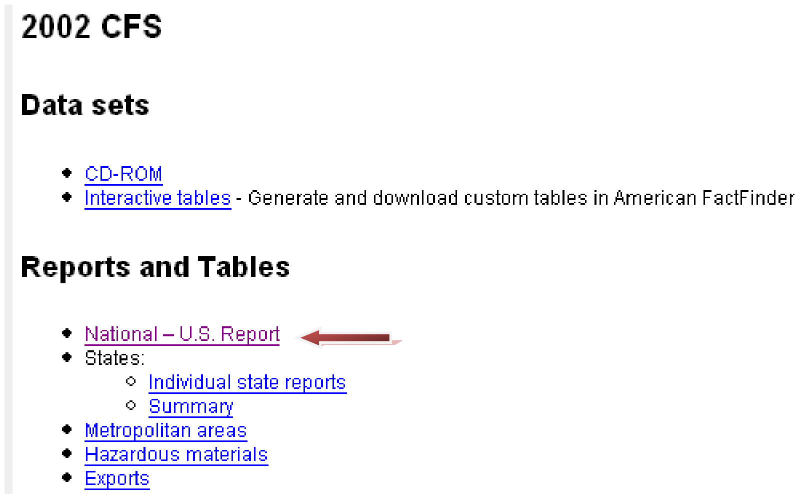
Material Weight: CFS Codes

Material weights are estimated using Commodity Flow Survey (CFS) so that transportation energy/GHG can be calculated for each purchase. The US Census Bureau and US Department of Transportation publish the CFS every five years to track shipments of materials throughout North America. The CFS classifies industry sectors much like the EIOLCA dataset above into categories called Standard Classification of Transported Goods (STGC) codes that are designed to be comparable to NAICS codes used in EIOLCA. CFS data is available online at http://www.bts.gov/publications/commodity_flow_survey/. Steelcase Wood Division Codes refer to proprietary manual calculations that use data directly from SWD instead of industry average data.

Updating CFS codes:

- Find "lookupSTGC" in the "lookups" worksheet.

- Load http://www.bts.gov/publications/commodity_flow_survey/ and scroll to the most recent year, which will appear at the top of the page. Under “Reports and Tables” click on “National – U.S. Report”



- Data will be available in a variety of formats. Download the entire repost in PDF format and save with the tracker file for future reference in case the link is updated or research methodology needs to be referenced. To calculate values for “lookupSTGC” it is easiest to download “Table 6. Shipment Characteristics by Three-Digit Commodity for the United States: yyyy” in excel format.

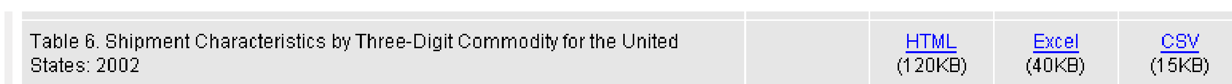


Table 6. Shipment Characteristics by Three-Digit Commodity for the United States: 2002		HTML (120KB)	Excel (40KB)	CSV (15KB)

- Once the file is open, divide the tons column by the value column in a new column and convert the results so the units are in tons/$. Make sure the STGC codes are sorted EXACTLY the same in the downloaded table and “lookupSTGC” (they should already be in ascending STGC number), copy the entire calculated column and paste special as values into the short-tons/$ column in “lookupSTGC” to update the tracker calculations. Note that this will update shipment information for ALL time periods in the tracker.

- If different sets of CFS shipment data are to be used for different years, each new set of ton/$ values must be given a unique numeral code in the STGC/SWDC column of any number of digits. The data set can then be pasted into “lookupSTGC” under the existing values in the table. To utilize these two sets of data independently, the new unique codes must be added to “lookupMPC” and “LookupEIOLCA”, and unique material group numbers must be assigned for any new purchases to use these new values. This is an advanced operation that should not be necessary as shipment characteristics remain relatively constant over time.

Impact Calculations for Fuel Use: Franklin Associates Data

The environmental impacts of fossil fuel combustion are relatively stable over time but may change with advances with technology and trends within the energy industry. To update standard emissions from fuel use, calculation cells must be modified individually. In "mat_trans" and "ecalc" look through the calculation steps and N tags for an individual purchase to understand the equations, then simply update the new emission or energy factor or value into the formula update the N tag to indicate the source of that information.

Replacing Averaged Datasets with SWD Specific Data

The tracker model is designed to remain flexible so that new sources of information in a variety of formats can be included in calculations with a minimum user input. To update the information listed below or to customize the model, the function of each lookup code must be properly understood. Material product codes and date codes are used to categorize data throughout the model and the only way to bypass automatic categorization is to introduce unique material purchase code (stored as text, see table A-2) numerals in the [Material Group] column in "mat_trans" and lookup tables that reference this value. Similarly, each set of data requires a unique time code in the various "[…Date (yyy)]" columns throughout the tracker for calculations, so unique time codes will need to be introduced in these columns if parallel independent calculations are to be performed using the same temporal data (e.g. to compare EIOLCA and process based data for the same time period if it process based Inventory data becomes available). Refer to figures A-1 and A-2 and "N" tags within the calculation formulas for specific data flow information throughout the model.

Updating SWDC Codes:

- SWDC codes are material group codes with an appended "111" prefix for use in transportation energy/GHG calculations and are interchangeable with STGC codes for calculations.
- SWDC codes can be updated whenever enough information can be gathered to calculate a ton/$ value for a material purchase code within SWD. SWDC codes are preferable to STGC codes for ton/$ calculations but the data required for these calculations is generally not sufficient. Only the woodcore and veneer material purchase codes could be calculated through SWDC codes at the completion of this project. Values for SWDC codes are treated exactly the same as STGC codes from CFS data in calculations and are formatted as numerals.
- Once a ton/$ value has been calculated for a material group code at SWD, append a "111" as a prefix to the material group code number, extend the "lookupSTGC" table (using the dark blue wedge in the bottom left hand corner or inserting rows commands) and add the value, description, and the new unique SWDC code.

- In “lookupMPC” place a set of parenthesis around the material purchase group code that you will be replacing (note “(064)” in the [Material Group Code] column for veneers that have already been switched from STGC to SWDC codes). This effectively disables the STGC ton/$ value for calculations.
- Copy the MPC description, EIOLCA sector description and EIOLCA sector number (columns 2-4 in the table).
- Extend “lookupMPC” by the number of rows you will be updating at the bottom of the table.
- Paste in the three values copied above, add the unique SWDC (e.g. 111###) to the last column and the original MPC from mat_trans in the first column (this will be the same code that was disabled with parenthesis above). This completes the SWDC code calculations and all calculations should be updated.

APPENDIX B

Process Energy Data Treatment

Table B-1 compiles the process energy data from SWD personnel and the adjusted data values used for Environmental performance indicator calculations. Adjusted values were used for the Fletcher and Grand Rapids wood plant during the 2003/2004 time period because the six month sample size overestimated gas use based on cyclic annual gas purchases. No significant periodicity was found in electricity purchases. Figures B-1 and B-2 depict the cyclic gas purchase data for selected time periods while Table B-1 shows all input data used in the 2003/2004 and 2006/2007 sensitivity analysis. Figure B-3 shows the formula used for adjusting monthly natural gas data. This formula provides a rough estimation that is inaccurate enough for EPI calculations.

Table B-1. Process energy data used for sensitivity analysis

PROPRIETARY DATA REMOVED

PROPRIETARY DATA REMOVED

Figure B-1. Fletcher natural gas purchases from January 2001 to July 2004 indicating the data period of sensitivity analysis and the two points used for calculating monthly gas use over the 03/04 period

PROPRIETARY DATA REMOVED

Figure B-2. Grand Rapids Wood plant natural gas purchases from November 2003 to December 2007 indicating both data sets for 2003/2004 and 2006/2007 historical case studies

PROPRIETARY DATA REMOVED

Figure B-3. Equation used for calculating the average therms of natural gas for a given period using adjacent data when period length is less than one year and data is cyclic and periodic. Exclusion of the $months_{period}$ variable yields monthly therm use.

PROPRIETARY DATA REMOVED

APPENDIX C

Economic Data Sources Treatment

Calculations involving economic data prior to the tracker model were minimal and involved using two months of average data for NDN and Units for the 2006/2007 historical case study, as summarized in Table C-1 below. For 2006/2007 the average of the available 22 months data within the period were used for November and December 2007 where data was unavailable at the time of this report.

Table C-1. Process energy data used for historical case studies

PROPRIETARY DATA REMOVED

APPENDIX D

Glossary of Terms and Acronyms

- ACCA - Association of Chartered Certified Accountants, England.
- Airtouch – SCS product line.
- BS – British Standards.
- ccf – hundreds of cubic feet.
- CFS – Commodity Flow Survey. Published by the US Department of Transportation and US Census Bureau to track commodity shipment characteristics by STGC.
- CL – Climate Leaders Program.
- CO_2eq – Carbon dioxide equivalents. A normalized unit for aggregating the impact (GWP) of various GHG's based on the climatic impact of a mass of carbon dioxide emitted to the atmosphere. Developed by IPCC.
- CPI – Consumer Price Index. Published by the US Department of Labor to provide monthly data on changes in the prices paid by urban consumers for a representative basket of goods and services. Used for calculating inflation rates in this model and nationally.
- Cradle – The earliest possible system boundary for life-cycle analysis, referring to the acquisition of raw materials in their natural state before incorporation into the life cycle of a product.
- CSS – Center for Sustainable Systems, School of Natural Resources and Environment, University of Michigan.
- DFO – Distillate fuel oil.
- ECI – Environmental Condition Indicator. Standardized by ISO 14031.
- EEA - European Environmental Agency.
- EI - environmental indicator.
- EIOLCA – Economic Input-output Life Cycle Assessment. A variation of life-cycle assessment that uses an Input-output matrix to characterize environmental impacts by industry sector developed by Carnegie Mellon University.
- EMAS – European Union's Eco Management and Auditing Scheme.
- EPI – Environmental Performance Indicator. Standardized by ISO 14031.
- EU – European Union.
- FL – Fletcher Wood Plant, SWD.
- Garland – SCS product line.
- Gate – a transition point for the stages in life-cycle analysis, referring to either the end or beginning of a product or material life-cycle stage; the boundaries of one "leg" in transportation modeling.
- GHG – Greenhouse Gas(es).
- GR Wood – Grand Rapids Wood Plant, SWD.
- GRI - Global Reporting Initiative.

- Grid – National electric distribution system.
- GWP – Global Warming Potential. A characterization of the climatic impacts of individual GHG's over a certain time scale (100 years for this report) normalized to CO2eq units. Developed by IPCC.
- HFC – hydrofluorocarbons. Compounds consisting of hydrogen, fluorine, and carbon.
- IMP – Inventory Management Plan.
- Insourcing – The opposite of outsourcing; the act of moving material processing activities into a facility rather than purchasing higher value processed goods for input materials, thereby increasing both value added and in-house process energy.
- IO – Input-output matrix.
- IPCC – Intergovernmental Panel on Climate Change.
- IPCC 2007. IPCC 2007 GWP report.
- ISO 14040 & 14031 – International Organization for Standardization guidelines for environmental reporting.
- kWh – kilowatt hours. A unit of energy equal to 3,600 joules.
- LCA – Life-cycle Assessment.
- LEED – Leadership in Energy and Environmental Design, standard for US Green Building Council.
- MGC – Material Group Code (see Material Purchase Code).
- MJ – Megajoules.
- MPC – Material Purchase Code (synonymous with Material Group Code). A category developed by SCS to group material purchases. The basis for categorizing calculations; all purchases within a material group/purchase code are characterized the same way, using the same data.
- MT – Metric Tons.
- MUC – Model Unit Count. A derivative of standard hours used to estimate the labor/work efficiency for a unit. In this report, MUC refers to the summed MUC for all units sold within the time period of interest.
- NAICS – National American Industry Classification System. Developed by the US Census Bureau in cooperation with Canada and Mexico to classify business sectors to ensure comparability in statistics about business activity in North America.
- NDN – Normal Dealer Net. Defined as half of the list price for a unit sold. In this report, NDN refers to the sum of all NDN for all units sold within the period of interest.
- NO_X- A mix of binary compounds containing nitrogen and oxygen – NO, NO_2, N_2O, etc.
- NTREE - Canadian National Roundtable for the Environment and the Economy.
- PFC – perfluorocarbons. Compounds derived from hydrocarbons where hydrogen is replaced with fluorine.
- RCRA – Resource Conservation and Recovery Act. Hazardous waste regulations by USEPA.
- RFO – Residual Fuel Oil.
- SCS – Steelcase Inc.
- SD – Stow Davis Furniture Plant, SWD.
- Siento – SCS product line.

- SSC - Sourcing Service Center. SCS center responsible for managing sourcing for all divisions.
- STGC – Standard Classification of Transported Goods Codes. Developed by the US Department of Transportation in cooperation with Canada and Mexico to ensure comparability in statistics about transportation of commodities in North America. Designed for comparability with NAICS codes.
- SWD – Steelcase Wood Products Division.
- SWDC – Steelcase Wood Products Division Calculation code. A unique code in the form of "111###" used to introduce SWD specific ton/$ values instead of CFS standard data. Used for calculating shipping impacts. Calculated and updated manually.
- TJ – Terajoules.
- US EIA- US Energy Information Administration.
- USDOE – US Department of Energy.
- USEPA – United States Environmental Protection Agency.
- WBCSD – World Business Council for Sustainable Development.
- Wood Forms & Assy's – Material purchase code.
- Woodcore – Material purchase code.
- WRI - World Resources Institute.

APPENDIX E

Standard Environmental Impacts from Transportation

FIGURE E-1 is intended for quick reference when evaluating transportation options for any shipment. GHG emissions are highly correlated with energy consumption, so the same relationship below can be approximated for GHG emissions.

For more specific comparisons involving a known weight, purchase value, material type, mode, and/or shipping distance, refer to the “Compare” worksheet in the tracker model file and Appendix A “Using the E-GHG Tracker Model” for more information.

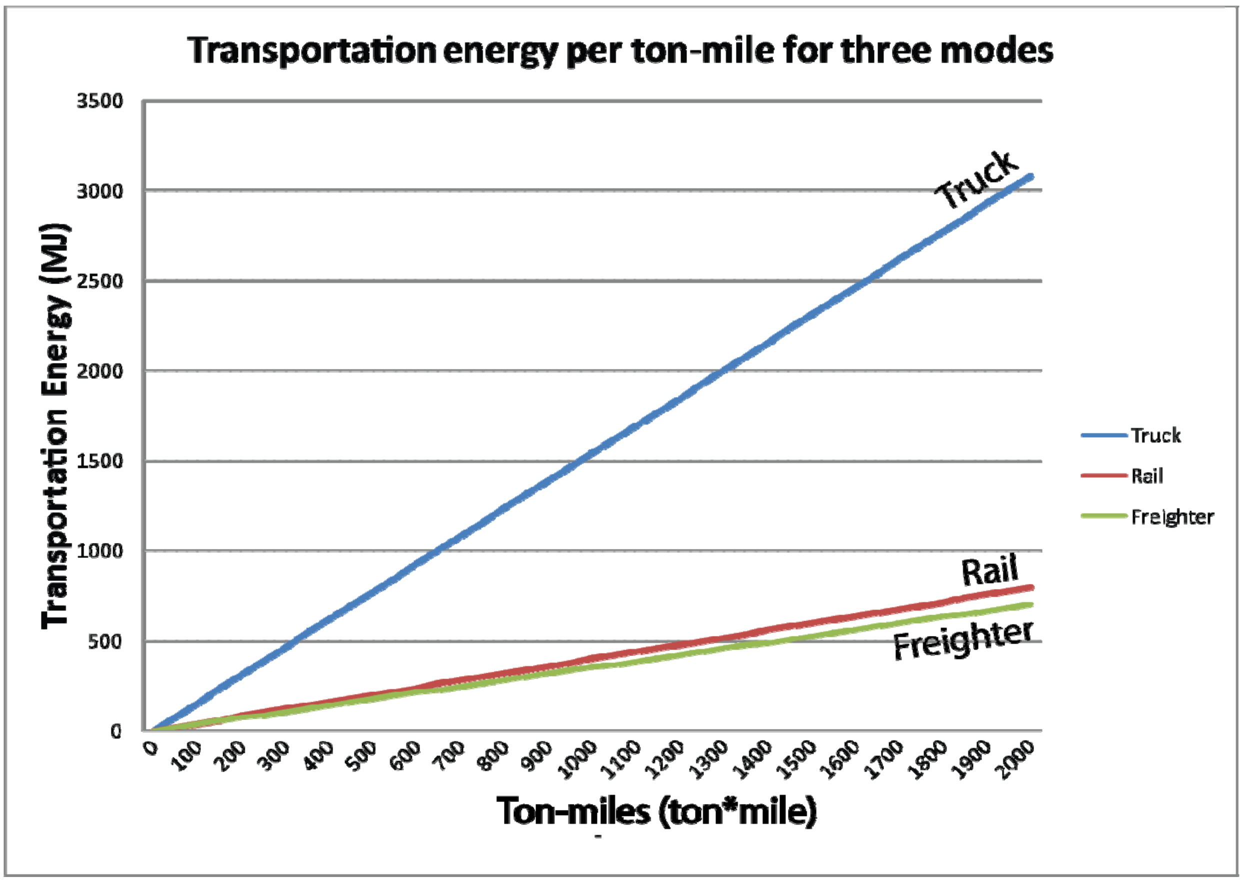


Figure E-1. Transportation total fuel cycle energies for diesel powered tractor-trailer truck, diesel powered rail car, and RFO powered ocean freighter by ton miles of material shipped from Franklin Associates 98.

APPENDIX F

Standard Environmental Impacts from Material Production Energy by Material Group Codes

FIGURES F-1 and F-2 are intended for quick reference when evaluating the general environmental impacts for material groups as calculated for this report. GHG emissions are highly correlated with energy consumption, so the same relationship below can be assumed for GHG emissions.

For more specific comparisons involving a known weight, purchase value, material type, mode, and/or shipping distance, refer to the “Compare” worksheet in the tracker model file and Appendix A “Using the E-GHG Tracker Model” for more information.

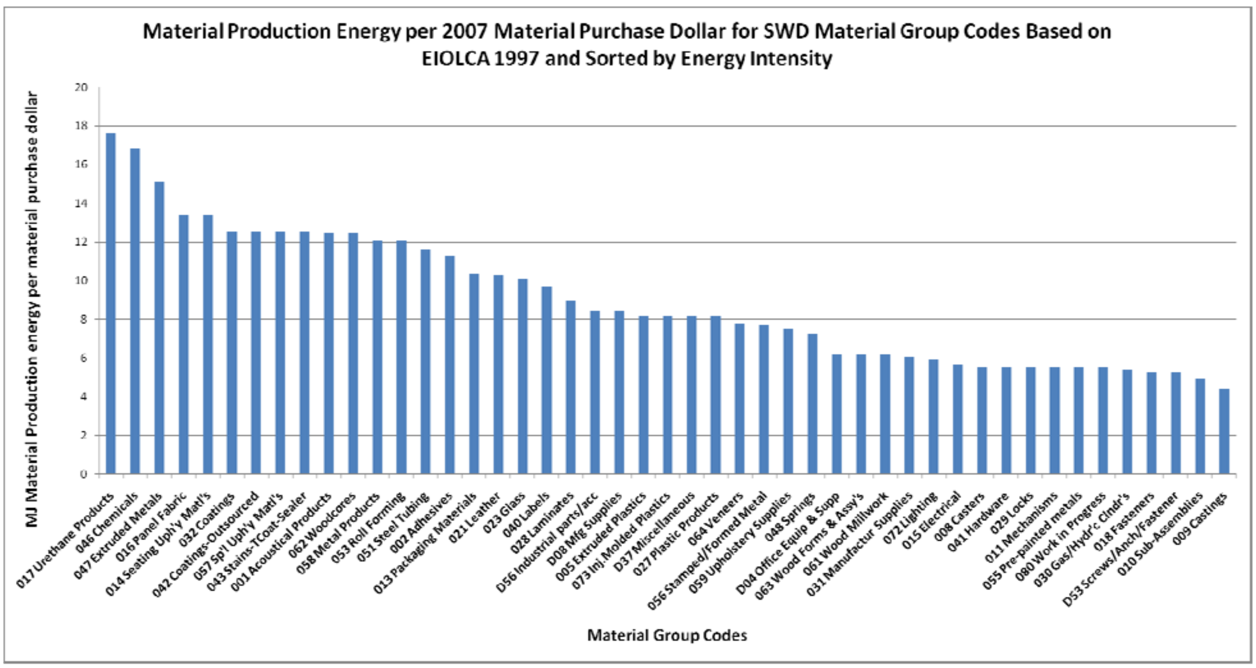


Figure F-1. Material production energy per dollar of material purchase group sorted by descending energy intensity.

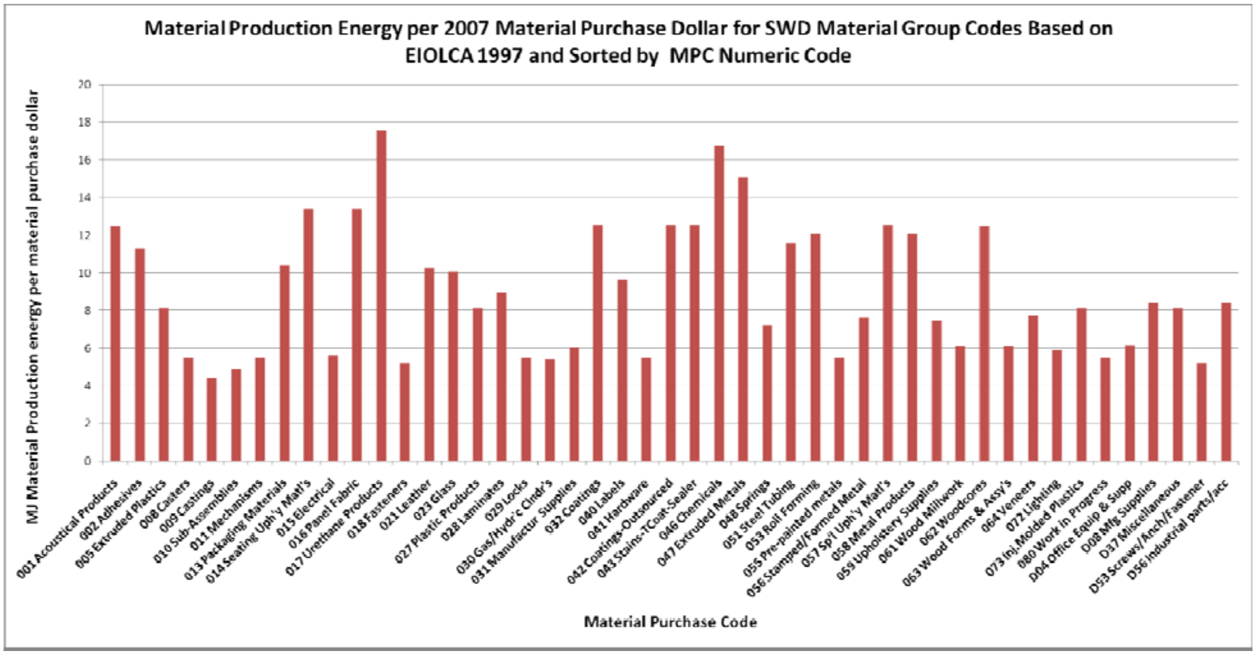


Figure F-2. Material production energy per dollar of material purchase group sorted by ascending material purchase code

APPENDIX G

Material Purchase Code Categories Used with Averaged Datasets

Material purchases are summed over a material group code, then characterized using averaged datasets within the tracker model. The charts and figures below indicate the categories used for the SWD material purchase groups.

Table G-1. Material group code and EIOLCA categories used for upstream material production impact characterization

MGC	Mat Purchase Codes	EIOLCA Sector	EIOLCA #
001	Acoustical Products	Reconstituted wood product manufacturing	321219
002	Adhesives	Adhesive manufacturing	325520
005	Extruded Plastics	Plastics plumbing fixtures and all other plastics products	32619A
008	Casters	Hardware manufacturing	332500
009	Castings	Industrial mold manufacturing	333511
010	Sub-Assemblies	Machine shops	332710
011	Mechanisms	Hardware manufacturing	332500
013	Packaging Materials	Plastics packaging materials, film and sheet	326110
014	Seating Uph'y Matl's	Broadwoven Fabric Mills	313210
015	Electrical	Miscellaneous electrical equipment manufacturing	335999
016	Panel Fabric	Broadwoven Fabric Mills	313210
017	Urethane Products	Plastics Material and Resin Manufacturing	325211
018	Fasteners	Turned Product and Screw, Nut, and Bolt Manufacturing	332720
021	Leather	Leather and Hide Tanning and Finishing	316100
023	Glass	Flat Glass Manufacturing	32721A
027	Plastic Products	Plastics plumbing fixtures and all other plastics products	32619A
028	Laminates	Laminated plastics plate, sheet, and shapes	326130
029	Locks	Hardware manufacturing	332500
030	Gas/Hydr'c Clndr's	Fluid Power Cylinder and Actuator Manufacturing	333995
031	Manufactur Supplies	Broom, brush, and mop manufacturing	339994
032	Coatings	Paint and coating manufacturing	325510
040	Labels	Coated and laminated paper and packaging materials	32222A
041	Hardware	Hardware manufacturing	332500
042	Coatings-Outsourced	Paint and coating manufacturing	325510
043	Stains-TCoat-Sealer	Paint and coating manufacturing	325510
046	Chemicals	Other basic organic chemical manufacturing	325190
047	Extruded Metals	Aluminum extruded product manufacturing	331316
048	Springs	Spring and wire product manufacturing	332600
051	Steel Tubing	Iron, steel pipe and tube from purchased steel	331210
053	Roll Forming	Rolled steel shape manufacturing	331221
055	Pre-painted metals	Hardware manufacturing	332500
056	Stamped/Formed Metal	All other forging and stamping	33211A

057	Sp'l Uph'y Matl's	Knit fabric mills	313240
058	Metal Products	Rolled steel shape manufacturing	331221
059	Upholstery Supplies	Other miscellaneous textile product mills	31499A
061	Wood Millwork	Other millwork, including flooring	321918
062	Woodcores	Reconstituted wood product manufacturing	321219
063	Wood Forms & Assy's	Other millwork, including flooring	321918
064	Veneers	Veneer and plywood manufacturing	32121A
072	Lighting	Lighting fixture manufacturing	335120
080	Work in Progress	Hardware manufacturing	332500
073	Inj.Molded Plastics	Plastics plumbing fixtures and all other plastics products	32619A
D04	Office Equip & Supp	Office supplies, except paper, manufacturing	339940
D08	Mfg Supplies	Abrasive product manufacturing	327910
D37	Miscellaneous	Plastics plumbing fixtures and all other plastics products	32619A
D53	Screws/Anch/Fastener	Turned Product and Screw, Nut, and Bolt Manufacturing	332720
D56	Industrial parts/acc	Abrasive product manufacturing	327910

Table G-2. Material group code and SCTG/SWDC categories used for transportation impact characterization

MGC	Mat Purchase Codes	SCTG Sector	SCTG#/ SWDC
001	Acoustical Products	Veneer sheets and sheets for plywood, particle board…	263
002	Adhesives	Other chemical products and preparations	239
005	Extruded Plastics	Manmade fibers and plastics basic shapes and articles	242
008	Casters	Miscellaneous manufactured products	409
009	Castings	Other articles of metal	339
010	Sub-Assemblies	Other articles of metal	339
011	Mechanisms	Other articles of metal	339
013	Packaging Materials	Manmade fibers and plastics basic shapes and articles	242
014	Seating Uph'y Matl's	Textile fibers, yarns, and broadwoven or knitt	301
015	Electrical	Other electronic and electrical equipment	359
016	Panel Fabric	Textile fibers, yarns, and broadwoven or knitt	301
017	Urethane Products	Manmade fibers and plastics basic shapes and articles	242
018	Fasteners	Handtools, cutlery, except of precious metals…	333
021	Leather	Leather and articles, luggage of related materials…	305
023	Glass	Glass and glass products	313
027	Plastic Products	Manmade fibers and plastics basic shapes and articles	242
028	Laminates	Manmade fibers and plastics basic shapes and articles	242
029	Locks	Handtools, cutlery, except of precious metals…	333
030	Gas/Hydr'c Clndr's	Other machinery	349
031	Manufactur Supplies	Miscellaneous manufactured products	409
032	Coatings	Paints and varnishes, tanning or dyeing extracts…	231
040	Labels	Other printed products	299
041	Hardware	Handtools, cutlery, except of precious metals…	333
042	Coatings-Outsourced	Paints and varnishes, tanning or dyeing extracts…	231
043	Stains-TCoat-Sealer	Paints and varnishes, tanning or dyeing extracts…	231
046	Chemicals	Organic chemicals, nec	205
047	Extruded Metals	Other articles of metal	339

048	Springs	Other articles of metal	339
051	Steel Tubing	Pipes, tubes, and fittings	331
053	Roll Forming	Flat-rolled products of iron or steel	322
055	Pre-painted metals	Handtools, cutlery, except of precious metals…	333
056	Stamped/Formed Metal	Handtools, cutlery, except of precious metals…	333
057	Sp'l Uph'y Matl's	Textile fibers, yarns, and broadwoven or knitt	301
058	Metal Products	Other articles of metal	339
059	Upholstery Supplies	Textiles and textile articles, nec	303
061	Wood Millwork	Veneer sheets and sheets for plywood, particle board…	263
062	Woodcores	Manual SWD Woodcore Calculations	111062
063	Wood Forms & Assy's	Veneer sheets and sheets for plywood, particle board…	263
064	Veneers	Manual SWD Veneer Calculations	111064
072	Lighting	Other electronic and electrical equipment	359
080	Work in Progress	Miscellaneous manufactured products	409
073	Inj.Molded Plastics	Manmade fibers and plastics basic shapes and articles	242
D04	Office Equip & Supp	Miscellaneous manufactured products	409
D08	Mfg Supplies	Miscellaneous manufactured products	409
D37	Miscellaneous	Miscellaneous manufactured products	409
D53	Screws/Anch/Fastener	Handtools, cutlery, except of precious metals…	333
D56	Industrial parts/acc	Coated, impregnated, treated, or worked paper and paperboard…	274